REPORTS OF THE DEPREDATION PILOT STUDIES

Delegates are kindly invited to bring their own documents to the Meeting.
This document will be available only in electronic format during the Meeting.

Context

Human-dolphin interaction has become an issue worldwide because it can affect both the survival of wild dolphin populations and the livelihood of fishers. In the Mediterranean and Black Sea, there are growing interactions between small-scale fisheries and dolphins (mainly common bottlenose dolphins and common dolphins) whereby dolphins are removing catches from nets, referred to as "dolphin depredation" and damaging fishing gear. In response to this growing issue and thanks to the support of the MAVA Foundation, the ACCOBAMS Secretariat and the Secretariat of the General Fisheries Commission of the Mediterranean (GFCM), in collaboration with 'the Regional Activity Center for Specially Protected Areas of the Barcelona Convention (UNEP-MAP/SPA-RAC) and the Low Impact Fishers of Europe Platform (LIFE) have run since 2018 targeted activities in several countries of the Mediterranean Sea to better understand depredation and to identify potential measures to mitigate these interactions in order to support sustainable fisheries and protect dolphin populations.

During the last phase of the MAVA-Funded depredation project ''Mitigating dolphin depredation in Mediterranean fisheries – Joining efforts to strengthen cetacean conservation and sustainable fisheries" (2020-2022) activities were conducted to assess the status of dolphin depredation and to test research activities on possible mitigation measures in five different study sites. The reports of those pilot studies are compiled in this document, as follow:

- « An Acoustic Alert System to mitigate the effects of the Feeding in Net behaviour by the Bottlenose dolphin » MareCamp ONLUS Association, Sicily
- « Towards solutions to interactions between fisheries and cetaceans – The Malta case » - Malta College of Arts, Science and Technology (MCAST) & the Department of Fisheries and Aquaculture (DFA), Ministry for Agriculture, Fisheries, Food and Animal Rights
- « Bottlenose dolphin interactions with purse seine fishery in the Moroccan Mediterranean Sea » - Institut National de Recherche Halieutique (INRH)
- « Vers des solutions aux interactions entre communautés de pêcheurs et Tursiops truncatus dans les eaux tunisiennes » Institut National d'Agronomie de Tunis (INAT) & Institut National des Sciences et Technologies de la Mer (INSTM)
- « Interactions between air breathing marine vertebrates, particularly cetaceans, and artisanal fisheries in northern Alboran Sea (CETAFISHBE) » - Asociación Herpetológica Española – AHE

MITIGATING DOLPHIN DEPREDATION IN MEDITERRANEAN FISHERIES
JOINING EFFORTS FOR STRENGTHENING CETACEAN CONSERVATION AND SUSTAINABLE FISHERIES

An Acoustic Alert System to mitigate the effects of the Feeding in Net behaviour by the Bottlenose dolphin

Clara Monaco

6 October 2022

TECHNICAL REPORT

An Acoustic Alert System to mitigate the effects of the Feeding in Net behaviour by the Bottlenose dolphin

Study conducted in collaboration with:

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GFCM Secretariat
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Low Impact Fishers of Europe
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And funded by:
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Study reference:
Memoranda of Understanding No. 07/2021/LB 6411, No. 08/2021/LB 6411, and No. 04/2022/LB 6411 between the Secretariat of the Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and Contiguous Atlantic Area (ACCOBAMS), and the Marecamp ODV Association.

Photo credit:
Clara Monaco (Marecamp Association)

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TECHNICAL REPORT

An Acoustic Alert System to mitigate the effects of the Feeding in Net behaviour by the Bottlenose dolphin

FIGURES

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Executive Summary

The most intelligent animals are those who apply the least predictable and difficult to classify behaviours. Cetaceans have sophisticated social behaviour and remarkable cognitive abilities according to which certain performances appear to be learned from other pod members like a form of social transmission of behaviour (Gregg, 2013). Among these, the depredation of the fishing gears, which consists in the partial or complete removal of the catches from the gear leading to its damage and loss of catch, is the major cause responsible of conflicts between fishers and dolphins.

Opportunistic behaviours applied by dolphins for their feeding activities respond to optimization models which foresee to spend the minimum energies to have the highest gain. In this sense, foraging in the proximity of a fishing net represents for dolphins the best key to respond to their energy and nutritional needs, especially in marine areas overexploited and subject to pauperization (Monaco, 2020).

This issue has a high socio-economic impact on fisheries, especially the small-scale ones, which appear the most affected by interaction cases with coastal species of cetaceans with which they share the same fishing areas. Over time, several attempts have been made to solve conflicts by employing mitigation devices such as acoustic deterrents to push away dolphins from nets and other fishing gears. However, to date, there is still no effective measure capable of loosening the establishment of this type of interaction in the Mediterranean, so the conservation of vulnerable cetacean species and the sustainability of small-scale fisheries are still in danger and require urgent management plans to be taken both at local, regional, and national level.

Following a pilot project carried out in the Gulf of Catania (Ionian Sea, Italy) aimed at identifying new possible solutions to dolphin depredation, this report describes the experimentation made to develop an Acoustic Alert System (AAS) to mitigate the effects of the "feeding in net" behaviour applied by the bottlenose dolphin on artisanal gillnets and trammel nets. The action is included in the "Mitigating dolphin depredation in Mediterranean fisheries – Joining efforts for strengthening cetacean conservation and sustainable fisheries" project, also known as "Depredation-2" project.

This is the first trial of its kind in the world. Since the earliest system simulation surveys, it has shown to be very effective in allowing fishers to haul up their fishing gear when the danger of depredation is near, helping to limit the suffered damage. Moreover, field investigations required for its development permitted to collect a vast repertoire of dolphin vocalizations, as well as to characterize the soundscape of the Gulf. Thus, every well-defined sound has been classified and included in a catalogue which could be the starting point for setting a future prototype of AAS.

Preliminary results promise a decrease in depredation events when the AAS is applied, with a consequent increase in catches for the fishers and a decrease in the risk of by-catch for the dolphins that usually feed on the nets. Further investigations may define more accurately the effectiveness of the AAS in mitigating depredation, leading to the definition of more specific characteristics and requirements that the system has to respect in order to work as expected.

Insights of the study suggest deepening the experimentation using the technologies like passive acoustic monitoring to implement the development of the AAS, and to apply the same trial protocol in other Mediterranean fleets capitalising the outcomes of this project and strengthening them for the final development of the system.

1. Introduction

The Sicilian fishing fleet, strongly characterized by traditional and multipurpose *métiers*, it is dangerously exposed to the phenomena of climate change and overfishing because of which fish resources and so catches in the area are decreasing.

The targeted small-scale fishing fleet of the Gulf of Catania, which is located in eastern Sicily, is composed by vessels having six main recurring licenses: trammel nets (*tremaglio*), longlines (*palangaro*), single layered gillnets (primarily including the *monofilo*, and also the *menaida* net), hooks and lines (mainly used for the *totanara métier*), encircling nets (like the *sciabichedda*), and pots (*nassa*). Diversification of fishing techniques and their alternation in the seasons permit to access to a wide range of resources which include 98 seafood species, even if each *métier* capture only a few of them and in low quantity.

Previous studies demonstrated the persistence of conflicts between cetaceans and fisheries in the island and verified bad feasibility and efficacy of using pingers to reduce dolphin depredation, especially made by bottlenose dolphin.

Regarding annual strandings of cetacean, about 46% registered in Italy happen in Sicily. The bottlenose dolphin and the striped dolphin are the most involved species (39% each). Furthermore, in 29% of total cases, the hypothesized cause of death was that of anthropogenic origin, above all the interaction with activities linked to fishing.

It is also to be underlined that some individuals of striped dolphin and bottlenose dolphin of the Gulf of Catania present injured peduncles as evidence of surviving to prior fishery interactions with longlines.

Depredation events caused by dolphins took place in every area of the Gulf where fishing activities are carried out, however, the most affected gear is the single wall type. Recurring damages include holes in the nets, bended hooks, reduction in the amount or value of the catch, and loss of time for fishers.

Direct observations of the animals in interaction during the “Depredation-1” project made possible to construct an ethogram of the “feeding in net” behavioral pattern, defining three principal attack phases including respiration, and surfaces and submergence behavioral units.

Through a thought on these behaviors and an overall vision about mitigation methods experimented in the world, a series of useful strategies to further investigate the issue and to propose first solutions to be tested have been suggested. Among these, an “Acoustic Alert System” (AAS) indicating the presence and the occurrence of feeding sounds emitted by cetaceans close to the nets was proposed for nets that are deployed at sea for several hours, during which normally fishers leave the area, such as trammels and single wall nets, permitting them to haul up it in presence of dolphins engaged in depredation activities and to limit the economic damage (Monaco, 2020).

According to the Memoranda of Understanding No. 07/2021/LB 6411, No. 08/2021/LB 6411, and No. 04/2022/LB 6411 between the Secretariat of the Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and Contiguous Atlantic Area (ACCOBAMS), and the Marecamp ODV Association, in the framework of the “Dolphin watching and conservation in the Gulf of Catania” programme carried out by Marecamp, and of the “Mitigating dolphin depredation in Mediterranean fisheries – Joining efforts for strengthening cetacean conservation and sustainable fisheries” project (Depredation-2) financed by the MAVA Foundation, Marecamp has been commissioned for the implementation of the Action “An Acoustic Alert System to mitigate the effects of the Feeding in Net behavior by the Bottlenose dolphin”, under the supervision of the ACCOBAMS Secretariat, the General Fisheries Commission for the Mediterranean (GFCM) Secretariat, the Regional Activity Centre for Specially Protected Areas (RAC/SPA), and the Low Impact Fishers of Europe (LIFE) platform.

The study aims to capitalize results obtained in the previous “Depredation-1” project, continuing to seek solutions through engaging with small-scale fishers and promoting exchanges on best practices between them, in strict collaboration with the scientists.

In this framework, the field work has been addressed to:

- deepen the knowledge on the presence and distribution of cetacean species in the Gulf of Catania;
- maintain the floating laboratories network as source of collaboration and information about cetacean presence, distribution, and conflicts;
- strength the understanding about the dynamics of depredation on fishing gears through direct observation and acoustic recordings;
- strength the estimation about the incidence of interaction events per species and gear, and the consequent economic damage;
- deepen available information about the occurrence of by-catches of vulnerable species;
- verify the utility of an “Acoustic Alert System” or “Alarm System” integrated in the fishing nets to mitigate damages due to depredation by dolphins;
- share and implement the protocols developed in the study to investigate depredation in a standardized way in other small-scale fleets at local and regional level.

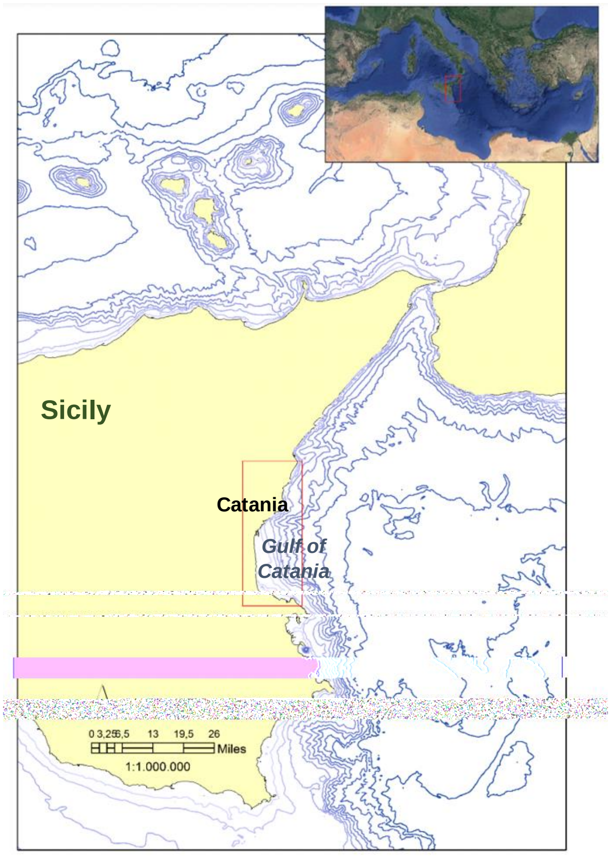

Figure 1. *Zoom on the Eastern coast of the Sicily Island, South Italy. The red rectangle indicates the area of the Gulf of Catania where the study took place. Map processed with ArcGIS.*

This report describes the main activities carried out during the first ever experimentation of an Acoustic Alert System (AAS) as mitigation measure to depredation made by dolphins in the small-scale fishery fleet of the Gulf of Catania.

1.2 Study area

The study area is the Gulf of Catania (Figure 1) which covers 300 km^2 in the western Ionian Sea, central Mediterranean (FAO area 37.2.2; GSA 19). This zone has a high level of primary and secondary productivity despite it is subjected to a strong anthropogenic impact, among which an intense commercial and touristic marine traffic. It includes many nature reserves (e.g. the MPA “Isole Ciclopi”; the ONR “Foce del fiume Simeto”), sites of community interest (e.g. “Fondali di Brucoli e Agnone”), and marine areas to be enlarged or established (e.g. “Grotte di Aci Castello”). The area hosts a rich marine flora and fauna, including several resident or migratory marine reptiles, sharks and seabirds. Regular species of cetaceans in these waters are common bottlenose dolphin, striped dolphin, Risso’s dolphin, short-beaked common dolphin, Cuvier’s beaked whale, sperm whale and fin whale. Other occasional marine mammal species are observed too such as false killer whale, rough-toothed dolphin, and monk seal.

The Gulf is a breeding area for many vulnerable species of cetaceans that live in its waters year around, where they also forage and initiate group life. Depredation events on the gears of small-scale fisheries are well known in the whole area and they cause huge losses to the fleet. The Northern and Southern Gulf of Catania appear to be the most affected by this type of interaction (Monaco, 2020).

2. Materials and methods

The main activity foresees by this study was to experimentate a new mitigation technology capable to respond to the depredation issue, repeatable and applicable in different contexts. The choice of testing an "Acoustic alarm system" for the fishing nets derives from the results of the first Depredation project and it was designed specifically for the small-scale fleet of the Gulf of Catania after having studied its characteristics, problems, and needs.

Creating a sophisticated alert system to advise fishers on the presence of dolphins feeding on their fishing nets would be very costly. In order to prove the usefulness of the system that could be developed, this study is based on the experimentation of the possible functionalities that such system would have, simulating manually, with operators at sea, the "Acoustic Alert System" (AAS), or alarm, detecting and indicating the presence of dolphins as well as the occurrence of feeding sounds emitted by them close to the nets.

Essential characteristics required by this system so that it could be efficient are: a) to be capable to detect the presence of dolphins; b) to be able to distinguish feeding sounds (burst pulses, clicks); c) to make real time recording and analysis of the sounds; d) to be able to send to the fisher an alarm call when the presence of dolphins feeding in net is confirmed.

The trial during which all the requirements above have been respected, included visual and acoustic surveys carried out in proximity of trammels and single wall nets deployed at sea, during the whole fishing set.

Two scenarios have been followed for testing the utility of the system in limiting the damages to the fishing gears and to the catch in case of presence of dolphins engaged in depredation activities:

1) to alert the fisher and haul up the net;

2) not alert the fisher without interrupting the fishing set.

Results coming from the two different scenarios have been analyzed to establish the real degree of mitigation of the alert system in depredation events.

The study included the following phases:

1. Bibliographic research and planning project.
2. Draft of the trial protocol with creation of survey sheets and databases.
3. Investigation on the SSF fleet of the Gulf to choose the best platform of opportunity (two fishing vessels belonging to the Floating Laboratories Network have been selected) to engage for the trial, taking into account their probability to suffer depredation depending on fishing gear and fishing zone used.
4. No. 4 surveys for setting up the onboard instrumentation, especially to find the better way to place the hydrophones in a stable way avoiding interferences due to currents or boat movements.
5. No. 36 specific trial surveys of the Acoustic Alert System onboard a sentry boat near fishing nets deployed underwater during their entire fishing set.
6. Data analysis and presentation of first results during meeting and workshops.
7. Integration with recent references and finalization of the work.

2.1 Data collection

The data collection was carried out by integrating several sampling methods with the aid of specialized instruments and specific survey cards for each type of data.

Thanks to direct observation at sea and interviews with the fishers involved in the fishing set of the day, the visual data were included in paper surveys on the continuous observation activity (Figure 2; Figure 3) where to write down geographic, temporal, and meteorological information, presence of fauna and anthropogenic activities, and any noteworthy event; on sighting events (Figure 4) specifying species, group composition and behaviour; on fishing activities and on interaction with cetaceans (Figure 5) such as characteristics of the fishing gear used, on the catches, and the presence of damages.

CAMPAGNA DI MONITORAGGIO DEPREDATION-2

SURVEY OSSERVAZIONE N° ______ *DATA* ____________

PIATTAFORMA DI OSSERVAZIONE ______________________

OSSERVATORI: ____

	POSIZIONE		PIATTAF. DI OSSERVAZ.			CONDIZIONI METEO-MARINE					
ORARIO	LATITUDINE	LONGITUDINE	ROTTA	VEL.	ATTIV.	CIELO	VISIB.	MAR.	VENTO	NATANTI	NOTE
	N	E									
	N	E									
	N	E									
	N	E									
	N	E									
	N	E									
	N	E									
	N	E									
	N	E									
	N	E									
	N	E									
	N	E									
	N	E									
	N	E									
	N	E									
	N	E									
	N	E									

Figure 2. *Survey sheet dedicated to the continuous observation onboard the scientific sentry boat. Survey Marecamp.*

LEGENDA SURVEY OSSERVAZIONE

La seguente scheda deve essere compilata con continuità durante l'attività di osservazione dedicata alla cetofauna. Una nuova riga dovrà essere compilata ogni qualvolta si verifichi il cambiamento di una delle variabili in tabella (es. rotta, velocità, meteo, natanti, avvistamento, attività, etc.).

1. ORARIO
Indicare la **data** solamente ad eventuale cambio giorno, negli altri casi indicare esclusivamente l'**orario**.
Es. 01/07/14 13.30; es. 5.00

2. POSIZIONE
Indicare le **coordinate geografiche** nelle apposite caselle di **Latitudine N** e **Longitudine E**.
Es. 37°29.094 N, 15°12.900 E

3. NAVE (piattaforma di osservazione)
ROTTA – Indicare la **rotta** della nave in gradi. Es. 144°
VEL. – Indicare la **velocità** della nave in nodi (KN). Es. 5

4. CONDIZIONI METEO-MARINE
CIELO – Indicare il grado di **copertura del cielo** in percentuale. Indicare inoltre la presenza di **precipitazioni atmosferiche** (Pioggia=**P**; Grandine=**G**) e la loro intensità (Lieve=**L**; Moderata=**M**; Forte=**F**; Molto forte=**FF**). Es. 70% PF
VISIB. – Indicare il grado di **visibilità** (Ottima=**O**; Buona=**B**; Media=**M**; Scarsa=**S**). Es. B
MAR. – Indicare lo stato del **mare** secondo la scala Douglas (vedi tabella 1). Es. 1
VENTO – Indicare la provenienza del **vento** (N-S-O-E) e la sua intensità secondo la scala Beaufort (vedi tabella 1). Es. S-O 2

5. NATANTI
Indicare il numero di imbarcazioni visibili ad occhio nudo e distinguerle in Vicine=**V** (entro il raggio di un miglio–NM) e Lontane=**L** (oltre 1NM). Per ciascuna, indicarne la **categoria** (vedi tabella 2), le dimensioni (Piccola=**P**; Media=**M**; Grande=**G**), e specificare se in moto=**T** o ferma=**R**. Nei casi possibili, indicare anche l'**attività** (vedi tabella 3). Es. (2FM2+1GM+1CP1) V T + (2IG) L T

6. NOTE
Indicare la presenza di meduse, uccelli, pesci, rettili, cetacei (numero e specie) e specificare l'ID della relativa scheda di **avvistamento**. Segnalare la presenza di grosse quantità di **rifiuti** galleggianti, oltre che boe, reti, bandierine, ed ogni altro elemento/evento che si ritenga utile. Inoltre, ove possibile, indicare la **temperatura** dell'acqua in gradi centigradi (es. 27 °C) e la **salinità** in parti per mille (es. 38.27‰). Indicare nei pressi di quale peschereccio (nome o matricola) si rilevano dati video-fotografici.

Tabella 1

FORZA VENTO	NOTE DESCRITTIVE	FORZA MARE
0	Mare come uno specchio	0
1	Piccole increspature, niente spuma	
2	Piccole onde, le creste non si infrangono	1
3	Onde più grandi, le creste cominciano ad infrangersi, qualche ciuffo di spuma	2
4	Molti ciuffi di spuma	3
5	Molti ciuffi di spuma, qualche spruzzo	4
6	Prime onde grosse	5
7	Cavalloni	6
8	Onde piuttosto grandi	
9	Onde alte	
10	Onde molto alte	7

Tabella 2

CATEGORIE PER LE IMBARCAZIONI	
A	Barca a vela con vele giù
B	Barca a vela con vele su
C	Gommone
D	Motoscafo (< 7 m)
E	Motoscafo (> 7 m)
F	Barca da pesca
G	Peschereccio a strascico
H	Imbarcazione di gruppi DIVING
I	Imbarcazione transito passeggeri
L	*Jetski* (moto d'acqua)
M	Imbarcazioni di corpi operativi: G di F, C di P, CF, PM, MM
N	Nave oceanografica

Tabella 3

CATEGORIE DI ATTIVITÀ	
1	Pesca a traina
2	Pesca con reti
3	Pesca con palamiti
4	Pesca con canna
5	Pesca in apnea
6	Pesca con bombole
7	Snorkeling
8	Nuoto
9	*Divers*

Figure 3. *Legend of the survey sheet dedicated to the continuous observation onboard the scientific sentry boat. Survey Marecamp.*

CAMPAGNA DI MONITORAGGIO MARECAMP

SURVEY AVVISTAMENTO CETACEI N° ______

www.marecamp.it
info@marecamp.com

AVV. N.	AVVISTATORI	DATA E ORA	POSIZIONE					CETACEI			COMPORTAMENTO >>PIATTAF. OSSER.			N. NATANTI			NOTE
			LATIT.	LONGIT.	DIST.	ANG.	DIR.	SPECIE	N. TOT.	N. JUV.	AV.	AL.	I.	P	M	G	
			N	E													
			N	E													
			N	E													
			N	E													
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			N	E													
			N	E													
			N	E													
			N	E													

Figure 4. *Survey sheet dedicated to sightings of cetaceans. Survey Marecamp.*

DEPREDATION 2 / SURVEY PESCA

ID SURVEY
ORARIO INIZIO SURVEY
ORARIO FINE SURVEY

COORDINATE INIZIO RETE
COORDINATE FINE RETE

ORARIO INIZIO CALA
ORARIO FINE CALA

ORARIO INIZIO RITIRO ATTREZZO
ORARIO FINE RITIRO

PESCHERECCIO
ATTREZZO TIPOLOGIA
LUNGHEZZA RETE

AREA PESCA
PRESENZA CETACEI
INTERAZIONE
REGISTRAZIONE VOCALIZZAZIONI
DANNI

PESCATO (KG PER SPECIE)

ID ULTERIORI SCHEDE SURVEY COLLEGATE

NOTE

Figure 5. *Survey sheet dedicated to information on fishing activities. Survey Marecamp.*

The acoustic data were collected on a paper card in which take note of information on the fishing vessel, the hydrophones, the recorder status and settings, identified sounds and biophonies, their source, type and gathering time, associated sighting and dynamics, etc. (Figure 6).

CAMPAGNA DI MONITORAGGIO MARECAMP

SURVEY BIOACUSTICA N° ______ Data __________ Sampler ______________

ID peschereccio _____________ Piattaforma di ascolto ______________ Impostazioni rec. _________

Idrofono 1 ______________ Idrofono 2 ______________ Idrofono 3 _____________

ID OSS.	DATA	ORARIO	Categoria suono	Comportamento associato	Fonte	ON/OFF	Riferimenti visivi	Direzione

Figure 6. *Survey sheet dedicated to collect bioacoustics data. Survey Marecamp.*

All the collected data have been uploaded on a combined Excel Database counting about 27 000 record lines.

Surveys at sea were conducted using the following equipment:

- 7.20 m inflatable boat with a 150 cv Honda engine (sentry boat 1)
- 12 m inflatable boat with three 250 cv engines (sentry boat 2)
- GPS Garmin eTrex 10 to trace routes, sightings, and fishing sets
- 8x40 and 7x50 binoculars for a better view
- Nikon Bridge P1000 photo-camera to document activities and sightings
- Sony FDR-AX53 video-camera to document activities and sightings
- Insta 360 camera placed onboard the fishing vessel to check every damage to the catch and to the nets before and after every fishing set (Figure 7)
- Three HTI-96-MIN marine-mammal hydrophones (2 Hz–30 kHz flat frequency response; sensitivity −164 dB re: 1 V/µPa)
- Zoom H5 handy recorder (96-kHz sampling frequency) to digitize the hydrophone output signal and save it as an audio file in .wav format (16-bit resolution)

To collect high-quality data, we did surveys with good weather conditions and calm waters (Beaufort scale <2), using a sentry scientific vessel with expert personnel on board (at least 1 skipper, 2 observers, 2 bioacousticians), constantly in contact with the fisher that was carrying out the fishing set. The fishing activity was never influenced by the experimentation, but the whole study was carried out by totally reproducing the normal conditions of work (timing, fishing area, fishing gear, crew, etc.) of the fishing vessel under consideration. The unique variations were due to the test of the AAS when the fishing set was interrupted.

Each trial survey started in the night (between 3:00 and 4:00 AM) and finish in the early morning (between 8:00 and 10:00 AM). Fishers involved in the trial belong to the Floating Laboratories network established by Marecamp and LIFE in the framework of the Depredation-1 project.

Figure 7. *A screenshot of the video recorded in continuum by the Insta360 camera to detect any damage on the net before and after the fishing set. Source: Marecamp.*

Regarding the collection of acoustic data, they were collected on board the scientific boat positioned near the investigated fishing gears at sea during the fishing sets, and equipped with the three hydrophones lowered at a depth between 5 and 10 m (depending on the bottom depth in each survey), and the recorder (96-kHz sampling frequency) (Figure 8).

Since the use of two different hydrophones placed at a distance of a minimum of 5 meters makes possible to localize from where the sounds come, two hydrophones were positioned at a distance of seven meters to each other to localize the dolphins along the net using a time-of-arrival analysis of the signal to the acoustic sensors when possible (Janik et al., 2000). Occasionally, one hydrophone was connected to a laptop PC to visualize a real-time spectrogram of the acoustic scene.

Figure 8. *Instrumentations used for the acoustic data collection: a) HTI-96-MIN marine-mammal hydrophones; b) Zoom H5 handy recorder.*

Recordings started when fishers set their nets to verify whether the dolphins were already in the vicinity at the beginning of the survey. Once the net was set entirely, the sentry boat was placed in the middle of the length of the net, and the recording session continued until the end of the net haul up.

Analyzes of the records were performed using the software Adobe Audition 2.0

3. Results and discussion

Between July 2021 and August 2022, a total of 36 surveys have been carried out spending 205 hours at sea, and covering about 600 Nautical Miles. Surveys were carried out in collaboration with local small-scale fishers during their fishing trips at night in the Gulf of Catania, Ionian Sea, Italy.

We assisted to 36 fishing sets occurred in the northern and in the southern part of the Gulf, lasting a total of 159 hours with an average of 4 hours per fishing set (min 1.52 h; max 5.48 hrs; σ 0.85).

Considering a total of 33 surveys having a good quality of data, the presence of dolphins interacting with fishing activities was verified in 23 cases (69.69%) thanks to bioacoustic analyzes, 8 times it was also confirmed by visual sighting (34.78%) (Figure 9). This data shows an increasing of the negative interactions with cetaceans rather than the last investigations which reported for the small-scale fleet of the Gulf of Catania 45% of the fishing trips made in one year affected by conflicts with cetaceans (Monaco, 2020).

The *tremaglio* (trammel net), the *monofilo* and the *menaida* (single layered nets) have been the investigated fishing nets which were positioned at different depths, from 10 to 300 meters. The alert system has been experimented on this gears no. 8, 27, and 1 times respectively.

Figure 9. *A bottlenose dolphin approaching a fishing vessel during fishing activities. Source: Marecamp.*

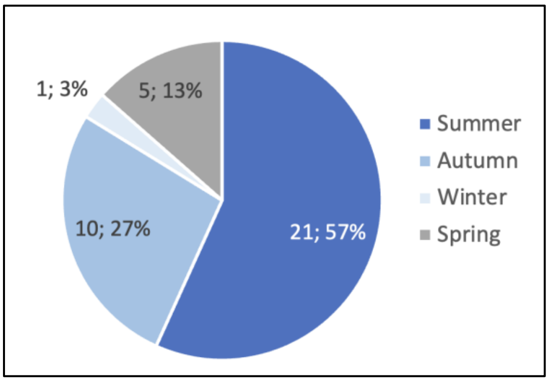

Figure 10. *Distribution of the survey effort during the seasons.*

Since the project includes two summer seasons, most of the sampling effort was concentrated in the summer and in the autumn (Figure 10). Moreover, field activities were suspended at the end of November 2021 due to adverse weather conditions because of a Medicane that brought storms and unstable weather for some weeks. As a result, the flooding of rivers along the coast has resulted in a salt and food chain imbalance. Fishers who use the menaida net, no longer fished their only target species (anchovy) for months, carrying out unsuccessful catches. At the same time, fishers reported that they no longer saw dolphins in the surrounding area. This unexpected event caused the stand-by of the research activities and the end of the trial on the menaida gear.

In addition, the Gulf of Catania was the seat of the annual military exercises “Dynamic Manta” of the Allied Maritime Command of the NATO in the months of February and March 2022, including anti-submarine warfare activities. This has caused a temporary drastic reduction in the encounter rate of cetaceans in the Gulf and neighboring waters.

In the following paragraphs we will examine in greater detail the results deriving from the study of the fishing activity involved in the experimentation of the acoustic warning system (AAS) with reference to the fishing effort, the target species, the types of events detected that may involve cetaceans, the soundscape of the study area including the vocalizations of dolphins interacting with fishing gears, and the empirical evidence of the AAS experimentation phase.

Figure 11*. A couple of bottlenose dolphins approaching the net of a small-scale fishing vessel in the Gulf of Catania. Source: Marecamp.*

The activities carried out during the 13-months period of the project permitted to deepen the knowledge on the presence and distribution of the bottlenose dolphin and the striped dolphin in the Gulf of Catania and to in-depth their relationships with the local small-scale fishing fleet. Field investigation allowed us also to strength the understanding about the dynamics of depredation on fishing gears through direct visual observations and acoustic recordings, during which also important information about the occurrence of by-catch events of dolphins has been gathered (Figure 11).

The study took advantage of the floating laboratories network maintaining with local fishers the collaboration established during the Depredation-1 project, and continuing to share with them data on their landing, cetacean presence, distribution, and conflicts. Detailed analysis brought to an accurate estimation of the incidence of interaction events among the sampling fishing vessels and the suffered economic damage which denote an increasing of the phenomenon compared to the last 2 years.

About the AAS, its utility to be integrated in the fishing nets to mitigate damages due to depredation by dolphins has been verified thanks to the manual simulation of the system in which results coming from two scenarios were compared: 1) AAS deactivated and no mitigation actions; 2) AAS active and consequent alert of the fisher to remove his net as soon as a very distinct and close dolphin vocalization, compatible with the feeding in net behaviour such as clicks and bursts, was detected.

The procedures applied in the experimentation, the survey cards used for data collection and the databases has been developed for different type of artisanal nets (small set gillnets and driftnets), usually left in the sea to fish for a couple of hours, and they are adaptable to other contexts. This makes the study replicable in a standardized way in other small-scale fleets at local and regional level for new investigation on the depredation.

3.1 Fishing effort and conflicts

Landings linked to the fishing trips investigated during this study amounts to a total of 435 kg, with an average of 12.44 kg (min. 1.3 kg; max 55 kg). There were no particular differences in the quantities for the various fishing gears (between the tremaglio and the monofilo). However, each investigated net could affect different depths. Indeed, while the total average fishing depth was 85 meters, we recorded minimum values for the tremaglio (20 m) and the monofilo (50 m), and maximum values for the menaida (300 m) and the monofilo (200 m). The main target species captured during the surveys by these gears are listed in

Table 1 and correspond to mullet, cod, bream, parrot fish, sole, etc. (Figure 12).

Total number of ports covered by the programme				
Italy				
	Number of fishing trips covered	***% Number of depredation events***	***Type of events***	***Main commercial species***
GSA 19 (FAO 37.2.2)				
Aci Trezza	35	67%	Removal of the prey or their damage when trapped in the gears, tearing of portions of the net with production of holes of various sizes, scattering preys, changing in target species, variation in the amount of the catch, dolphin by-catch.	*Trachurus trachurus, Pagellus sp., Sparisoma cretense, Mullus sp., Palinurus elephas, Scorphaena sp., Boops boops, Chelidonichthys lucerna, Dactylopterus volitans, Merluccius merluccius, Muraena Helena, Solea solea.*
Catania	1	0%	na	*Engraulis encrasicolus, Sardina pilchardus.*
Total	36			

Table 1. *Fishing trips investigated in the Gulf of Catania and reported conflicts with dolphins.*

Figure 12. *Cods caught with the monofilament net in the Gulf of Catania (the gillnet "monofilo" in the background). Source: Marecamp.*

We calculated the catch-per-unit-effort (CPUE) of the fishing trips in terms of units of kilograms per hour by dividing the catch of each fishing trip by the number of hours spent capturing during that trip. Distinguishing the cases of fishing in the presence (Table 2) and absence (Table 3) of dolphins, it was found that the CPUE is lower when cetaceans are present and interact with the fishing gears (value almost double when dolphins are absent).

	CPUE (kg/h)
Average	2.51
Minimum	0.25
Maximum	11.74

Table 2. *CPUE of the investigated fleet when dolphins are detected near their fishing gears.*

	CPUE (kg/h)
Average	4.02
Minimum	1.42
Maximum	12.77

Table 3. *CPUE of the investigated fleet when dolphins are not detected near their fishing gears.*

3.2 Catalogue of sounds

The analysis of the recordings permitted to create a catalogue of the sounds that characterize the soundscape of the underwater coastal area of the Gulf of Catania. During the surveys, data both on the presence of anthropogenic activities and on the biological component has been collected.

Regarding the trial of the alert system, particular attention was paid assigning categories to the recorded biophonies, especially to those corresponding to cetacean vocalizations.

The study of the background noise of an environment can provide a lot of information on the existing relationships between the fauna that populates it. Furthermore, in order to develop an automatic alert system, it is necessary to know what it must look for, what it must distinguish it from, and how to find it in the event of a background disturbance.

Among the vocalizations attributable to dolphins are included:

- Echolocation clicks: high intensity, short duration, broadband sounds with ultrasonic peak frequencies, usually produced in rapid succession (click trains) for the detection and discrimination of targets (Au, 1993).
- Whistles: frequency-modulated, narrowband sounds, principally used in social contexts, which in dolphins such as *Tursiops* spp. range between 0.8 and 28.5 kHz in frequency (Schultz and Corkeron 1994; May-Collado and Wartzok 2008).
- Burst: for example, burst pulse (BP) sounds are broadband discrete aural packets of pulses that due to their high repetition rate appear in spectrograms as harmonic bands that are perceived as a continuous sound by the human ear (Watkins 1967; Herzing 2000). The exact function of BP sounds is still debated (Janik 2009) and may vary with species and context. However, many studies confirm the correlation between foraging and feeding behavior with the emission of bursts (Acevedo-Gutiérrez et al., 2004; Ridgway et al., 2015; Tellechea et al., 2016).
- Castanets: category of impulsive sounds, predominant in night time on the other signals produced especially by the striped dolphin. It is believed that this acoustic behavior is part of a hunting strategy to find food (Unipv, 2015).
- Moan: named also “meow”, they are low frequency narrow band sounds emitted especially by the bottlenose dolphin (van der Woude, 2009).

Other bottlenose dolphin vocalizations, poorly described from an acoustic and behavioral perspective, include low-frequency moans, and low frequency narrow-band (LFN) sounds which are short-duration (1 s) tonal sounds, usually under 1 kHz in frequency (Schultz et al., 1995; Simard et al., 2011). Like BP sounds, their function in the dolphin acoustic repertoire has yet to be resolved.

The sounds that occurred during our study in the Gulf of Catania range from different type of noise generated by the engine of the vessels or other devices they have onboard such us depth sounders or winches, to other sounds generated by marine fauna such as vocalizations produced by dolphins. Sounds of human origins can be mixed with those emitted by cetaceans (Gridley et al., 2015), especially in case of marine areas with an intense maritime traffic or during depredation events including the typical sounds of a fishing vessel.

The catalogue showed below resumes from Figure 13 to Figure 31 all the sounds patterns recorded during the trial that should be placed in a repertory module recognizable by the AAS.

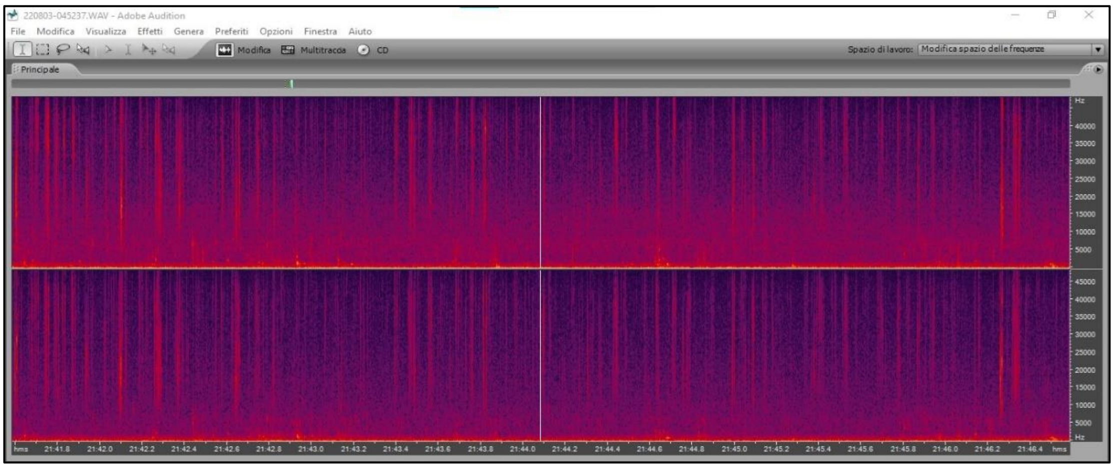

Figure 13. *Spectrogram of a ship pulsed noise. Processed with Adobe Audition 2.0. Our elaboration.*

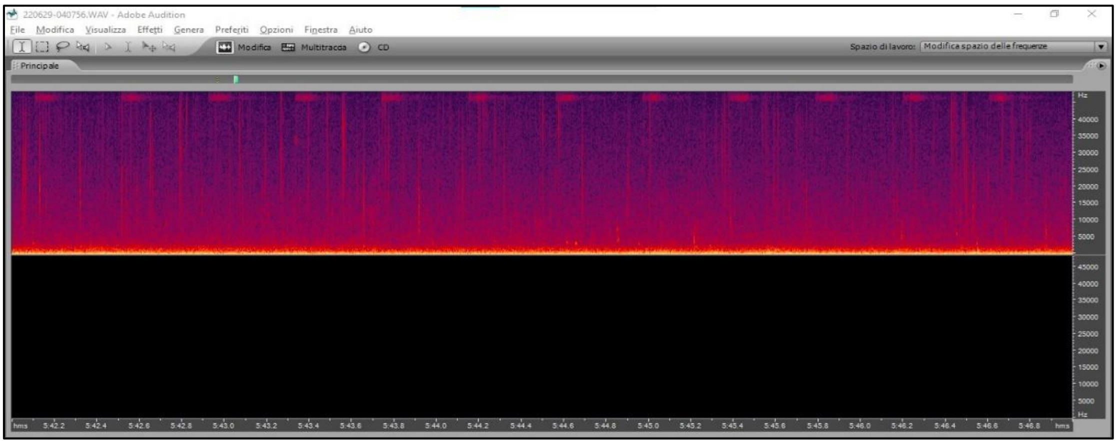

Figure 14. *Spectrogram of a continuous ship noise at low frequency (0-4 kHz) and ship pulsed noise. Processed with Adobe Audition 2.0. Our elaboration.*

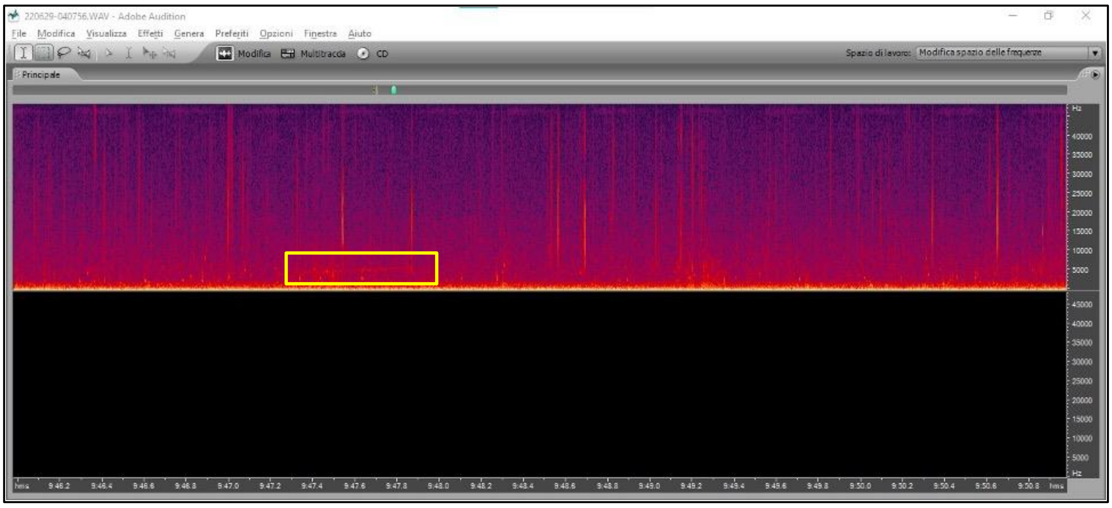

Figure 15. *Spectrogram of feeble whistle and ship pulsed noise. Processed with Adobe Audition 2.0. Our elaboration.*

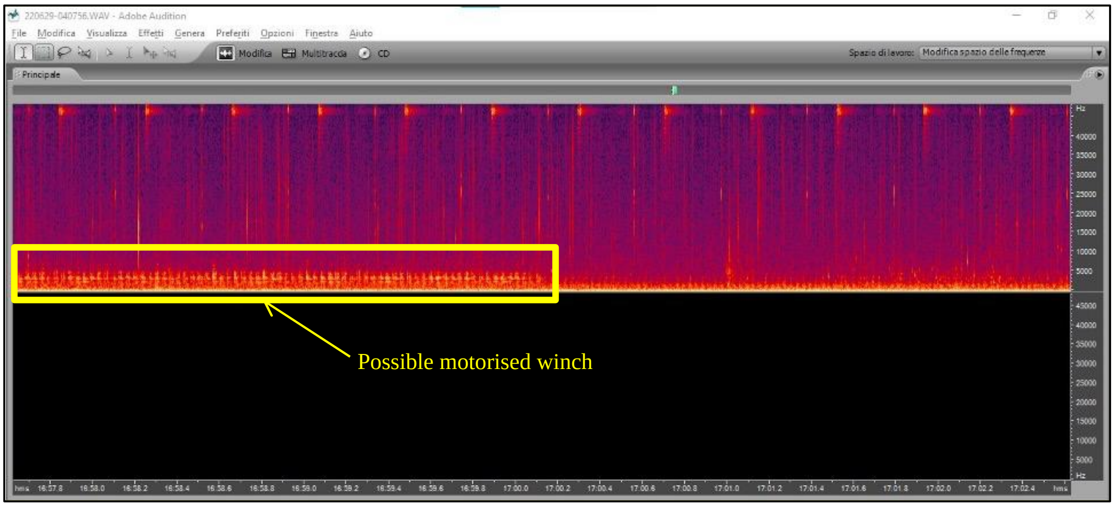

Figure 16. *Spectrogram of ship pulsed noise, continuous ship noise and a motorized winch. Processed with Adobe Audition 2.0. Our elaboration.*

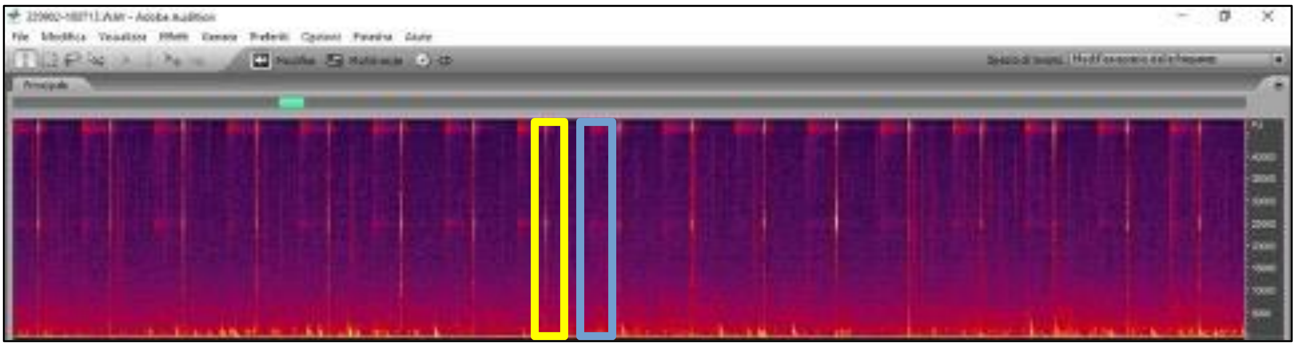

Figure 17. *Spectrogram of the active sonar of a fishing vessel. The source impulse (very clear spectrum in the yellow frame), and the return echo (more nuanced spectrum in the blue frame) are highlighted. Processed with Adobe Audition 2.0. Our elaboration.*

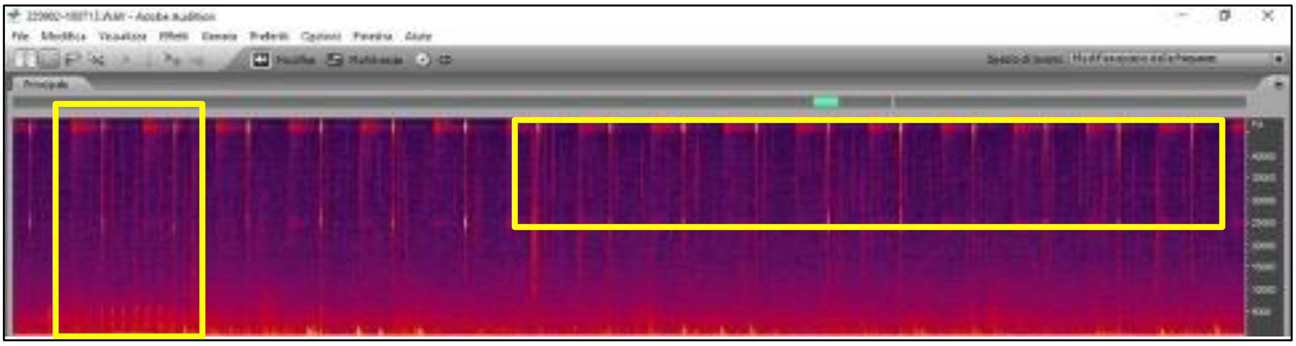

Figure 18. *Spectrogram of the active sonar of a fishing vessel in conjunction with vocalizations emitted by dolphins. The yellow frames highlight dolphins' clicks. Processed with Adobe Audition 2.0. Our elaboration.*

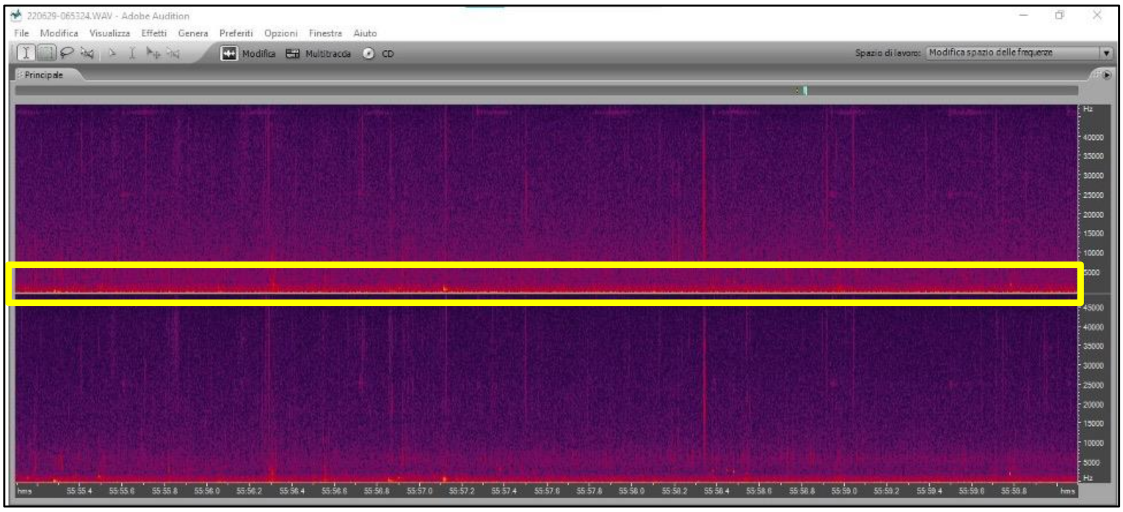

Figure 19. *Spectrogram of ship continuous noise (inflatable boat). Processed with Adobe Audition 2.0. Our elaboration.*

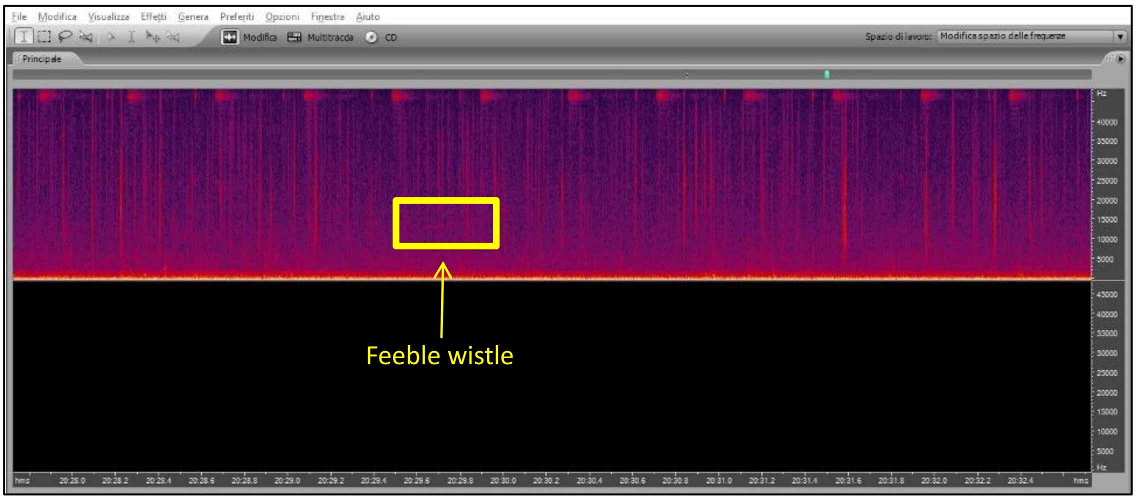

Figure 20. *Spectrogram of feeble whistle. Our elaboration with Adobe Audition 2.0.*

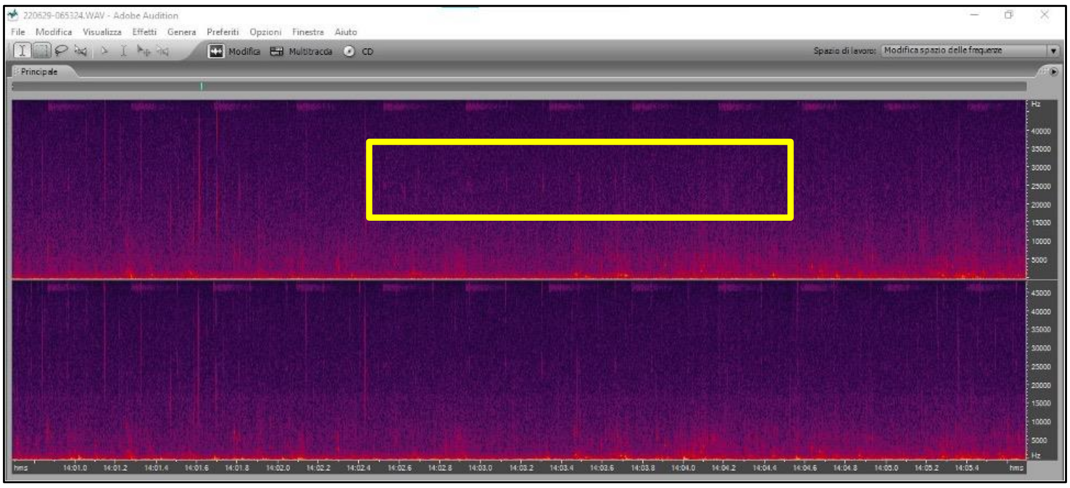

Figure 21. *Spectrogram of feeble high frequency clicks (>20 kHz). Our elaboration with Adobe Audition 2.0.*

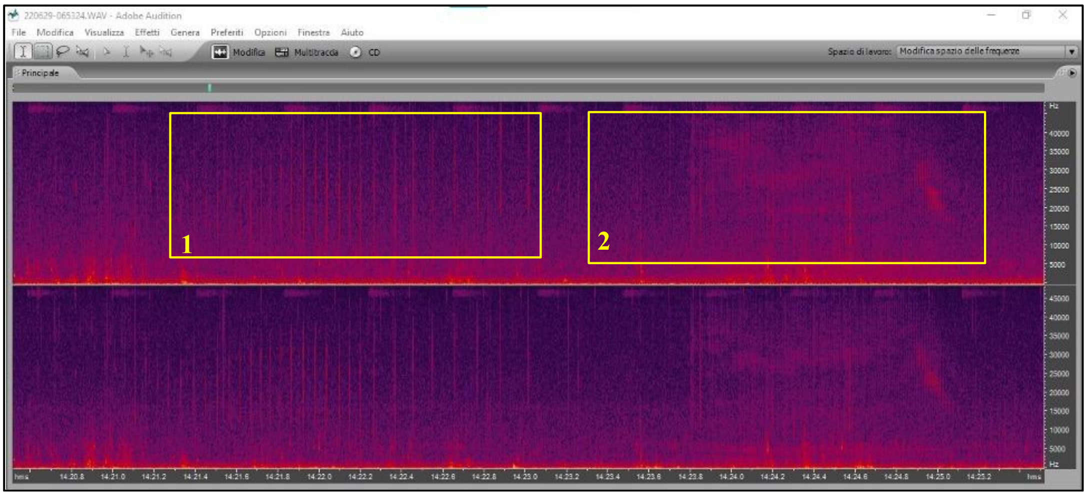

Figure 22. *Echolocation clicks (1): group of clearly distinguishable clicks, used above all to orient oneself and to identify objects or obstacles underwater. Burst or buzz (2): group of very close and indistinguishable clicks that generate a harmonic sound, generally used for social purposes. Our elaboration with Adobe Audition 2.0.*

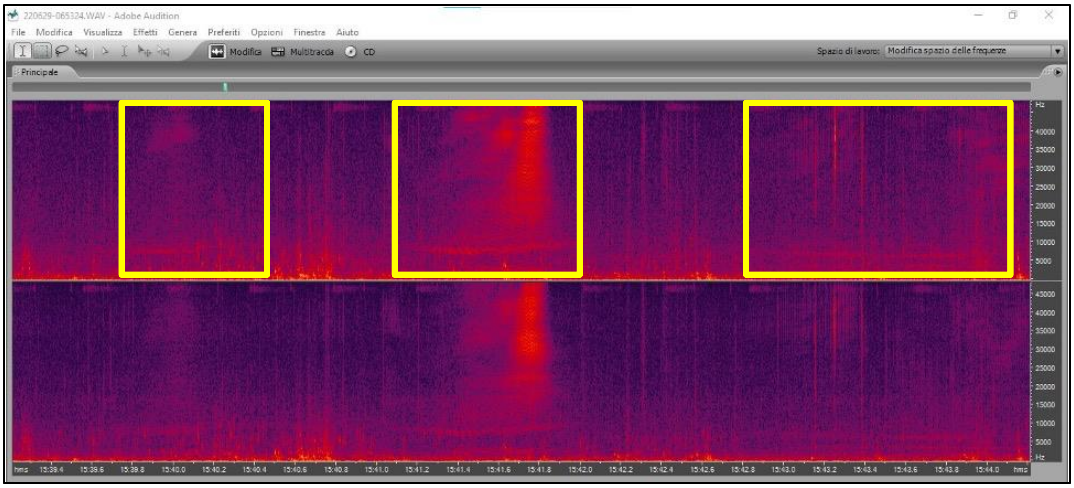

Figure 23. *Series of Burst with the central strong enough that generate a whistle around 10 kHz. Our elaboration with Adobe Audition 2.0.*

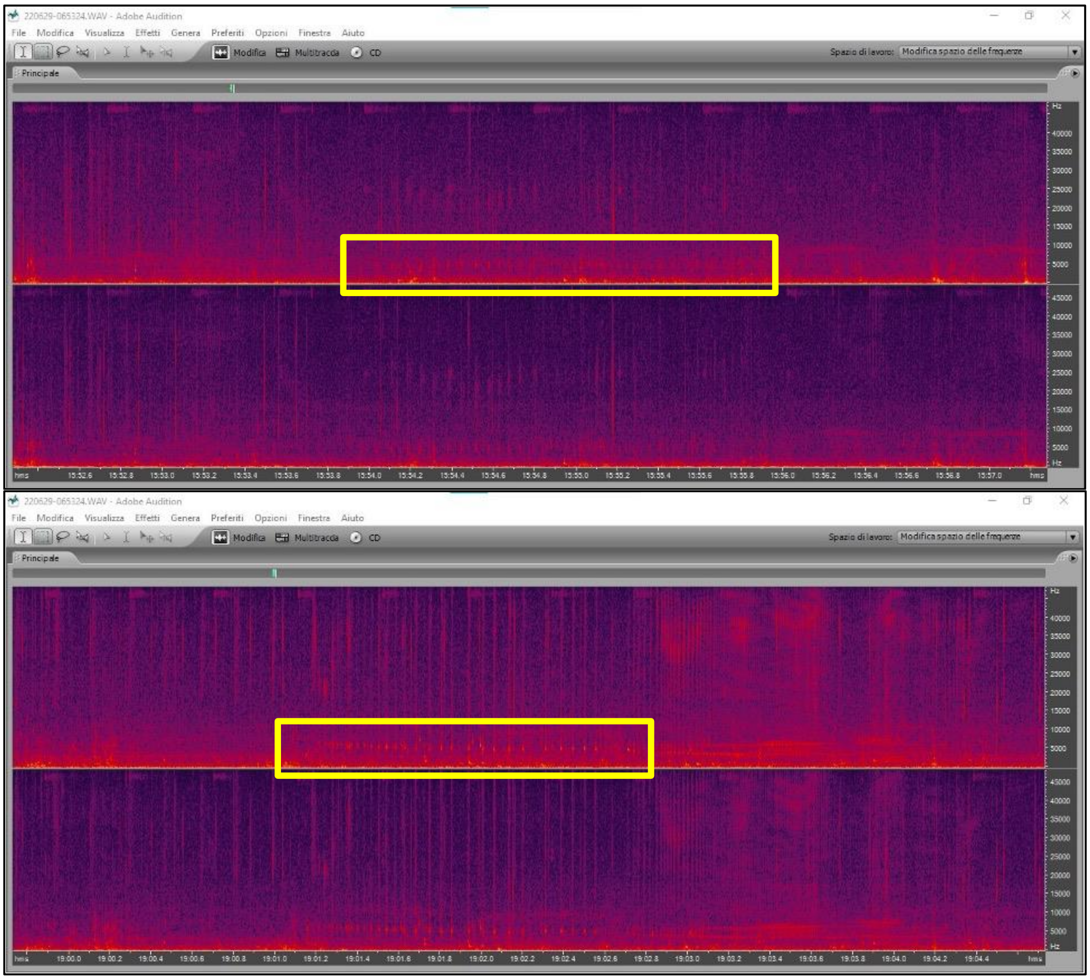

Figure 24. *Two examples of "nacchere" as low frequency clicks (3-6 kHz) used by some fish to echolocalize. Our elaboration with Adobe Audition 2.0.*

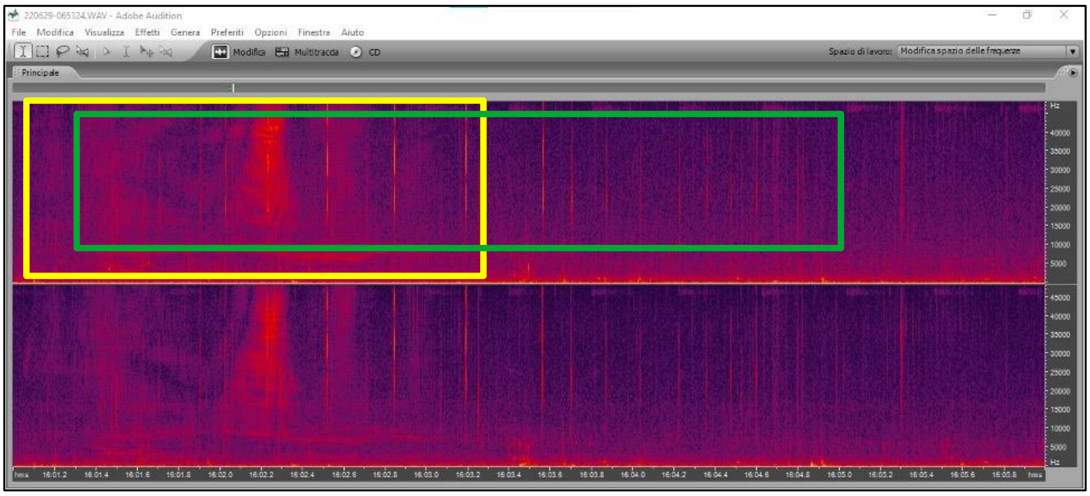

Figure 25. *Burst (yellow) and echolocation clicks (green) emitted by two different dolphins. Our elaboration with Adobe Audition 2.0.*

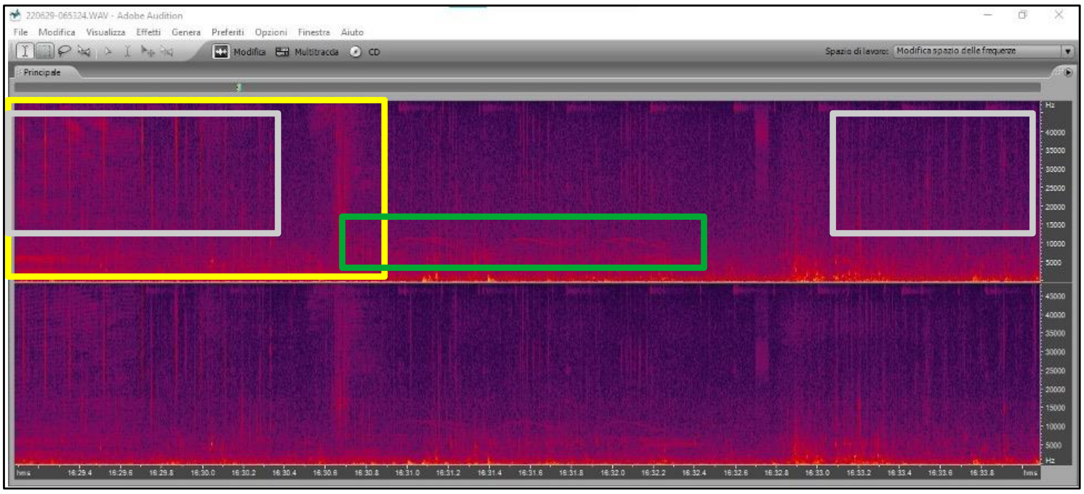

Figure 26. *Burst (yellow), whistles (green), and echolocation (grey). Our elaboration with Adobe Audition 2.0.*

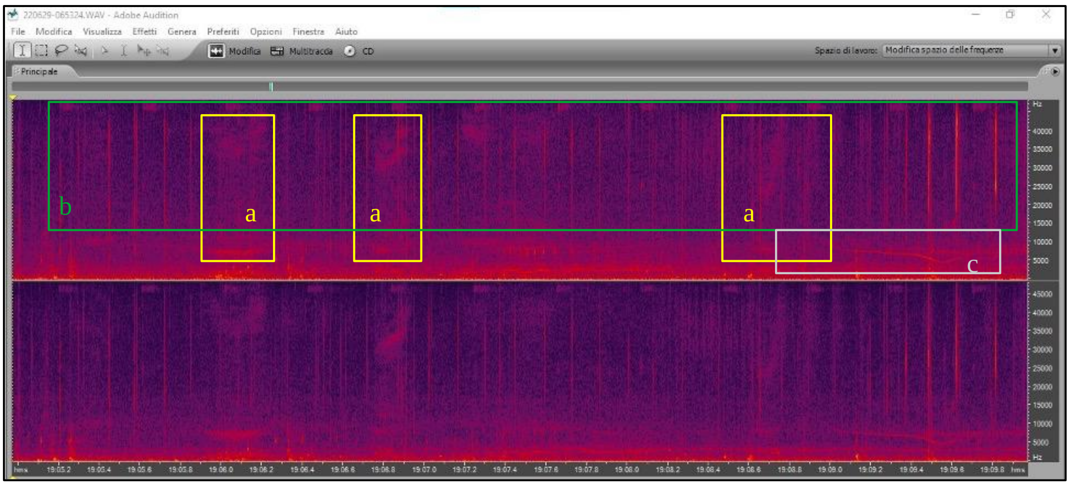

Figure 27. *Series of burst (a), echolocation (b), and whistles (c) produced by three different animals. Our elaboration with Adobe Audition 2.0.*

Figure 28. *Echolocation clicks (green and grey), and whistles (yellow) of at least three different dolphins. Our elaboration with Adobe Audition 2.0.*

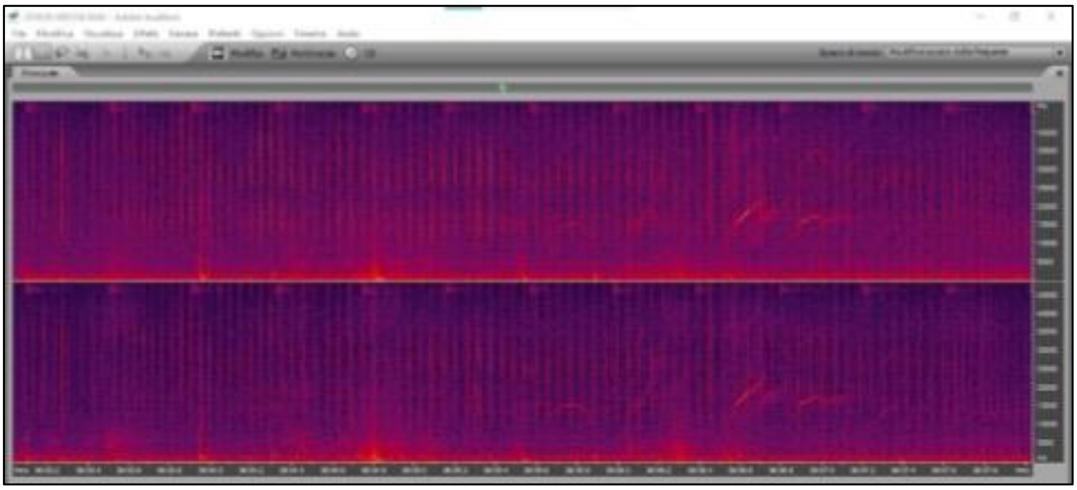

Figure 29. *Echolocation and whistles produced by at least two dolphins. Our elaboration with Adobe Audition 2.0.*

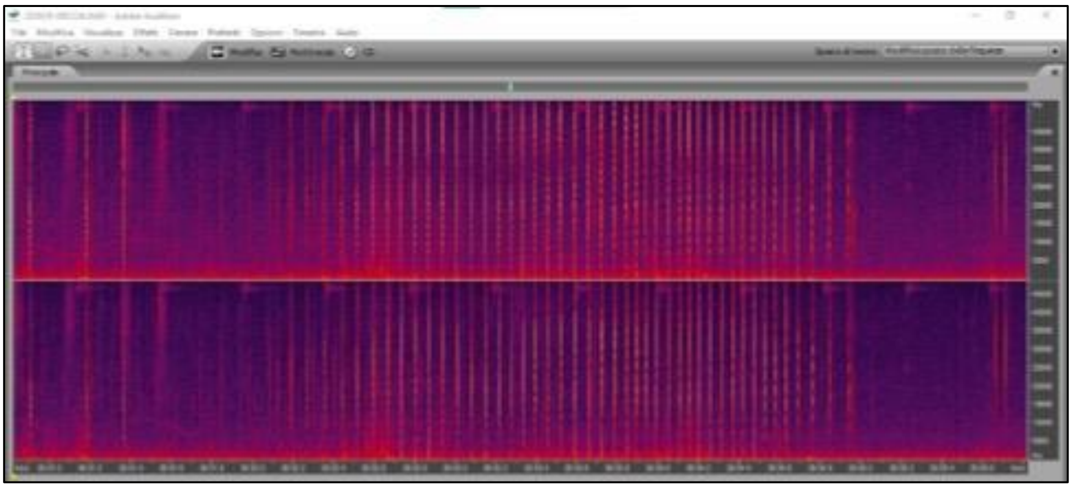

Figure 30. *Very high echolocation clicks. Our elaboration with Adobe Audition 2.0.*

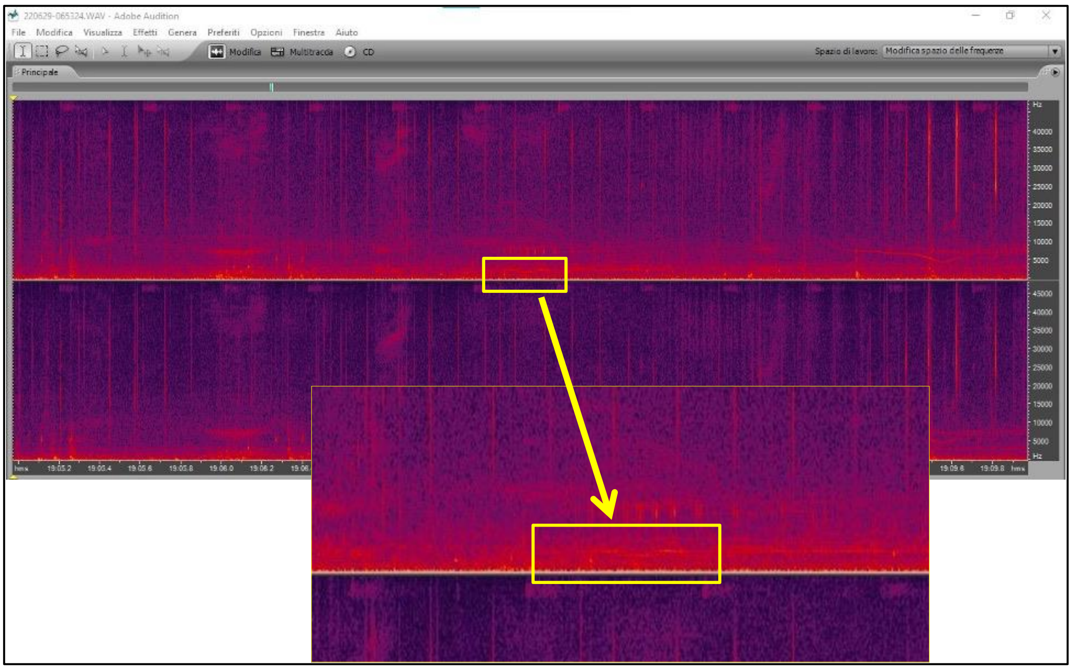

Figure 31. *Low frequency whistles of dolphins (2-4 kHz). Our elaboration with Adobe Audition 2.0.*

During the sightings of bottlenose dolphins with more than 6 individuals, it was also possible to hear various social vocalizations including signature whistles. In particular, we have identified 11 signature whistles (Figure 32; **Error! Reference source not found.**) that could be compared with new recordings in the future. This is the first acoustic characterization of the signature whistles provided for the bottlenose dolphin population inhabiting the Ionian Sea (Annexes I-II-II) (Terranova et al., 2022).

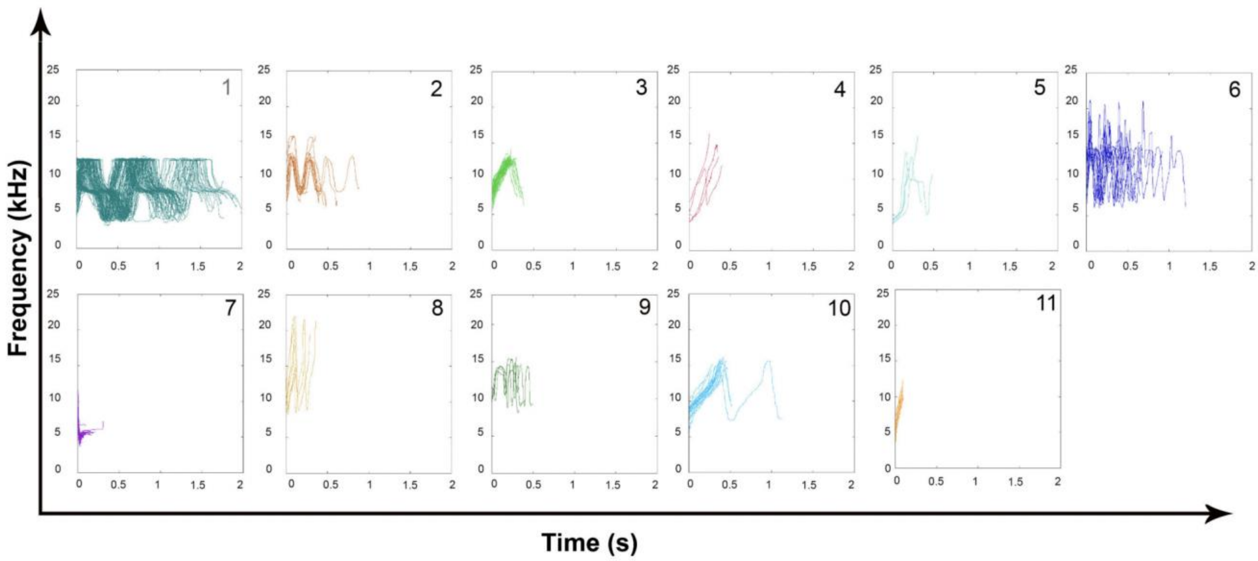

Figure 32. *Pitch contours extracted for the 11 signature whistle types identified using the SIG-ID method (Janik, 2013). Extract from Terranova et al., 2022.*

3.3 Testing the Acoustic Alert System

Considering the events of visual or acoustic detection of cetaceans applying a possible feeding behavior, in 14 cases the fishing set was not interrupted while in 9 cases we simulated the activation of the Acoustic Alert System out of a total of 23 events.

Due to low visibility or to feeble vocalizations, in some occasions we were not able to recognize the involved species (2; 9 %), while in the most cases the species interacting with the fishing net was the bottlenose dolphin (18; 78%) followed by the striped dolphin only in 3 cases (Figure 33).

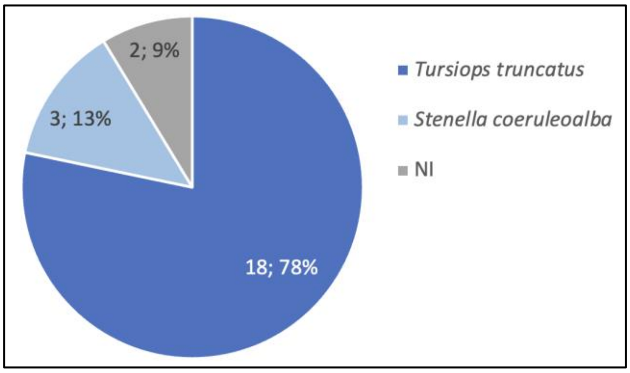

Figure 33. *Sightings of dolphins per species during the fishing set studied. Our elaboration.*

Bottlenose dolphin and striped dolphin have been sighted near the fishing nets (Figure 34). The method of approach applied by the bottlenose dolphin during the feeding in net opportunistic behaviour correspond to the ethogram proposed by Monaco (2020) including the succession of long dives and short emersions near the fishing gear with which one or more individuals interact during their search of preys.

Figure 34*. Striped dolphins in emergence near the buoy of an artisanal gillnet in the Gulf of Catania. Source: Marecamp.*

The dolphin can use the net as a wall to which conduct its preys, or depredate the fish already entangled. In the first case, the fisher can catch species that are unusual for the gear and fishing area used (this is the case of huge quantity of bogues and mackerels when the pod of dolphins exceeds six individuals); the latter case requires to interact with the net generating holes of various entity and, in such case, also compromising the anatomical integrity of the preys. Respiration, and surfaces and submergence behavioral units like silent vaporous breath, surface exhalation with a few large bubbles, drop foresection submergence, and flat foresection surfacing has been observed both in case of single dolphin and for pods composed on average of 7 individuals. In some cases, noisy vaporous breaths made possible to detect the dolphin presence when visual recognition would not have been possible in the dark.

When the bottlenose dolphin interacted with the fishing gears in group, the presence of calves in the pod has been confirmed. Moreover, it has been noticed that in case of larger groups the fishing net is damaged more quickly and therefore the action of the AAS can be reduced. When interacting in pods, we noticed the presence of adult animals previously photo-identified in the Gulf applying both the feeding in net and the feeding in wild behaviours (Figure 35).

Figure 35. *Small pod composed by adult bottlenose dolphins in the Gulf of Catania. Source: Marecamp.*

To evaluate the impact of a depredation case of a fishing gear, we first studied the main characteristics of the nets chosen for the trial and the possible catches with those gears. We therefore assumed as control values of a fishing set without interaction or any damage the average of 12 kg of catch, and 0.46% average damage of net before a set counting the meters interested by holes on the total length of the gear. Moreover, we established an average catch price of 10 €/kg.

Table 4 and Table 5 show the results of the AAS trial. The decision to consider the AAS active was made in a casual way so that the fisher could not make assumptions about the presence of dolphins and the alert received from the researchers in order reproduce the natural working conditions as best. For 14 times on 23 the AAS has been considered deactivated, so no alert was communicated to the fisher in presence of dolphins. In 9 cases the AAS has been considered activated, so the researchers called the fisher once they detect the first vocalization of a close dolphin involved in possible feeding behavior. Depending on the fishing area, the fisher took 30-45 minutes to reach the fishing net and start the hauling up that lasted an hour and a half on average.

From acoustical analyses subsequently conducted on the recordings, we found that in some cases dolphins were present earlier than field observers believed. This is because often the listening conditions at sea are not ideal, moreover, when dolphins emit high frequency impulses (>20 kHz) they are not audible and therefore it is possible to find them only through the examination of the spectrogram. Furthermore, with the instruments available in the field it was not possible to isolate particular frequencies or background noises that could mask the dolphin biophonies. Consequently, the intervention time elapsed between listening to the first useful vocalization and the beginning of the retirement of the net has in some cases been recalculated and for this reason result longer than the 45 minutes estimated as maximum time.

Cases of feeble vocalizations or belonging to categories recognized as more related to social events (as whistle and moan) were not considered to activate the AAS.

The bottlenose dolphin and the striped dolphin were present both during fishing set under AAS-on and AAS-off. Only when the AAS was disabled we recorded damages on the catch such as body of the fish partially eaten or the presence of only the fish heads entangled in the net.

The experiment showed that in the 9 cases of AAS-on the damage to the net was limited compared to that found in the 14 cases with AAS-off. Indeed, the highest values of loss of catches and percentage of damaged fishing gear were detected during the depredation events with the ASS disabled, and they also occurred more frequently than in the cases with ASS-on.

The reduction of the damage suffered by the fisher in the event of AAS-on eliminates the cases of damage to the catch and drastically lowers both the loss of catch and the meters of net affected by holes of various sizes (Figure 36). Indeed, it seems that timely intervention can not only avoid receiving damage due to depredation but that in addition the quantity of fish may be higher than normal, probably thanks to the wall-hunting method applied by dolphins on the net.

Figure 36. *A big hole on a single-layer net (monofilo gear) caused by dolphin depredation in the Gulf of Catania. Source: Marecamp.*

Comparing results from the trial we note that greater damage was recorded when the fisher was not notified of the presence of dolphins (AAS-off). The maximum value of damage to the net during AAS-on (20% of damaged net) is even lower than the minimum value recorded in cases with AAS-off (26% of damaged net). While the minimum percentage of damage on the net considering the AAS active stands at 4%, depredation events with the AAS-off bring to fishing gears damaged up to 77% more than a normal fishing set without interaction. However, although with the AAS activated on average there is no damage to the catch quantities, and indeed in some cases this increases up to 342%, there have been cases in which the catch was very poor (-76%) despite having promptly retired the fishing gear and having not reported any damage to it. In this specific case, we believe that the numeric composition of the pod (more than 10 dolphins simultaneously on the net) may have influenced the results. On the contrary, with the AAS-off the catch decreased drastically with -44% average and -90% maximum (Table 6).

Figure 37 and Figure 38 show how the amount in catch variation and of damaged net are, respectively, directly and inversely proportional to the activation or deactivation of the AAS.

No. Event	Alert activated	Involved species	Catch variation	Damage (net)	Damage (catch)
1	N	*Tursiops truncatus*	-19,61%	77%	N
2	N	*Tursiops truncatus*	-27,65%	10%	N
3	N	*Tursiops truncatus*	-43,73%	2%	N
4	N	*Tursiops truncatus*	-46,95%	30%	N
5	N	*Stenella coeruleoalba*	-7,56%	0%	N
6	N	*Tursiops truncatus*	-51,77%	56%	N
7	N	*Tursiops truncatus*	-71,86%	62%	Y
8	N	*Stenella coeruleoalba*	-2,73%	0%	N
9	N	*Tursiops truncatus*	-25,24%	0%	N
10	N	*Tursiops truncatus*	-59,81%	43%	N
11	N	*Tursiops truncatus*	-89,55%	8%	Y
12	N	*Tursiops truncatus*	-3,54%	0%	N
13	N	*NI*	-83,92%	6%	N
14	N	*Tursiops truncatus*	-83,92%	64%	Y

Table 4. *Damages recorded during depredation cases with the Acoustic Alert System disabled. High values of catch loss in red. Our elaboration on trial data.*

No. Event	Alert activated	Involved species	Catch variation	Damage (net)	Damage (catch)
1	Y	*Tursiops truncatus*	-75,88%	4%	N
2	Y	*Tursiops truncatus*	-47,75%	20%	N
3	Y	*Tursiops truncatus*	+4,50%	2%	N
4	Y	*Stenella coeruleoalba*	-27,65%	2%	N
5	Y	*Tursiops truncatus*	+28,62%	2%	N
6	Y	*Tursiops truncatus*	+125,08%	0%	N
7	Y	*Tursiops truncatus*	+36,66%	0%	N
8	Y	*Tursiops truncatus*	+342,12%	4%	N
9	Y	*NI*	+26,21%	0%	N

Table 5. *Damages recorded during depredation cases with the Acoustic Alert System activated. High values of catch loss in red. Increasing catches in blue. Our elaboration on trial data.*

AAS status		Catch variation	Damage (net)	Damage (catch)
Disabled	*Average*	-44,13%	26%	3 cases
	Min	-2,73%	0%	
	Max	-89,55%	77%	
Activated	*Average*	+45,77%	4%	N
	Min	-75,88%	0%	
	Max	+342,12%	20%	

Table 6. *Summary of the results from the trial of the Acoustic Alert System with average, minimum and maximum values of damages depending on the AAS status. Our elaboration on trial data.*

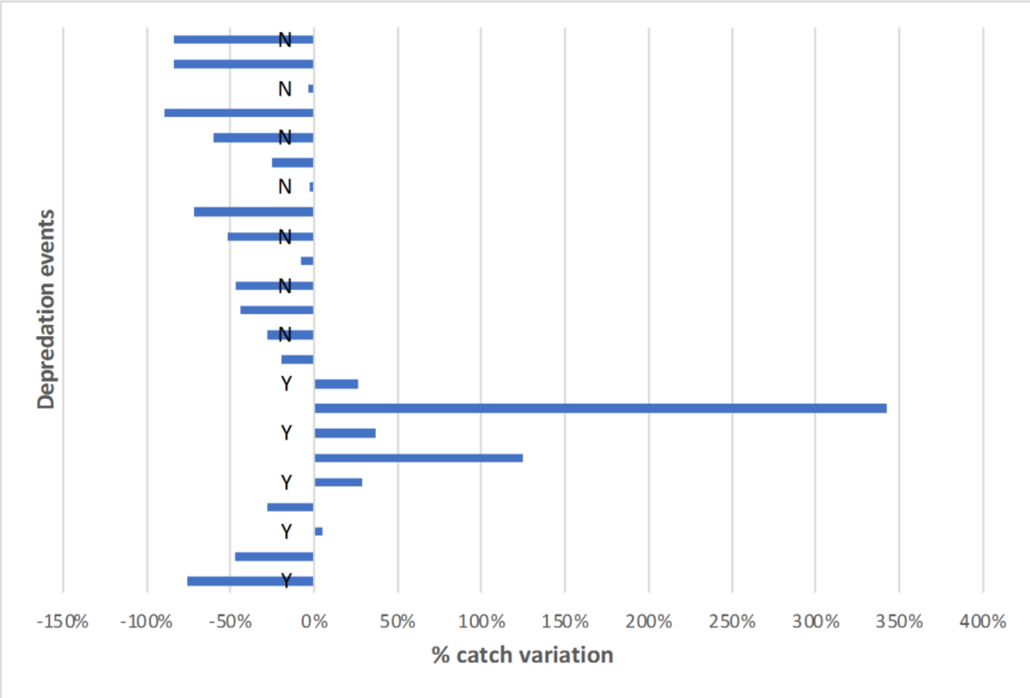

Figure 37. *Variations in the quantity of catch (kg %) in relation to the AAS activated (Y) or deactivated. Our elaboration on trial data.*

Making an economic estimate of the damages suffered and of any benefits due to the activation of the AAS, we calculated that in the considered 9 cases the fisher did not have any losses and probably earned more than expected (+ € 512 considering the average of landings and prices). On the other hand, the uninterrupted depredation during the other 14 fishing sets caused an economic loss of - € 768. This value refers only to the missed catch, while adding the time spent by the fisher to fix the net, the material necessary for the repair, and the fixed costs necessary to carry out the fishing trip such as fuel, the loss is higher and is around € 1 500.

Further analysis shows how intervening during the first hour in which the dolphins have been intercepted is fundamental for a consistent reduction of the damage both for the integrity of the net and for maintaining good quantities of catches (Figure 39). This suggests that it is advisable that the fisher stay at sea near the fishing gear when it is lowered without coming back to the port, even if relatively close, to be quicker in the event of a necessary retirement intervention. In any case, if the AAS will be created and the interception methods of the sounds are precise and automated, there should no longer be cases in which a vocalization is not detected and therefore the fisher can be notified earlier.

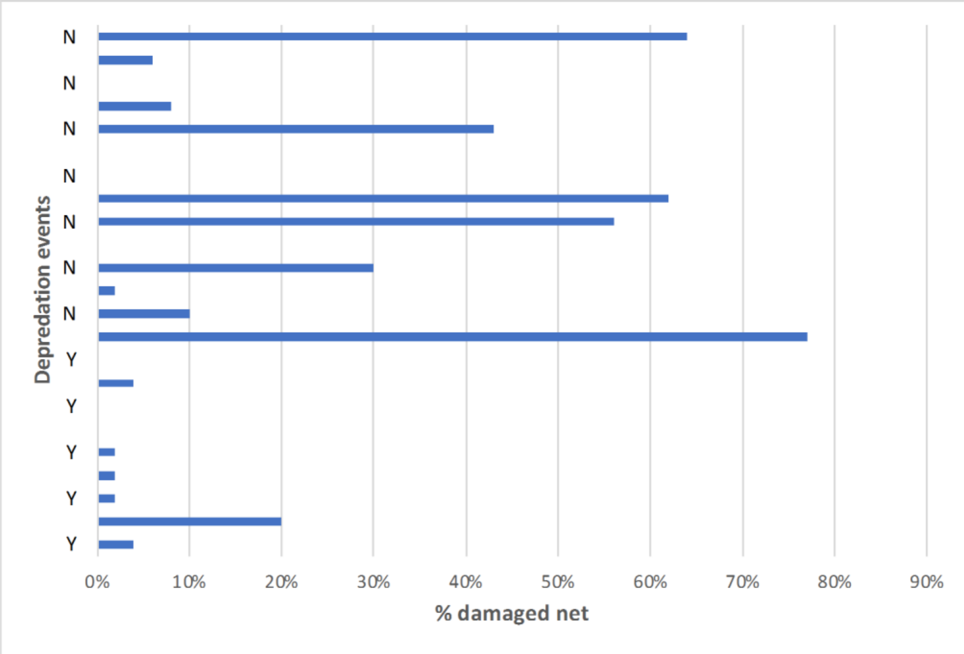

Figure 38. *Amount of damaged net (m %) in relation to the AAS activated (Y) or deactivated. Our elaboration on trial data.*

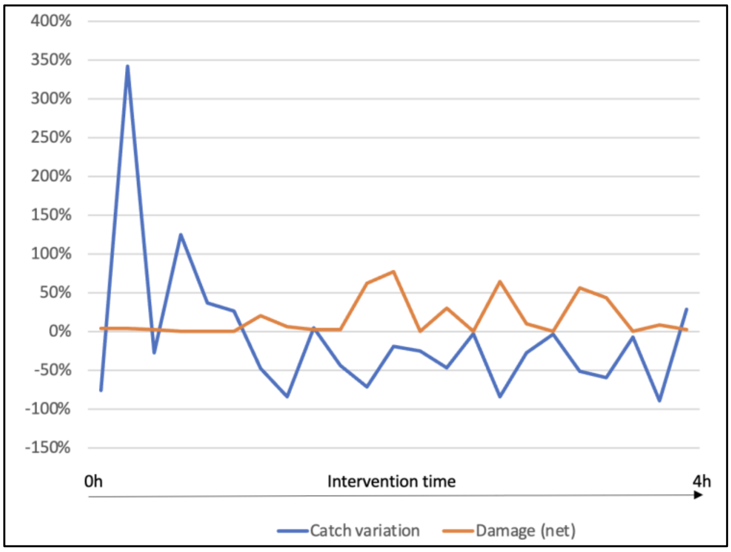

Figure 39. *Catch and damage variation depending on the intervention time in haul up the net in case of dolphins detected. Our elaboration on trial data.*

Despite the preliminary results of this experimentation indicate a good success of the use of AAS, there are still few cases of interaction studied, so to carry out significant statistical analyses it is necessary to carry out a greater number of tests. However, first analysis of data collected underlined also the following outcomes which may be useful to consider when developing an AAS:

- The manual alert system had a greater effectiveness in intercepting sounds if further from the coast and with less background noises such as those caused by boat engines, so an automatic one should be set to be capable to intercept the requested sounds in different soundscapes and conditions.

Figure 40. *Screenshot of a video sent by a fisher involved in negative interaction with bottlenose dolphins while fishing with a trammel net in the Gulf of Catania. Source: Marecamp.*

- Having occurred cases of "visive sighting" or "acoustic detecting" hearing the blow of the dolphins, before the "acoustic sighting" with the hydrophones underwater, especially with pods composed by less than 3 individuals, the AAS could activate after the real arrival of the dolphins near fishing gear.
- It was difficult to produce video-photographic material during interaction events because they occur at night or at the first light of dawn. However, also underwater cameras could be placed into the fishing gear to better understand the feeding behavior of dolphins interacting with the nets.
- In many cases it was difficult to identify the dolphin species if not sighted visually. This means that the automatic alert system may not be able to provide information on the species involved in a given depredation event.
- The simultaneous participation in the experimentation by several fishers could give more precise information on the actual frequency of the depredation events suffered by the local fleet (Figure 40). Furthermore, testing the AAS on different fishing gears would broaden the answers regarding its degree of efficiency.

3.4 A case of by-catch of a bottlenose dolphin

During one of the surveys carried out for this study we were able to document, for the first ever time, the vocal behavior of a bottlenose dolphin pod during the entangling (and subsequent death) of a groupmate in a fishing net (Figure 41). The event occurred in the early morning, under good weather conditions and calm waters (Douglas scale 0-1 and Beaufort scale 0-1). The dolphins approached the fishing boat during the setting of a single wall net (monofilo) 900 m length, placed at 50 m of depth, which had been left in place for three hours. The passive acoustic listening confirmed the dolphins' presence from the beginning of the fishing net positioning. Once the sun rose, we visually inspected the area and spotted about 10 bottlenose dolphins. When the fishing boat withdrew the net, we found a subadult bottlenose dolphin male entangled and dead.

During this exceptional event, we recorded a vast number of dolphins' vocalizations: overall, we collected 02h:18m:54s of audio recordings and identified a total of 654 vocalizations, including 51 non-signature whistles, 399 signature whistles, and 204 burst pulses (Terranova et al., 2022).

From reflections with the fisherman involved, the dolphin was accidentally caught in the last 20 meters of the net which had been armed with a more reinforced portion rather than ordinary fishing trips to counter the strong currents that persisted in those days in the Gulf. This reinforcement consisted of thicker net wire and larger meshes, with a lead line also reinforced and therefore heavier so that the net was not pierced by the current or by the strong impact against the rocks of the seabed being a set gillnet. In the attempt to free itself, the dolphin may have become tangled in nearby portions of the net and also got trapped in the rope of the last part of the gear. The dynamics of this by-catch event suggest how also little changes to the fishing gears could avoid or not the recurrence of such cases, with or without interfering with the success of fish catches. However, once the cause that determined this accidental capture has been identified, and since it is the first case ever for the Gulf of capturing a cetacean with an artisanal gear, the fisherman has decided autonomously not to use more reinforced nets even in the case of strong currents, and Marecamp has started an awareness campaign towards the entire fleet to prevent the event from happening again.

Figure 41. *Entangled dead subadult bottlenose dolphin in a single wall net just hauled up, Gulf of Catania. Source: Marecamp.*

4. Conclusion and recommandations

Past studies on small-scale fishing fleets in the Gulf of Catania (Ionian Sea, Italy) have shown that the use of acoustic deterrents is not capable of solving the problem of the interaction between cetaceans and fishing activities (Monaco, 2020). The question becomes more and more urgent as it adds up to a whole series of other elements such as climate change, the depletion of marine resources, anthropogenic impacts of various origin, which jeopardise the sustainability of the entire fishing sector and, at the same time, threaten the conservation of vulnerable species such as cetaceans.

After a pilot study aimed at better understanding the dynamics that determine the events of depredation of fishing gears by dolphins, and having identified as a possible mitigation measure the use of an automatic Acoustic Alert System (AAS) capable of informing the fishers in real time on the presence of dolphins in the proximity of his fishing gear lowered at sea, we manually tested the effectiveness that this device could have in reducing the damage caused by fishing-cetacean interactions (Figure 42).

***Figure 42**. Surfacing of a dolphin near a fishing signal of net start in the Gulf of Catania. Source: Marecamp.*

Investigations highlighted an increase in the frequency of the occurrence of dolphin depredation events in the last 2 years (+ 25%) in the study area, despite the fishing effort remained fairly constant. The CPUE values of a fishing trip are 38% lower when there is depredation, compared to one without interaction. Reported consequences of this type of event include: removal of the prey or their damage when trapped in the gears, tearing of portions of the net with production of holes of various sizes, scattering preys, changing in target species, variation in the amount of the catch, dolphin by-catch.

The target fish of the nets selected for the experimentation (a single-wall gillnet, and a trammel net) include 23 main species among which they are mullet, cod, bream, parrot fish, sole, etc., which can be all interested by dolphin depredation. The damage to the catch recorded during 14 depredation cases occurred in the trial amount to € 1 500, including the time spent by the fisher to fix the net, the material necessary for the repair, and the fixed costs necessary to carry out the fishing trip such as fuel.

Longer nets resulted more likely to be damaged as they extend over a greater space and require a longer amount of time to be hauled up, thus remaining more time underwater. Moreover, any fishing gear is damaged more quickly in case of larger pods of dolphins.

Cetacean species involved in the recorded depredation events are bottlenose dolphin and striped dolphin, with prevalence of the first (78%) interacting alone or with up to 11 individuals together, including calves.

During the trial, one bottlenose dolphin was involved also in a mortal by-catch event while feeding in a gillnet, representing the first ever documented case for an artisanal fishing gear in the Mediterranean. Technical characteristics of the net that caused this negative event and that could be modified have been identified. Moreover, the related fishing set has been characterized by an unusual high number of signature whistles emitted by the pod, suggesting that an ad hoc-set acoustic alert system could prevent also entanglement deaths.

The experiment was focalized on the interception of the vocalizations emitted by dolphins associated with feeding behaviour near the nets, such as clicks and bursts, in order to advise the fisher in time permitting him to haul up his net before to suffer any damage. In anticipation of being able to design an automatic device, the tests were conducted directly in the field by a multi-specialized team equipped with hydrophones onboard a research vessel. Further bioacoustics analyses were carried out also by replaying the recordings afterwards. The fisher has not been warned in all cases of sighting or listening of cetaceans in order to maintain some “control events” to be later compared with cases in which the net was hauled up in advance at the first listening of nearby dolphin clicks.

Preliminary results indicate that the AAS can favour the reduction of the loss, indeed, in the 9 cases of AAS-on the damage to the net was limited compared to that found in the 14 cases with AAS-off. The highest values of loss of catches and percentage of damaged fishing gear were detected during the depredation events with the ASS disabled (-44% catch average), and they also occurred more frequently than in the cases with ASS-on. Also, the reduction of the damage suffered by the fisher in the event of AAS-on eliminates the cases of damage to the catch, and drastically lowers both the loss of catch and the meters of net affected by holes of various sizes. Indeed, it seems that timely intervention can not only avoid receiving damage due to depredation but that in addition the quantity of fish may be higher than normal (+45% catch average), probably thanks to the wall-hunting method applied by dolphins on the net.

The transition from a manual to an automatic warning system is not only costly, but requires further tests and adjustments. In any case, the main factor is to make it automatic and therefore capable of detecting the sounds emitted by cetaceans without the intervention of a researcher in the field. On the other hand, the same operator would not be able to distinguish the high frequency impulses (>20 kHz) modulated by the dolphins because they are not audible for human, if not through the examination of the spectrogram.

Among the other issues in detecting dolphin vocalization such as when they are a few individuals, the AAS should solve also the problems related to background noise which may depend on the proximity to the coast, and the presence of anthropogenic activities such as fishing or maritime traffic of vessels of various tonnage.

This requires that the AAS is well set up to be effective in each of these occasions, and that it can refer to a repertoire catalogue through which the detected sounds can be distinguished. To this aim, we created a catalogue of sounds (including recordings and spectrograms) with all the patterns recorded during the trial, including different type of noise generated by the engine of the vessels or other devices they have onboard such us echo-sounders or winches, and sounds generated by marine fauna such as vocalizations produced by dolphins.

With a view to a new third phase of the project that allows to deepen the aspects related to the damages suffered by the fishers, both without applying any mitigation measures and with the use of an AAS, it is recommended to continue to test the efficiency of this device using less and less manual methods. Statistically significant reference values can be achieved by testing the system for a number of times greater than 100, including the same number of cases in which the alert is considered to be ignored, and cases in which the fisher begins to haul up his gear within half an hour of the detection of the first clicks.

Essential characteristics required by such "automatic sampler" should include the capacity to detect and record all the sounds belonging to the cetacean spectrum (up to 150 kHz), eventually, using also more devices set up for different ranges) and to provide for each sound combined information such as the time. Additional information could be provided by the device itself or by the fishers such as date, depth, water temperature, current, and time of the fishing set, while elements such as the gear used, the amount of damage to the nets or the loss of catch could be verified by specialized operators at the landing. To facilitate the damage count, it could also be envisaged to purchase special nets intended solely for experimentation and therefore to be used only on trial days.

In this phase, the post-registration analyses would continue to be performed by a bioacoustics expert for the subsequent evaluations of the effectiveness of the model to be built. Should the new results confirm the validity of the AAS, the same records can be used to test the functioning of a prototype. Indeed, it must be considered that the final AAS has to distinguish the sounds of feeding behaviour of nearby dolphins from all the other vocalizations that could be a "false alarm" and are very common in the soundscape of the study area.

The continuation of such an experiment could be based on the technology used for the passive acoustic monitoring (C-PODs, T-PODs, F-PODs) based on hydrophones that passively monitor acoustics in the water detecting sounds of odontocetes, specially by recognising the trains of echo-location sounds they produce to detect their prey, orientate and interact (Jacobson, 2017; Paitach et al., 2021). These models could be modified at a later stage and therefore the sustainability of the initial economic investment to protect an entire gear from dolphin conflicts could be assessed.

Among the implementations to be made to the system, it is also suggested to study any frequencies emitted by the devices to avoid any possibility that could determine a "dinner bell" effect similar to that cause by pingers.

Further measures for population studies and in-depths on the depredation aptitude could include the placement of underwater video cameras on fishing gears in order to: better understand the dynamics of depredation; be able to associate certain signature whistles with photo-identified fins, verifying whether even the youngest individuals have a greater number of scars determined by frequent interactions as suggested by Leone et al. (2019); and ascertaining the presence of calves which is an important species conservation issue.

Figure 43. *A dolphin swimming near a small-scale fishing vessel in the Gulf of Catania during a depredation event. Source: Marecamp.*

It is also suggested to deepen the experimentation on other fishing gears such as other gillnets (i.e. the *menaida*), and also on gears of different nature such as that used for the flying squid fishing (*totanara*) for which a high percentage of cases of interaction is well known in the study area. Furthermore, given a certain cyclical nature with which dolphins can interact more or less with a fishing gear, testing mitigation measures on multiple gears can help to prevent new conflicts.

Regarding measures aimed at mitigating the occurrence of by-catch events, it should be found how, in case of strong currents, can prevent nets from breaking and, at the same time, that they tangle on dolphins, resulting in a useful solution for both fishers and dolphins. However, it is recommended not to apply reinforcements to the nets as in case of entrapment of a dolphin it could die entangled, instead of being able to free itself by tearing the net.

In order to achieve a greater number of results in a homogeneous format, and to favor mitigation actions where conflicts between fishing and cetaceans are increasingly urgent, it is recommended to apply the research protocol developed for this study in other areas of the Mediterranean with similar fleets, fauna, and issues, taking advantage from the replicability of the method. At local level, we suggest extending the possible new experimentation also in the southern Gulf area as it is notably very affected by the cases of depredation involving the bottlenose dolphin (Figure 43).

Insights coming from the next works could favor the reassessment of compensation measures for fishers affected by dolphin depredation, or determine the identification of a concrete solution to the conflicts that occur in a specific fishing segment such as that of small-scale fishery using trammel nets and gillnets.

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7. Annexes

Annexe I – Mean ± standard deviation (SD) of acoustic parameters of the 11 signature whistle types. Extract from Terranova et al., 2022.

SW ID	Frequency (kHz)						Inflections (n)	Duration (s)
	Start	End	Maximum	Minimum	Mean	Range		
SW1	9.88	7.3	12.2	4.74	8.79	7.46	2.3	1
±SD	2.1	1.61	1.03	1.1	0.53	1.8	1.86	0.46
SW2	9.52	8.09	13.48	7.22	10.64	6.26	0.8	0.96
±SD	2.22	2.31	1.03	0.88	0.87	1.23	1.47	0.32
SW3	7.92	11.74	12.56	7.77	10.62	4.79	0	0.51
±SD	0.85	1.73	0.43	0.85	0.42	0.95	0	0.12
SW4	5.35	13.79	14.08	4.91	9.04	9.18	0.25	0.74
±SD	1.34	1.87	1.97	1.11	0.98	2.61	0.5	0.14
SW5	4.12	11.73	13.65	4.04	7.38	9.61	0.8	0.66
±SD	0.37	3.36	1.59	0.36	0.95	1.88	1.3	0.26
SW6	10.56	10.27	17.72	6.73	12.02	10.99	6.47	1.3
±SD	2.96	2.8	2.18	0.43	0.43	2.43	6.31	0.54
SW7	7.42	5.37	7.51	4.93	5.24	2.84	0.15	0.25
±SD	1.98	0.69	1.96	1.14	1.15	1.9	0.36	0.14
SW8	11.1	16.59	17.85	9.24	12.92	8.61	0.57	0.41
±SD	1.85	2.6	3.72	1.13	1.58	3.65	1.13	0.23
SW9	10.41	10.8	15.15	8.98	12.71	6.17	2.5	0.83
±SD	0.88	3.21	0.44	0.79	0.65	0.63	2.08	0.19
SW10	8.54	13.68	14.65	8.41	11.16	6.25	0	0.4
±SD	0.95	2.15	0.98	0.96	0.43	1.52	0	0.18
SW11	5.23	10.37	10.41	5.19	8.08	5.22	0	0.18
±SD	0.92	0.78	0.78	0.94	0.48	1.23	0	0.04

Annexe II – Variance explained by the Principal Components showing eigenvalues > 1. Extract from Terranova et al., 2022.

Principal Component	Eigenvalue	% variance	% cumulative variance
1	3.16	39.52	39.52
2	2.72	34.10	73.62
3	0.98	12.27	85.89

Annexe III – Factor loadings for the eight acoustic parameters on the Principal Components showing eigenvalue >1. Extract from Terranova et al., 2022.

Acoustic parameters	Principal Component		
	1	2	3
Maximum frequency	**0.88**	0.40	-0.05
Mean frequency	**0.86**	-0.27	-0.14
End frequency	**0.72**	**-0.54**	-0.03
Duration	**0.69**	**-0.50**	-0.14
Range frequency	-0.02	**0.90**	0.13
Minimum frequency	0.24	**0.82**	-0.28
Inflection	**0.66**	**0.68**	0.05
Start frequency	0.35	-0.03	**0.92**

Bold text indicates the factor loadings with r > 0.5.

ACCOBAMS-MOP8/2022/Inf39

MITIGATING DOLPHIN DEPREDATION IN MEDITERRANEAN FISHERIES
JOINING EFFORTS FOR STRENGTHENING CETACEAN CONSERVATION AND SUSTAINABLE FISHERIES

Towards solutions to interactions between fisheries and cetaceans – The Malta case

Kimberly Terribile & Matthew Laspina

31st August 2022

MCAST

MINISTRY FOR AGRICULTURE, FISHERIES AND ANIMAL RIGHTS

TOWARDS SOLUTIONS TO INTERACTIONS BETWEEN FISHERIES AND CETACEANS – THE MALTA CASE

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- ⇒ Carmen Mifsud (Senior Environment Protection Officer, Environment & Resources Authority, Malta)

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TOWARDS SOLUTIONS TO INTERACTIONS BETWEEN FISHERIES AND CETACEANS – THE MALTA CASE

EXECUTIVE SUMMARY

Maltese scientists teamed up with foreign researchers to understand the status of cetacean occurrence, depredation, and their interaction with fisheries. In Malta, focus was deployed on small-scale fisheries which represent 93% of the national fleet and consist of vessels being under 12 metres in length and engaging in artisanal fishing, including surface longlines, trammel nets, entangling nets, pots and traps. The aim was to collate knowledge from fishers, and integrate it with scientific data to closely understand how increasing cetacean populations are interacting with Mediterranean fisheries, quantify their socio-economic impacts, and invest in innovative technologies to curb damaging interactions to safeguard the fishing sector and the cetacean populations.

The research project was initiated in 2019, focusing on three areas of the Western and Central Mediterranean Sea (*Figure 1*), namely, 1) the North Alboran Sea (Andalusia, Spain) between the Strait of Gibraltar (Tarifa) and Garrucha (Almería) (GSA01); 2) the Maltese islands (GSA15) (Malta); 3) the Ionian Sea, eastern Sicily (GSA19), and southern Tyrrhenian Sea, north-east Sicily and Aeolian Islands (GSA10) (Italy).

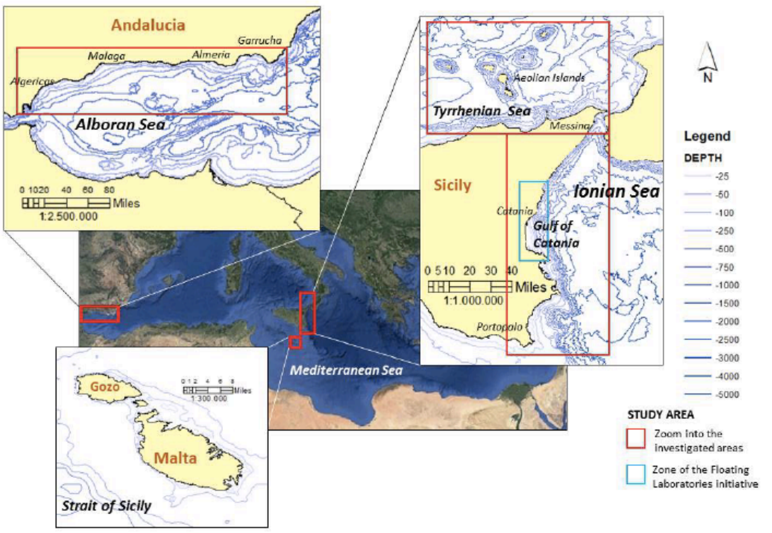

Figure 1: The location of the research areas showing the locations where investigations are being carried out (Monaco et al., 2020).

The use of the Local Ecological Knowledge of fishers was applied to understand the interaction occurrence between small-scale fisheries and cetaceans in these regions with the aim to conserve the cetacean population, while at the same time ensuring sustainable fisheries. Such interactions usually occur at regions where there is a spatial overlap between the cetaceans' habitat and the region where fishing activities take place, and in both cases, the same target species is involved. In coastal regions, including the Maltese Islands, such cetacean depredation often involves the bottlenose dolphin *Tursiops truncatus*.

Researchers conducted interviews using a pre-defined questionnaire with 38 small-scale fishers in various ports (Marsaxlokk, Marsascala, Msida, St Paul's Bay, Ġnejna, Mellieħa, Cirkewwa and Mġarr (Gozo)) to investigate interaction characteristics, including type of depredated species and gear damages and losses. Results show that 76% of the interviewed fishers claimed a continuous increase in encounters with dolphins (Terribile *et al.*, 2020), particularly in the vicinity of fish farm locations. When asked about the situation over the past 5 years, 12% of fishers believed that the encounter numbers remained roughly the same, 9% did not record any interaction and 3%

believed that the frequency of encounters decreased in the past 5 years. Reduction in catches and gear damages (60%) are the most common socio-economic impact related to cetacean depredation, a reality mostly experienced by those using trammel nets. It is interesting to note that despite cetacean entanglement is considered as a risk, no form of entanglement was reported in either of the Mediterranean studies.

This was one of the first national endevours to compile Local Ecological Knowledge from fishing communities, and it is evident that such knowledge can be a useful tool to obtain the fishers' perception on various marine factors, including the cetacean-fishery interactions. It is also essential that proper monitoring is carried out in order to assess the factors that drive the interactions and to evaluate the impact of dolphin depredation on the fishing sector. Such assessments could then be amalgamated with fisheries management to provide proper mitigation measures in an attempt to try and reduce the risk of depredation by dolphins.

During the second phase of this research, a total of 15 trammel nets were provided to 15 fishers which were chosen at random and which were given to fishers on a rotational basis. Fifteen pingers (DDD 03x Orange Line) and another fifteen pingers (DID 01 Green line) were purchased from STM Products Ltd and distributed to the mentioned Maltese fishers. Onboard observers joined fishers on a regular basis in order to determine the frequency, type and location of the dolphin interactions. Subsequently, pingers were tested with the aim of reducing the damaging depredation interactions on fishing activities. These acoustic devices were attached to trammel nets in two testing zones, and data was collected on their effectiveness. During this phase, the factors that are leading to an increase in the incidence of depredation by dolphins and other vulnerable marine species in recent years was examined in depth, as well as the changes in fishing productivity and in the incidence of interaction cases after the use of new mitigation systems. Results show that cetacean depredation is a commonly occurring phenomenon in Maltese waters, and even though the results achieved can be considered to be preliminary, it is clear that these pingers are proving to be effective mitigation measures, at least in the short-term.

Such an integration of local ecological knowledge and scientific data of the current status of dolphin depredation and its effects on small-scale fisheries in the Maltese Islands provides a more holistic picture and allows for bottom-up management. This can subsequently be used in the compilation of regulations and mitigation measures for the sustainability of the fisheries sector and cetaceans alike.

CONTEXT, AIM AND OBJECTIVES OF THE STUDY

CONTEXT

Depredation caused by cetaceans in fisheries is a growing matter of concern for several fisheries in the Mediterranean. Socio-economic impacts caused by the damages to the fishing gears and the loss of catches create situations of conflicts between fishers and dolphins, weakening the conservation and sustainability efforts.The issue of cetacean-fishery interaction is of such importance that it is included in the ACCOBAMS (The Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and contiguous Atlantic area), LIFE (French: L'Instrument Financier pour l'Environnement) and GFCM (General Fisheries Commission for the Mediterranean) strategies.

This research is part of a wider study that was carried out over a three-year period, and which includes partnerships with Marecamp (Italy), and Asociación Herpetológica Española (Spain). The study aims to assess the current status of cetaceans in Maltese waters and the relationship of these cetaceans with fisheries, and subsequently test mitigation measures. This will help reduce conflict between fishers and cetaceans, specifically bottlenose dolphins, ensuring conservation of cetaceans and sustainability of the fisheries sector.

AIM AND OBJECTIVES

The aim of this study was to analyse the interactions between cetaceans and small-scale fisheries around the central Mediterranean Maltese Islands

The objectives of the study were:

i. To understand the status of cetacean depredation in Maltese waters

ii. To provide mitigation measures if/where cetacean depredation occurs

iii. To join efforts with regional partners to strengthen cetacean conservation and ensure sustainable fisheries.

CHAPTER 1: INTRODUCTION

1.1 STUDY AREA

The Maltese islands are located 96km away from Sicily and 290km from North Africa. The marine biota of the Maltese Islands reflects their position and includes elements from the West and the East. Therefore the biogeographic location of the Maltese Islands at the centre of the Mediterranean Sea act as a sink for marine species that exist both in the Western and Eastern Mediterranean regions.

This study is being carried out within the Malta Fisheries Management Zone (*Figure 2*). Back in 1971, Malta declared an Exclusive Fishing Zone (EFZ) that extended to 25 nautical miles from the baselines of the Maltese Islands (Act XXXII of 1971), in accordance with the United Nations Convention on the Law of the Sea. With the entry of Malta into the European Union in 2004, this zone was maintained as a Fisheries Management Zone (FMZ) around the Maltese Islands.

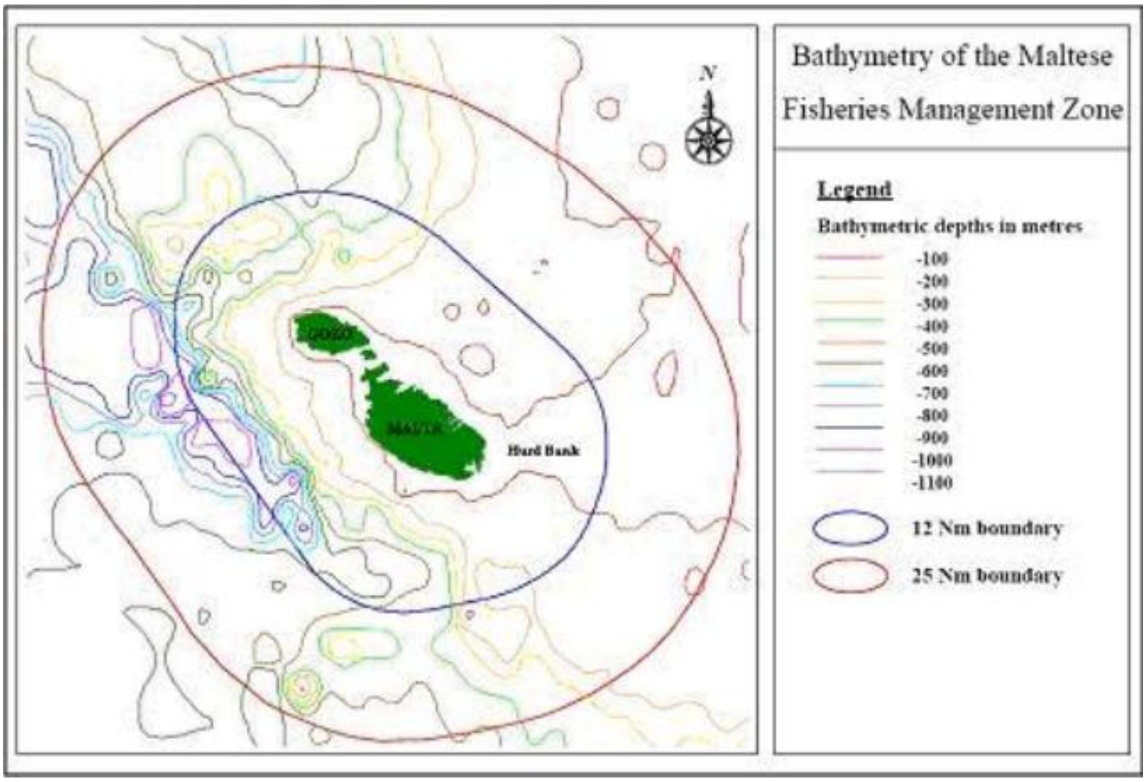

Figure 2: The Malta Fisheries Management Zone

1.2 TRAMMEL NET FISHERY

This study involved analysis of interactions between cetaceans and small-scale fisheries. In fact, by definition, small-scale fisheries is defined as "Fishing carried out by fishing vessels of an overall length of less than 12m and not using towed fishing gear". Following this definition, most of the Maltese fleet is considered as small-scale and most of the local fishing practices are small-scale fishing practices.

Trammel nets are considered to be bottom-set gillnets that consist of 3 layers of netting and are utilised to target demersal or benthic fish. The two outermost layers of the nets have large mesh sizes while the middle nets have a smaller mesh size. Since these nets consist of 3 layers which increases the entangling characteristics of this gear, they have a low selectivity in terms of catch.

Trammel nets generally have float line at the uppermost part of the gear, while a lead line is inserted at the bottommost part of the net to ensure that the gear sinks to the bottom. In Malta, the trammel net gear is generally marked with buoys at both ends. Generally, Maltese fishers set their trammel nets in the afternoon, they are left overnight and hauled back in the early hours of the morning with the help of motorised winch connected to the main engine. According to EC 2019/1241, Mediterranean fishers are only allowed to set 6000m of trammel net gear, however since most trammel net fishers in Malta are considered to be small in scale, the maximum length towed for Maltese fishers is approximately 4000m to 5000m. This fishery can be considered to be a mixed-species fishery since various fish species are captured such as cuttlefish, red mullet, spiny lobsters, octopus, scorpion fish, red snapper, john dory and dentex.

1.3 SPECIES INVOLVED

This study focused on cetaceans, and while 87 cetacean species has been recorded world-wide, the local sightings include the Common bottlenose dolphin Cuvier's whale, Sowerby's whale, Striped dolphin, Rough toothed dolphin and the Fin whale. These have all been sighted in Malta and recorded in written publications. There are also three other species, namely the Minke whale, the Killer whale and the False killer whale. These have been sighted in the Malta-Sicily Basin but not specifically in Maltese waters. Their distribution is all throughout the Malta FMZ as shown in *Figure 3.*

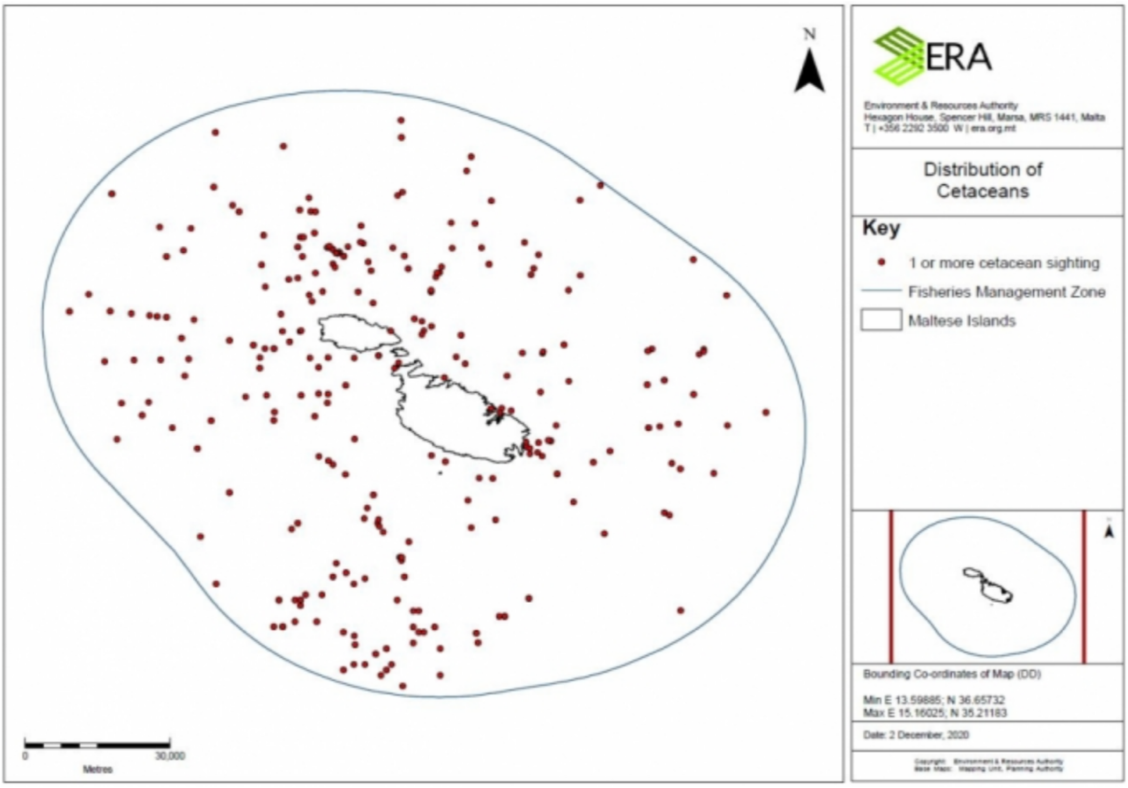

Figure 3: Distribution of cetaceans in the Malta FMZ (ERA, 2021).

CHAPTER 2 : MATERIALS AND METHODS

2.1 RESEARCH METHODOLOGY

Following *Figure 4*, in this study the research philosophy that was selected was "Positivism" (Alamgeer, 2022a). The "Positivisim" philosophy was chosen since this type of research values the importance of "a scientific, systematic and objective approach to study the social world." (Alamgeer, 2022b). Since the main aim of the study was to understand whether pingers decrease cetacean depredation on fishers' fishing gear, which is considered to be a social issue. After choosing the type of philosophy of the study, the researchers were able to choose the approach. In this case the "Deductive" approach was selected, as the aim of this research was to uncover the answer behind whether the DiD 01 or the DDD X3 would be considered to be the most effective pingers, to assess the abundance of the cetaceans when using trammel nets as opposed to fishing without trammel nets and to understand the abundance of the cetaceans when using pingers as opposed to fishing without pingers. In order to implement this "Deductive" approach, data collection was carried out by the researchers to reject or accept the hypothesis. The researchers then concluded that the type of data that will be collected throughout the study will be quantitative data. The latter data was collected since the main aim of qualitative research is to further the understanding of causes, patterns and various relationships between variables. This type of data ensures the validation of the hypothesis put forward by the researchers (Alamgeer, 2022a). In the fourth step the researchers selected the strategies of the study. In this case, the strategy chosen was "Case Study" since data was collected to understand cetacean depredation in the Maltese Islands. In the "Choices" layers the researchers selected the mixed methods approach both qualitative and quantitative data was collected throughout the study. With regards to the "Time Horizon" layer, the longitudinal time horizon was chosen since this study was carried out over a period of months from 2021 to 2022 (Phair and Warren, 2021). The sixth and final layer was utilised to establish the ideal methods for the collection of data and analysis, where decisions on how the various onboard observations were executed as well as the type of analysis that was used to obtain the desired result (Saunders *et al.*, 2007).

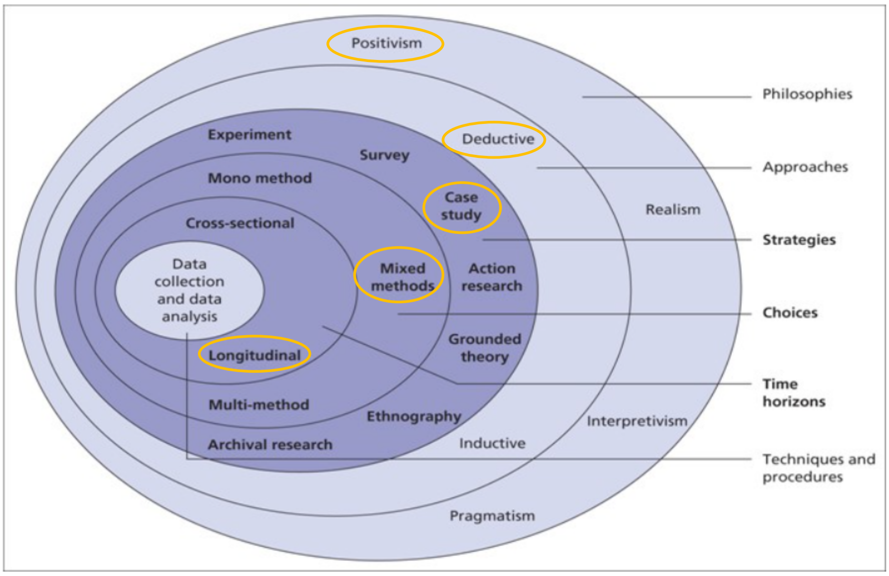

Figure 4: The research onion as applied to this study

In the case of this study, the researchers agreed that quantitative data was to be collected through onboard observations such as number of signs of depredation, size of catch in kilograms, number of cetacean sightings, monetary value lost, soaking time, distance from coast, proximity of other fishing vessels in the area and other types of quantitative data. On the other hand qualitative data was also collected such as locations which will be displayed through maps, the type of moon phase during the fishing activity, type of species captured, type of depredation and port location.

2.2 MATERIALS USED

Prior to carrying out the onboard observations with trammel net fishers and DiD 03X and DDD 01 pingers, the DFA and MCAST researchers recognized the need to organize a workshop (*Figure 5*) were fishers who participated in the onboard observations without the DiD 01 and the DDD 03X pingers, were invited. This workshop was organized at MCAST and the main aim of this workshop was to provide these fishers with the DiD 01 and DDD 03X pingers which were purchased through the MAVA Foundation funds as per PSMC procurement regulations. Throughout this workshop the fishers were given information on how to identify cetaceans and on how to distinguish between one species and another. Throughout the second part, the fishers were given the 2 sets of either the DiD 01 and DDD 03X pingers, a voltester, manuals, 2 chargers, a logbook to collect data and an identification guide as seen in image. Fishers were also given an overview of the specifications and technicalities of both the DiD 01 and DDD 03X pingers and how the former and latter should be installed in their trammel net fishing gears.

Figure 5: The workshop for fishers (LHS) and the package that was distributed to the fishers (RHS) who attended the workshop and which included the pingers.

2.2.1 Dolphin Interactive Dissuaders (DiD 01)

The DiD 01 (*Figure 6 and Table 1*) are electronic devices designed by STM Industrial Electronics, in collaboration with the Institute of Marine and Environmental Research (IRMA) of the CNR of Mazara del Vallo and the Institute of Marine Research in Moscow. Its sound frequencies range from 5-500kHz and these sounds are only emitted when in close proximity to dolphins since this technology utilises a special circuit that is activated by the clicks emitted by them. Fishes are insensitive to the frequencies emitted; therefore, it doesn't produce any harm to them nor to the dolphins. This system decreases the possibility of habituation. Since they only emit sound in the presence of cetaceans, there battery charge has an increased duration.

Figure 6: The DiD 01

Table 1: The Did 01 specifications (STM Industrial Electronics, 2020) (Mifsud and EcoMarine Ltd., 2022)

Frequencies	Random between 5 and 500 KHz
Emission power	165dB (1 µPa @ 1m)
Internal supply	NiMH Batteries, rechargeable from the external poles, only by the STM battery chargers
Batteries life	Up to 1000 charging/discharging Cycles
Batteries charge duration	Depends on the frequency of dolphin presences
Minimal depth	10 m
Maximal depth	200 m
Test pressure	3 MPa (30 Bar)
Dimensions	Diameter 62 mm x Length 215 mm
Weight	940 g

2.2.2 Dolphin Dissuasive Device (DDD 03X)

The DDD 03X (*Figure 7 and Table 2*) are electronic devices designed by STM Industrial Electronics, in collaboration with the Institute of Marine and Environmental Research (IRMA) of the CNR of Mazara del Vallo and the Institute of Marine Research in Moscow. DDDs deter cetaceans from fishing gear by interacting with their eco-location system. DDDs should be fixed to a buoy 15-20m below the surface and 20-30m from the seabed. These are activated when they come into contact with the water, hence they are constantly emitting sound, increasing the chances of habituation.The intervals between the signals are random and the emission frequency ranges from 5 to 500 kHz (STM Industrial Electronics, 2020) (Mifsud and EcoMarine Ltd., 2022)

Figure 7: DDD 03X

Table 2: The DDD 03X specifications (STM Industrial Electronics, 2020) (Mifsud and EcoMarine Ltd., 2022)

Emission Frequency	From 5 to 500 KHz
Recharge Voltage and Current	9/16 Volt, 300 mA max (internally limited)
Minimum depth	10-20 m depending from conditions
Maximum depth	200 m (20 bar)
Testing Pressure	30 bar
Horizontal Spacing between 2 devices	200/400 m depending from conditions
Vertical Spacing between 2 devices	50/80 m depending from conditions
Minimum operating batteries voltage	6V, see discharge diagram at page 4
Average life of the device	500-1000 battery charge/discharge cycles
Height	210 mm.

2.3 DATA COLLECTION

The case study was deemed to be a cooperative and participative approach as suggested by Lavigne-Delville *et al.*, 2000), since both fishers and third-party researchers aided the researchers at the Department of Fisheries and Aquaculture and MCAST in order to obtain information on depredation and hotspots of cetaceans in Malta's 25NM Fisheries Management Zone. Hence, both primary and secondary forms of data were collected. Primary data refers to data collected at first hand by the researchers (Benedictine University, 2022). Throughout this case study the DFA and MCAST researchers collected data through onboard observations with trammel net fishers (Annex 3) without the use of the DiD 01 and DDD 03X pingers. On the other hand, secondary data refers to information gathered by third-parties (Benedictine University, 2022). In this case, data was collected from other onboard observations without trammel net fishers to carry out sighting observations of cetaceans were carried out by EcoMarine Ltd., while more data was collected through onboard observations with both DDD 03X and DiD 01 pingers were carried out by trammel net fishers. Both primary and secondary data was collected since, only two main researchers were implementing the project in Malta. The total number of ports covered by the programme (Table 3) and the Main Fishing Gear per vessel group (Table 4) were tabulated.

Table 3 : Total number of ports covered by the programme

Total number of ports covered by the programme				
Country: Malta				
GSA 15	***Number of fishing trips covered***	***% Number of depredation events***	***Type of events***	***Main commercial species***
St. Paul's Bay	16	58.33%	Holes; Fish must have been depredated due to presence of holes, however no left-over fish were recorded, fish heads	Cuttlefish, saddled seabream, thronback ray, two-banded seabream, scorpion fish, Common Spiny Lobster
Marsaxlokk	5	80%	Holes; Fish must have been depredated due to presence of holes, however no left-over fish were recorded, fish heads	Cuttlefish, red mullet, Common octopus, Two-Banded Seabream, White Bream, red snapper, Scorpion Fish
St. Julian's	17	6%	Holes	Saddled Bream, Common Spiny Lobster, Amberjack, Chub Mackerel, Bonito, Grouper, Frigate Mackerel, Cuttlefish, Dentex, John Dory, Red Snapper, Scorpion Fish
Xemxija	4	0%	/	Cuttlefish, Bogue, Red Mullet
Mellieha	10	60%	Fish must have been depredated due to presence of holes, however no left-over fish were recorded	Common Octopus, Barracuda, Moray eel, Thornback Ray, Cuttlefish, Saddled-Seabream, Two-banded Seabream
Imsida	6	0%	/	Horse Mackerel, Cuttlefish, Scorpion Fish, Amberjack, Octopus, Frigate Mackerel
Lapsi	3	33%	Hole	Red mullet, Red Snapper, Scad, Scorpion Fish, Cuttlefish, Black Seabream
Marsalforn	2	0%	/	Rock Fish, Cuttlefish, Scorpion fish, Streaked Weaver
Total	**63**			

Table 4 : Main Fishing Gear per vessel group

Main fishing gear per vessel group			
Country Malta			

Port	***Main gear***	***Frequency (%) of gear used***	***Catch composition***
Trawlers	bottom trawls	N/A	
	midwater trawls	N/A	
Longliners	demersal bottom longline	N/A	
	pelagic longline	N/A	
Small-scale vessels (with and without engine)	gillnets	N/A	
	trammel nets	100%	Cuttlefish, Streaked Weaver, saddled bream,red mullet, bogue, red snapper, spiny lobster, octopus, barracuda, amberjack, grouper, dentex, White bream, Scorpion fish
	combined gillnets-trammel nets	N/A	
Polyvalents	gillnets	N/A	
	trammel nets	N/A	
	combined gillnets-trammel nets	N/A	
Purse-seiners	purse seine	N/A	

2.3.1 Onboard observations with trammel net fishers in the absence DiD 01 and DDD 03X pingers

This research was solely focused on trammel net fishery since the results achieved in the phase 1 of this study indicated that this fishing practice seemed to have several dolphin depredation issues. Since this study is based on the cetacean depredation in small scale fisheries, the researchers utilized the following European Maritime and Fisheries Fund (2020) and (EC) No 26/2004 definition: "Fishing carried out by fishing vessels of an overall length of less than 12m and not using towed fishing gear" (European Maritime and Fisheries Fund, 2020) and (EC) No 26/2004) to filter and identify the fisher participants for this study.

Once the fishers were identified, they were chosen at random and contacted by the researchers to fix a date and time for the onboard observation. In order to entice fisher participation, the DFA procured 15 trammel net fishing gear and gear repair monofilament nylon rolls by requesting quotations from trammel net suppliers in the Maltese Islands by consulting with fishers to inform the researchers on the ideal specifications for the construction of the trammel nets. The researchers ensured that the trammel nets were constructed according to EU CR 1241_2019 Annex IX which states that the mesh size for trammel nets should at least be 16mm. These specifications can be seen in Annex 1.

Generally the fishers deployed the trammel net gears the day before in the afternoon, the day prior to the onboard observation. The researchers reported for the onboard observation the following day in the early hours of the morning to collect data while the gears were being hauled. The researchers created an outline of a document that was used to collect information for these onboard observations as seen in Annex 2. The document was used to collect information on the following:

Onboard Number	Date	Time of Activity (Hours)	Port Location	Type of Fishing Gear	Width of Gear
Length of Gear	Material of Gear	Dimensions of Gear	Target Species	Catch Quantity	Time of Fishing Activity
Gear Retrieval Time (mins)	Soaking Time	Moon Phase	Seabed	Distance from Mainland (Nm)	Proximity of other Fishing vessels
Cetaceans Sighted	Number of Pods	Number of Cetaceans	Location of Cetacean Sightings	Number of Holes	Monetary Value Lost
		Depredation: Catch	Location of Depredation		

2.3.2 Onboard observations without trammel net fishers and in the absence DID 01 and DDD 03x pingers

The researchers decided to carry out other onboard observations without the use of trammel net fishing gear and also in the absence of the DiD 01 and DDD 03X pingers. The idea behind this was to eliminate the sounds of fishing vessel engines and gears. Since local fishers were adamant that cetaceans seem to get used to fishing vessel engines and the presence of trammel nets and also to eliminate the chances of sound pollution which might deter cetacean presence, the researchers opted to carry out these onboard observations to understand the presence of cetaceans in Maltese waters, better. These were carried out by EcoMarine Malta Ltd. Approval from the Continental Shelf Department was also sought to carry out such onboard observations.

The researchers were asked to carry out data collection in the Maltese Islands' territorial waters (12 nautical mile zone) using yacht. Cetacean occurrence in these waters was investigated by carrying out vessel-based sighting surveys, using line transect sampling methodology, through which the survey areas were surveyed along predetermined transects (*Figure 8*) or through *ad libitum* routes. The vessel-based surveys were carried out in favourable conditions such as calm weathers and seas. The onboard observations were haulted whenever Force 3 winds were recorded on the Beaufort scale.

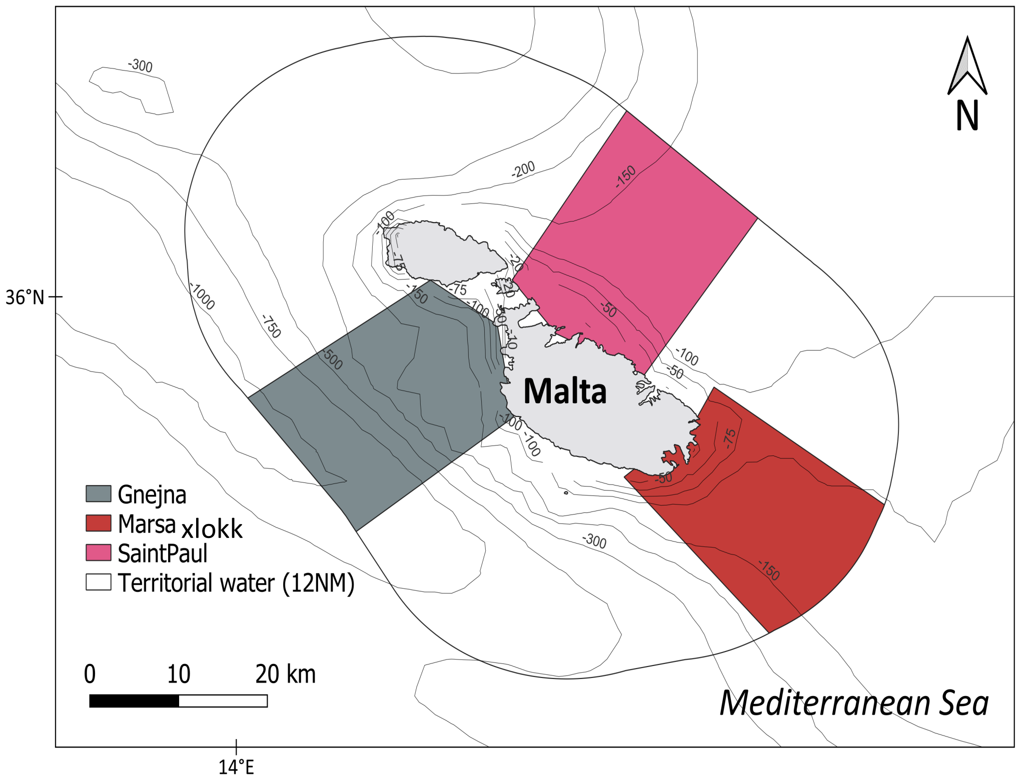

Figure 8: A map showing the transects which were sampled in the NE, SE and Western side of the Maltese Islands.

Two onboard observers were placed on a platform on the vessel, above 2m from the sea surface and both were positioned in a particular manner, to have a 180° vision angle, hence ensuring a 360° vision angle. The observers worked in shifts of 1 hour and were asked to scan the seas with their naked eye. Acoustic detections were carried out in conjunction with the visual analysis through the use of 2 towable hydrophone arrays. These were towed with a 150m cable and had an Aquarian Scientific AS-1 sensor as well as custom-made preamplifier/line driver with balanced output (HP filter set at 400Hz). These hydrophones were powered using a standard 48V phantom power (Kevlar reinforced starquad cable with PU sleeve; XLR termination). The hydrophone system was connected to a laptop through the Focusrite Scarlett 2i2 audio interface.gen3. Sample rates: 44.1 and 96 kHz, 16-bit resolution. The Sea wave software was utilized to detect cetacean vocalisations and was constantly analysed by an acoustic-trained operator throughout the onboard observation. This ensured that whenever cetaceans were detected through the hydrophones, the visual observers were asked to attempt to locate and identify the cetaceans in the area. Throughout the onboard observations several photos were taken whenever cetaceans were sighted. Environmental conditions were also recorded every half an hour or whenever the conditions seemed to change.

The parameters that were collected throughout these onboard observations are listed in *Table 5.*

Table 5: A table listed the environmental condition parameters that were collected

General environmental condition parameters that were collected during each onboard survey
• *Sea State surface* • *Sea State waves* • *Wind direction* • *Wind speed* • *Weather* • *Visibility* • *Number of vessels within 3nm* • *Types of vessels within 3nm*
Environmental condition parameters that were collected when cetaceans were sighted
• *Date* • *Time* • *Species classification* • *Group size* • *Group formation* • *Predominant behaviour* • *Surface behaviour* • *Direction of the animals to the nearest boat* • *Activity of the nearest boat*

2.3.3 Onboard observations with trammel net fishers and DID 01 and DDD 03x pingers

The data for onboard observations were mainly collected by fishers through a logbook provided. The same information collected for the onboard observations with trammel net fishers in the absence of DiD 01 and DDD 03X pingers was collected for these onboard observations.

The devices were placed on rope attached to a buoy at approximately 15-20m below the surface and 20-30m (*Figure 9*) above the seabed as seen in Image. Since they have an emission diameter of 500m (*Figure 10*), they were placed at least 600m to 800m apart to ensure that no interference would occur between the pingers. Since the DiD 01 is not able to distinguish between the echolocation signals from cetaceans and the sound emitted by the DDD 03x, fishers were asked not to place DiD at less than 1km from the DDDs. The researchers attempted to avoid this by ensuring that both types of pingers were placed in different areas around the islands. The voltesters were provided so that prior to the fishing activity fishers could check the charge level of the pingers, in order to ensure that they are fully charged prior to deployment.

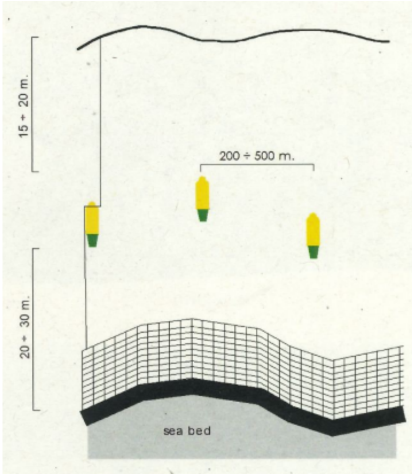

Figure 9: Locating deterrent devices above the seabed

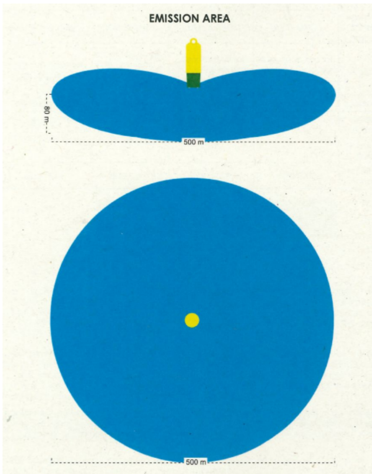

Figure 10: The emission area of deterrent devices

The depredation rate was tabulated as shown in Table 6 while the mitigation measures set in place are listed in Table 7.

Table 6: Depredation Rate

Depredation data	
Country Malta	
Fleet segment: Small-Scale Fisheries (Under 12m)	**Period: August 2021 - May 2022**
Total number of vessels	15
Main gear(s)	trammel nets
Total number of fishing trips (fishing days)	63
Total catches	1110 (kg)
Medium weight of catch per day per vessel*	17.62 (kg)
Number of fishing trips (fishing days) with depredation events	19
Frequency of conflicts	30%
Daily income per single vessel	100 Eur
Loss of catch in case of depredation event* (percentage)	30%
Main species affected by depredation event	Cuttlefish(27%); Barracuda(3.95%); Saddled Seabream(11%); Common Spiny lobster(3%); Common Octopus(3%); Moray Eel(1%); Two-Banded Seabream(2%); Thornback Ray(2%); Scorpion Fish(13.56%); Red Mullet(7%); Frigate Mackerel(2%); Bogue(2%); Squid(1%); White Bream(1%); John Dory(1%); Red Snapper(3%); Rockfish(1%); Streaked Weaver(1%); Amberjack(2%); Horse Mackerel(1%); Dentex(3%); Blue Runner (1%); Grouper(2%); Chub Mackerel(1%); Bonito(2%); Salema(1%)
Loss of money in case of depredation events (percentage)	13%

Table7 : Mitigation Measures in Place

Mitigation measures in place											
Country	**GSA**	**Description Area**	**Group of vulnerable species concerned**	**Main species concerned**	**The vessel group interested**	**N. of commercial vessels involved in the trials**	**Fishing gear**	**Mitigation Measure**	**Period**	**Number of trials (fishing days)**	**Comments**
Malta	15	The sampling area for the DiD 01,	Cetaceans	*Bottlenose Dolphin* (*Tursiops truncatus*)	Trammel Nets	8	Trammel Nets	DiD01 pingers	from March to May	30	The species that seemed to cause all the depredation issues in this area was the Common Bottlenose dolphins. The DiD01 did seem to work since depredation seemed to decrease by 38.1% when these pingers were utilised
Malta	15	The sampling are for DDD 03X	Cetaceans	*Bottlenose Dolphin* (*Tursiops truncatus*)	Trammel Nets	7	Trammel Nets	DDD 03X pingers	from March to May	17	The species that seemed to cause all the depredation issues in this area was the Common Bottlenose dolphins. The DDD 03X did seem to work since depredation seemed to decrease by 26.9% when these pingers were utilised.

CHAPTER 3 : RESULTS AND DISCUSSION

In this study, questionnaires were used to understand the perception of the dolphin depredation phenomenon and how fishers are mostly affected in the Maltese islands. Convenience Sampling was carried out through face-to-face interviews with Small-Scale Fishers and 38 questionnaires were carried out. Results are shown in *Figure 11 and Figure 12*.

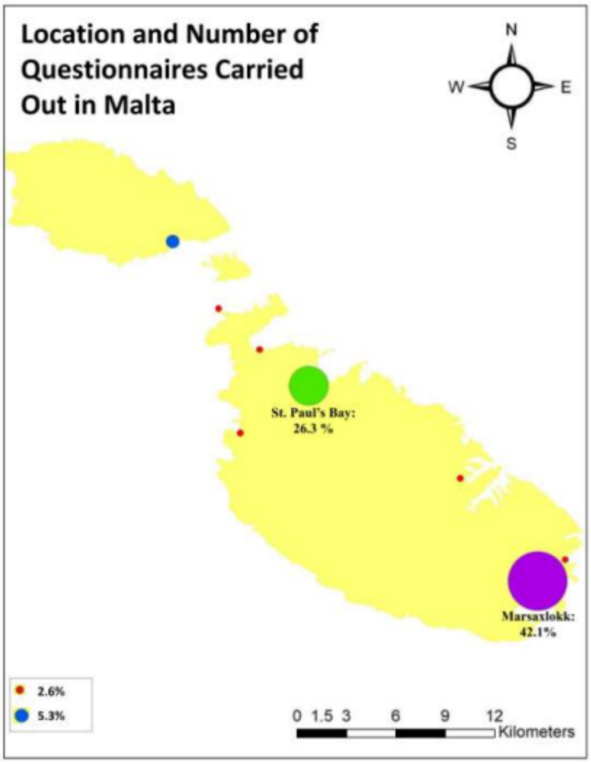

Figure 11: Locations and Number of questionnaires which were collected from around the Maltese Islands

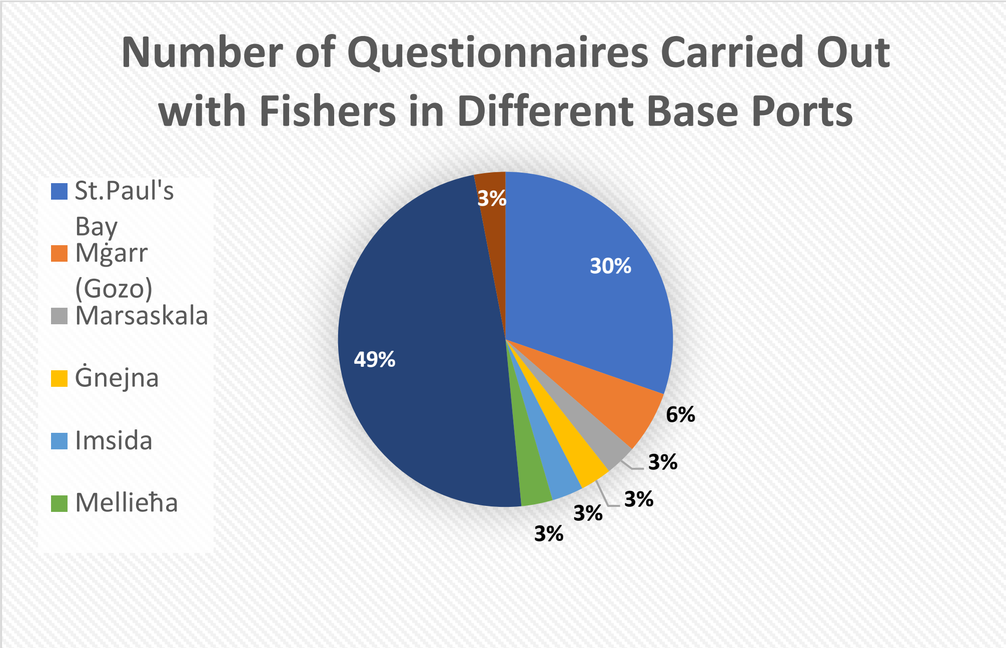

Figure 12: The number of questionnaires carried out in the different base ports

Results for frequency of cetacean encounters and location of encounters are shown in *Figure 13* and *Figure 14* respectively.

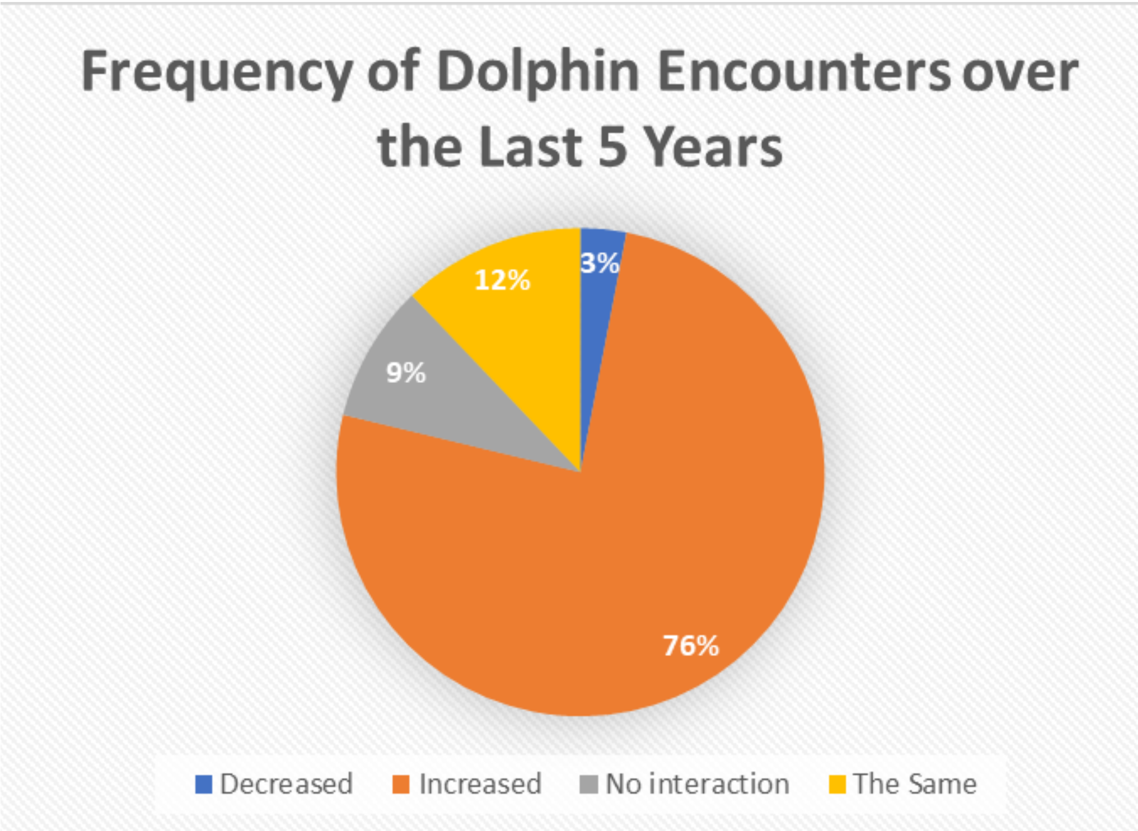

Figure 13: Frequency of dolphin encounters over the last five years

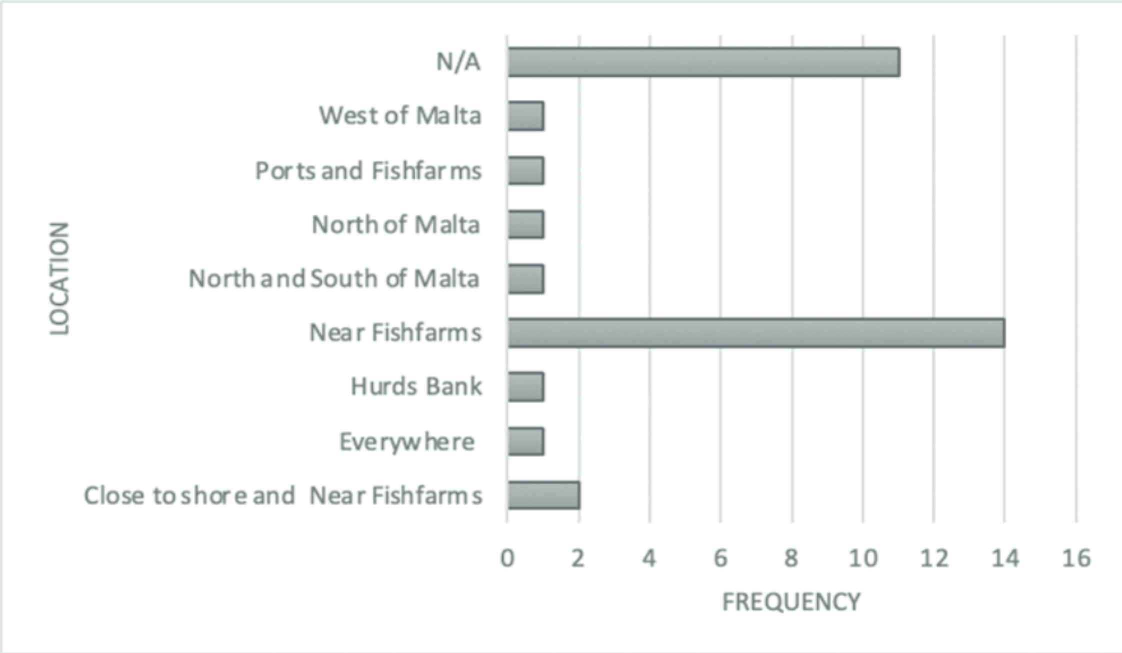

Figure 14: Location of dolphin encounters over the last five years

These results highlight the importance for further investigation into the probability of depredation and the proximity to fish farm location.

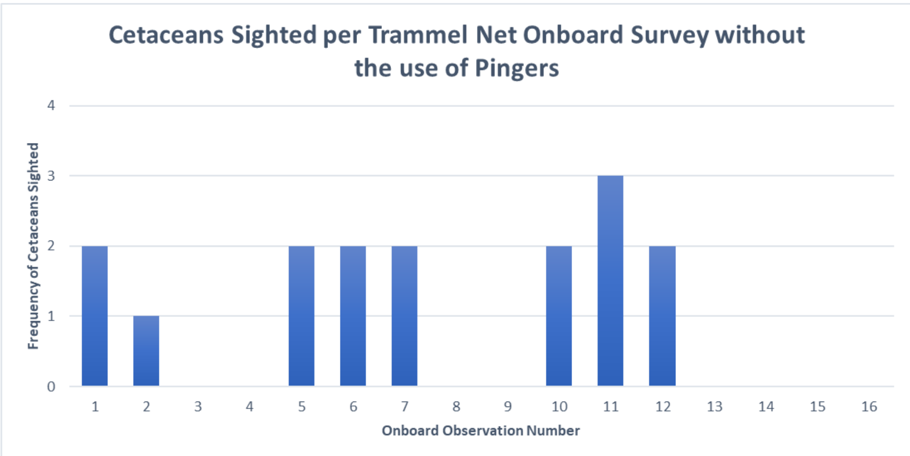

Figure 15: Cetaceans Sighted per Trammel Net Onboard Survey without the use of Pingers

50% of the fishers declared that no expenses were incurred due to the absence of depredation. However, the other 50% did incur varying expenses. Results are shown in *Figure 19*. 19% of fishers stated that they incurred between €1 and €25, 12% of fishers incurred between €26 and €50, 13% of fishers stated that they incurred between €51 and €75, while 6% stated that they incurred between €76 and €100.

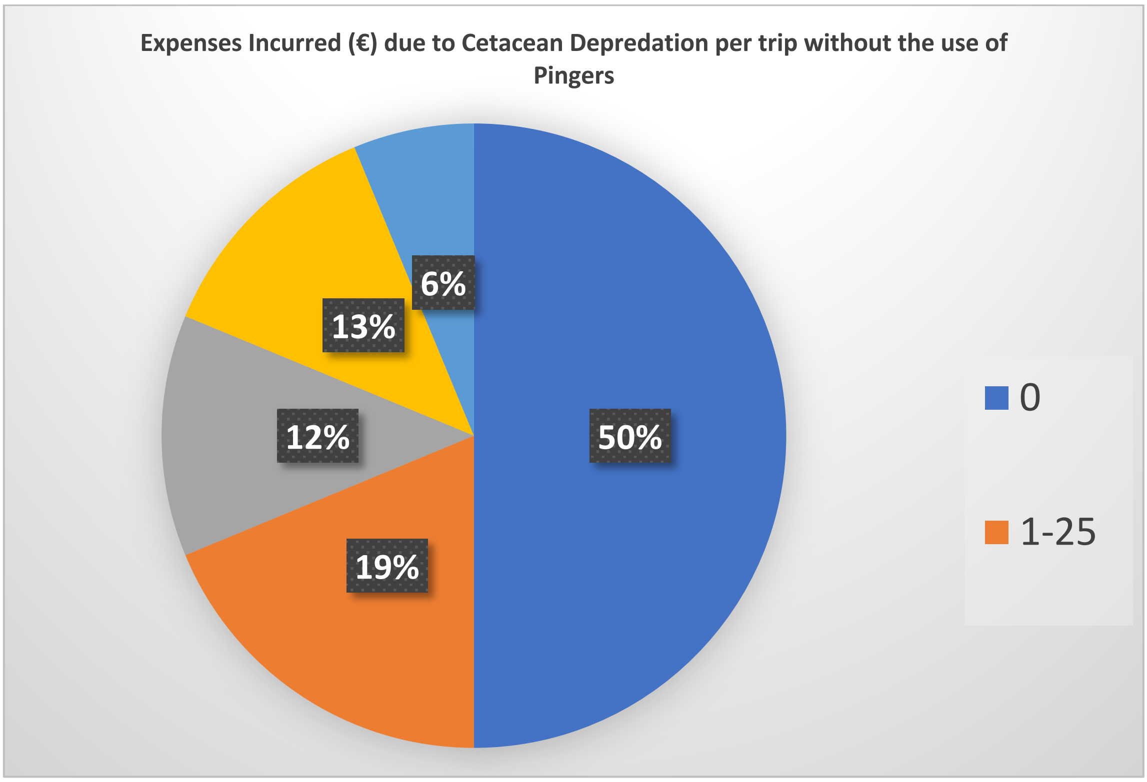

Figure 16: Expenses Incurred (€) due to Cetacean Depredation per trip without the use of Pingers

The overall number of sightings of *Tursiops truncatus* as observed during onboard surveys in Maltese waters was plotted as shown in *Figure 15.*

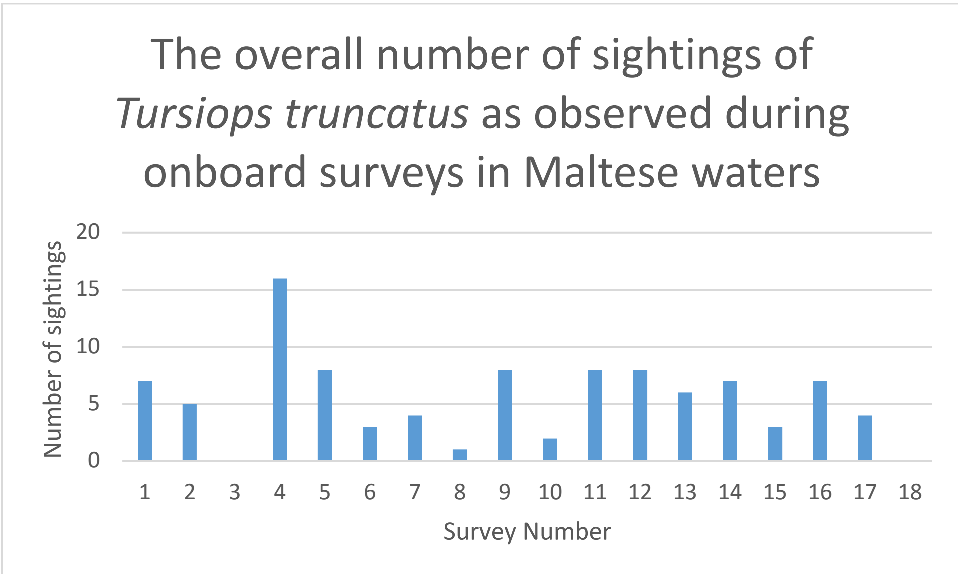

Figure 17: The overall number of sightings of Tursiops truncatus as observed during onboard surveys in Maltese waters

The occurrence of cetaceans in proximity of fish farm locations was plotted as shown in *Figure 18.*

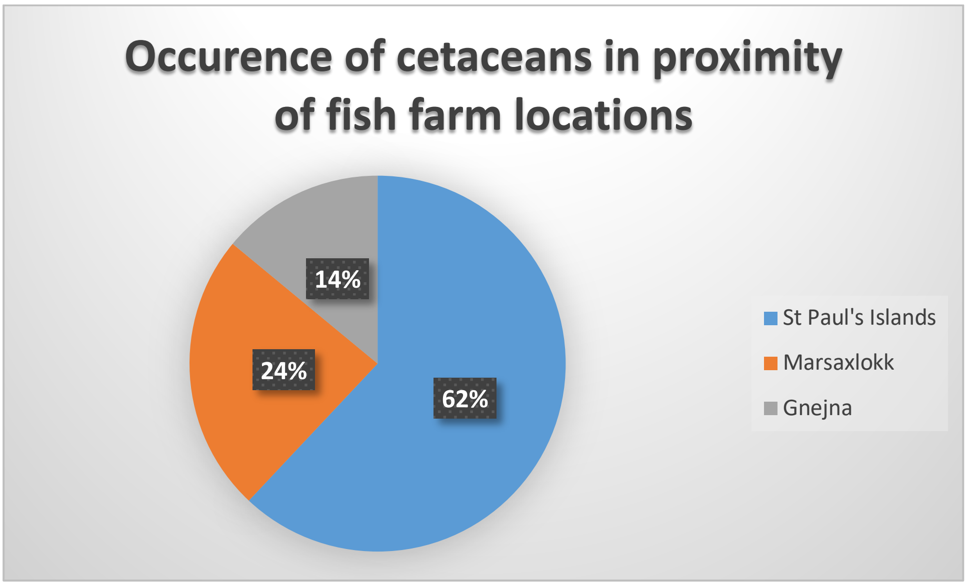

Figure 18: The occurrence of cetaceans in proximity of fish farm locations.

When onboard observations were carried out with trammel net fishers and DiD01 Pingers, the sightings were recorded in the 1st, 2nd, 5th, 8th and the 22nd onboard observations as seen in Figure 19.

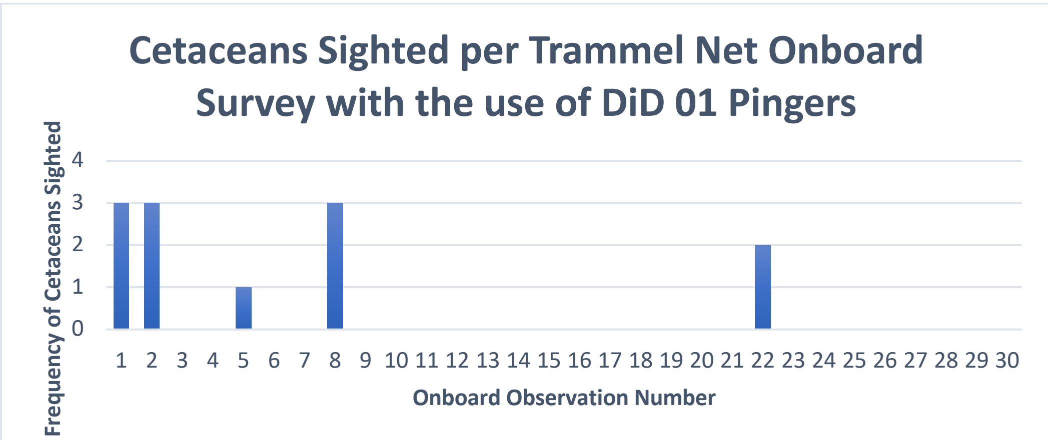

Figure 19: Total Number of Cetaceans Sighted throughout all Trammel Net Onboard Survey without the use of Pingers

A total of 19 onboard observations with DDD 03X Pingers have been carried. Out of 18 onboard observations cetaceans. Results are shown in *Figure 20*.

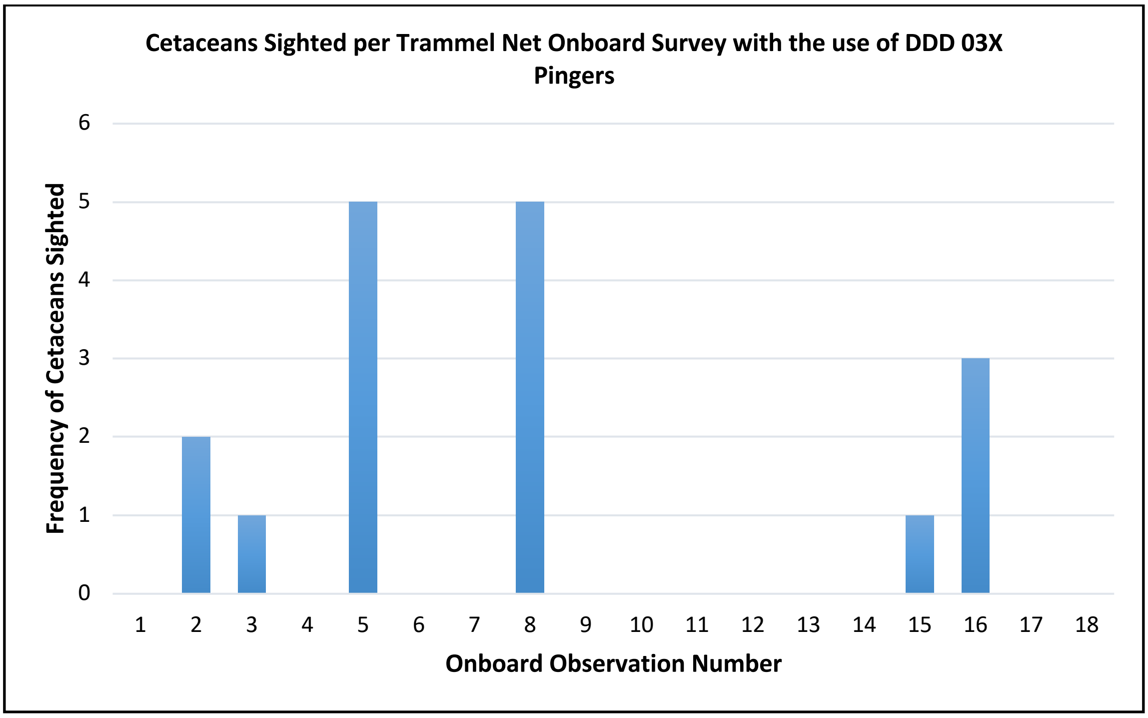

Figure 20: Cetaceans Sighted per Trammel Net Onboard Survey with the use of DDD 03X Pingers

Figure 21 shows that 72% of the fishers declared that no expenses were incurred due to the absence of depredation while using DDD 03X pingers. However, 5% of fishers stated that they incurred between €1-25, 6% stated that they incurred €26-50, another 6% stated that they incurred €51-75 and 11% stated that they incurred €76-100.

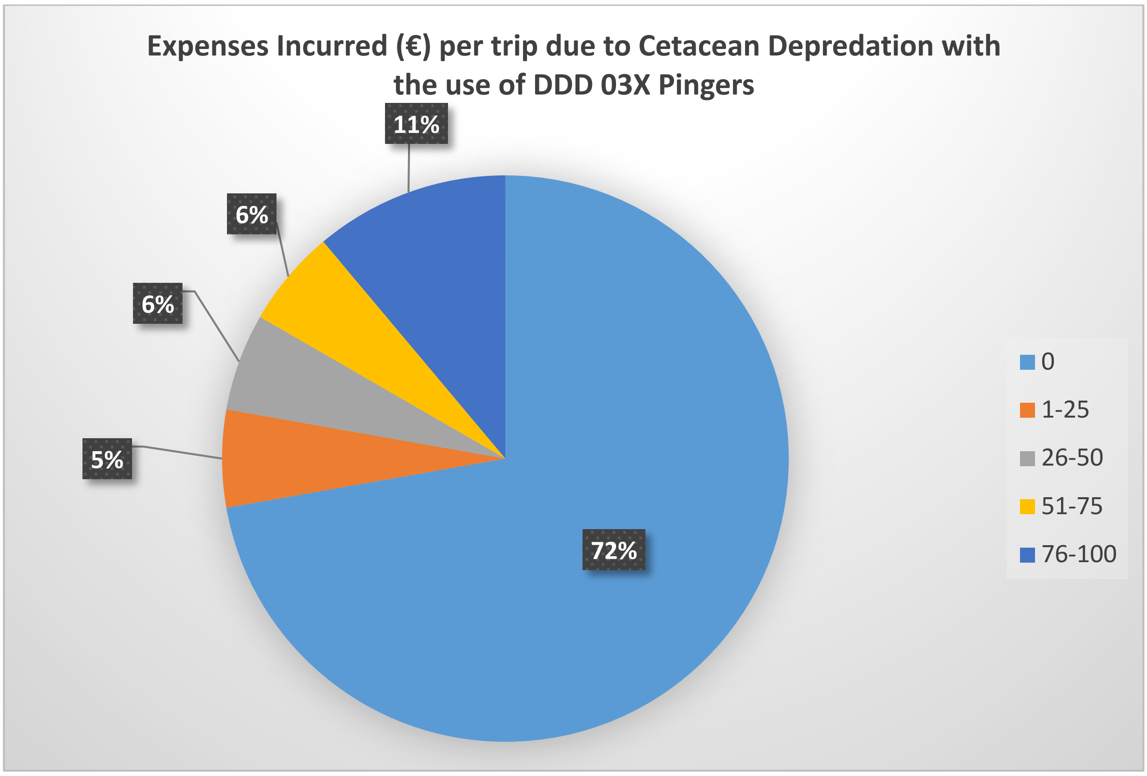

Figure 21: Expenses Incurred (€) per trip due to Cetacean Depredation with the use of DDD 03X Pingers

Comparison of results with and without use of pingers, and the subsequent signs of net depredation are shown in *Table 8.*

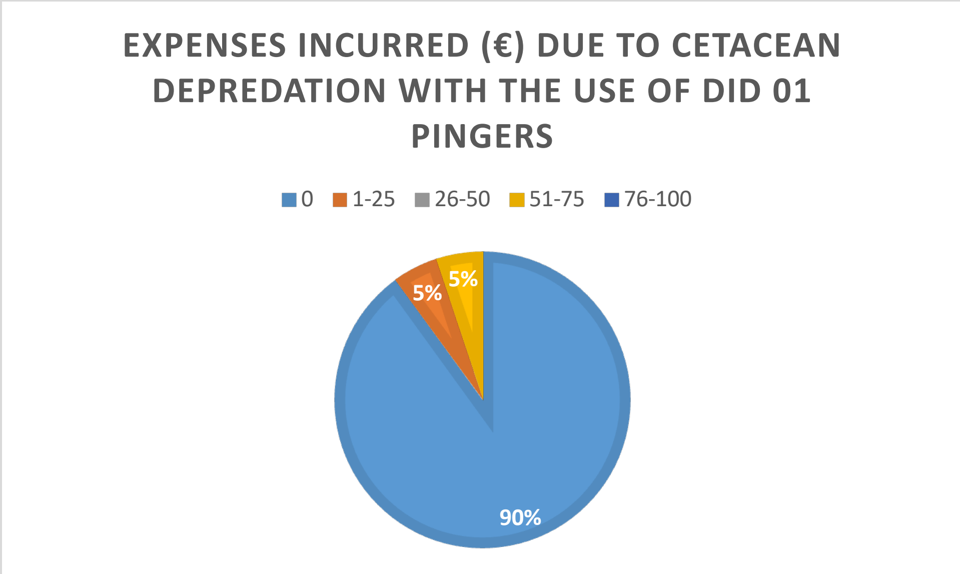

Figure 22: Expenses Incurred (€) per trip due to Cetacean Depredation with the use of DDD 03X Pingers

Table 8: A table showing the % amount of net depredation with and without use of pingers

	Signs of Net Depredation
Pingers used (DDD 03X)	29.4%
Pingers used DiD 01	18.2%
No Pingers	56.3%

Discussion

The cetacean depredation phenomenon has had both ecological and socio-economic impacts. Depredation has caused great concerns on the conservation of cetacean species, the profitability as well as the catches from fisheries (Rabearisoa *et al*, 2018). This cetacean-fisheries interaction is highly recognized as great threat to cetaceans due to accidental injury and bycatch of such species. However, the exploitation of fishers' catches from cetaceans must also not go unnoticed (Fader *et al.,* 2021). Therefore, this study aimed to identify the potential impacts, depredation may have on both the cetaceans and the fishers and to identify the appropriate mitigation to tackle the problems related to this cetacean-fisheries interaction.

In the first phase of the project the researchers carried out a total of 38 questionnaires in various ports around Malta and 1 port in Gozo. The idea behind these questionnaires was to provide us with their perceptions and issues they face due cetacean depredation. According to these questionnaires cetacean depredation has increased exponentially in the 5 years and this result was corroborated by 76% of the questioned fishers. A result obtained through an ACCOBAMS survey in 2018 showed that bottlenose dolphins have become more common in the Straight of Sicily, the Northern Adriatic and Aegean Sea (Panigada *et al.*, 2018). Fourty-two percent (42%) of the fishers also confirmed that most depredation interactions occurred near fish farms, which is a result similarly seen in a study carried out by Vella (2016). Cetacean foraging feeding behaviors were focused around fish farm areas due to aquaculture feeding practices are consistent with depredation activities (Vella, 2016).

Out of 16 onboard observations (Figure 15) sightings of *T. truncatus* were observed in 8 onboards amounting to 50%. This shows that there was large difference in cetacean sightings in the use and lack of engines during the onboard observations. This result is also reminiscent of the increase in the cetacean sightings close to various ports during the COVID-19 pandemic. This was a trend that was also observed in Malta. According to Prof. Alan Deidun, the reduction in marine traffic due to lockdowns and other COVID-19 restrictions resulted in an increase in dolphin sightings closer to ports (Malta Today, 2020). In terms of expenses incurred due to cetacean depredation per trammel net trip without the use of pingers, 50% of the fishers stated they incurred no expenses while the other 50% stated that they did incur expenses ranging from €1-€100 (Figure 16). A study carried out by Bonizzoni *et al. (*2016), fishers incurred various expenses due to this phenomenon. In the North of the Gulf of Corinth, the expenses incurred average to €1,398/boat/year in the north and €81/boat/year in the south of the Gulf of Corinth.

A total number of 18 onboard observations were carried out without trammel nets and without the use of pingers and *Tursiops truncatus* sightings were observed in 16 out of 18 onboards which amounts to approximately 88% (Figure 17). The highest recorded sighting was that of 16 individuals. The reason behind the regular sightings was also mainly due to the fact that the transects chosen where carried out in close proximity to fish farm areas. These onboard observations were also carried out onboard a yacht to decrease noise pollution. A study carried out by Papale *et al.* (2011) as part of the LIFE project 'Del.Ta.' (NAT/IT/000163), carried out approximately 559 hours of monitoring recording a total of 83 sightings. They utilized varying types of vessels throughout this monitoring experiment. Whenever sailing boats were used the interaction between cetaceans and the vessel seemed to be 100% neutral, however whenever faster boats utilizing engines resulted in avoidance behaviors from the cetaceans. The latter result can be confirmed through the results achieved from the onboard observations carried out with trammel net fishers and without pingers.

The pie chart in Figure 18 distinguishes the three different transect areas chosen to carry out this part of the study: St. Paul's Islands transect, Marsaxlokk transect and the Ġnejna transect. There are 2 main designated aquaculture zones, these are in the North and South-West of Malta (Times of Malta, 2022), which fall within the St. Paul's Islands transect and the Marsaxlokk transect. Sixty-two percent (62%) of the sightings occured in the St. Paul's Islands, 24% of the sightings occured in the Marsaxlokk transect and a further 14% of the sightings occured in the Ġnejna transect. A study carried out by Diaz Lopez (n.d.) from 1999 to 2004, analysed the interactions between *T. Truncatus* and fish farms, to further understand the economic impacts that may result from this interaction. Approximately 218 days at sea were carried out and 293 bottlenose dolphin sightings were observed interacting with aquaculture farms, due to feed inputted in the fish farm operation, increasing bottlenose dolphin opportunistic behaviours. Another study carried out in the Ionian Sea in the Mediterranean Sea by Piroddi *et al* (2011), further explained that mariculture activities have increased greatly in this region, which lead to an increase in the

T. truncatus activity in the area. The researchers stated that spatial analysis displayed an increase cetacean occurence in close proximity to the aquaculture fish farms. Since, the Mediterranean Sea is a highly oligotrophic area, the aquaculture fams provide focal areas with high levels of nutrition (Piroddi *et al.*, 2011).

The results achieved in Figure 19 show that out of 30 onboard observations with DiD 01 pingers, cetacean sightings were recorded in 5 onboard observations, while signs of depredation were recorded in 18.2% (Table 4). On the other hand Figure 20 shows that out of 18 onboards with DDD 03X pingers, sightings of cetaceans were observed in 6 onboards and signs of net depredation were observed in 29.4% of the time (Table 4). When no pingers were used, signs of depredation were 56.3% of the time (Table 4). The 11.2% difference between the DiD 01 pingers and DDD 03X pingers may be due to the fact that the DiD 01 pingers only produce ultrasound frequencies on the detection of marine mammals in the area, while the DDD 03X pingers constantly emit ultrasound frequencies. The former hence, aid to decrease the chances of habituation which could signify the reason behind the better result achieved by the DiD 01 pingers (STM Industrial Electronics, 2013). Eventhough bycatch of cetaceans was never recorded in the Maltese Islands and throughout this study, pingers are generally used as a mitigation device to reduce bycatch and not only depredation. Studies carried out by Gearin *et al.* (2000) on the Pacific cost reported 85–97% decrease in bycatch over a number of years, while Gönener & Bilgin (2009) carried out studies in the Black Sea showing a reduction of 98% in cetacean bycatch. Eventhough the pingers seemed to work in this study and the latter mentioned studies, certain studies have prooved otherwise. For example a study carried out by Cruz *et al.* (2013) on cetacean depredation in the Azorean squid fishery showed that there was not significant difference in the level of depredation in gear with pingers installed and the control gear (no pingers installed). Another study carried out by Zool *et al.* (2020) in the Bulgarian Turbot Fishery also showed a similar result to that of Cruz *et al.* (2013), since there was no significant difference in the control fishing gear and the pinger fishing gear.

Figure 21 and Figure 22 display the expenses incurred when both the DDD 03X and DiD 01 pingers were used respectively. Throughout the onboard observations with the DDD 03X, 72% of the fishers stated that they incurred no expenses (Figure 21), however throughout the onboard observations with the DiD 01 pingers, 90% of the fishers did not incur any expenses. It is also clear that fishers utilising the DiD 01 pingers did not incur more than €75.00. Both results are considered since in the onboard observations without the use of pingers, 50% of the fishers did incur expenses, while another 50% did not (Figure 16). This means that fisher incurred less expenses with both the DDD 03X and the DiD 01 pingers and faired even better with the DiD 01 pingers. According to Finezzo and Ipuche (2011), depredation activities can result in losses of approximately $1000 per month. This study stated that DDDs did reduce damages to bottom trammel nets and due to the upgrades of the DiD 01 to reduce habituation should lead to better results and this seems to be the case in this study. A study carried out by Maccarrone *et al.*(2014) showed that when costs such as fuel, maintenance, costs of crew and engine oil etc. are cut, pingers are economically viable in the long run, since damage on fishing gear decreases.

CHAPTER 5: CONCLUSION AND REDOMMENDATIONS

The first phase of the project introduced the researchers with a better understanding of the fishers' perceptions on cetacean depredation. The aim to understand which fishing gear was the most impacted was reached since the researchers were able to identify the trammel net gear to be the mostly negatively impacted gear. Fishers also seemed to indicate that this issue has increased greatly over the past 5 years, with high levels of depredation activity occurring in close proximity to aquaculture fish farms. Fishers seemed to also spend an average of €178.33 per trip. The cetacean species that seemed to be the one causing such an interaction seemed to be *T. truncatus.* However, since these results were solely based on a perception and could be subjective, it was vital that a second phase of the study would be implemented in the form of a proper in-situ study through onboard observations to assess this phenomenon at first hand.

In the second phase of the project researched aimed to carry out onboard observations to identify presence of cetacean depredation, to analyze the interactions of cetaceans with fishing gear and to apply and investigate the effect of using or not employing any mitigation technologies. These aims were reached through onboard observations with trammel net fishers. Three sets of different onboard observations were carried out with fishers, one set was carried out without pingers, another set was carried out with DiD 01 pingers and a third set was carried with DDD 03X pingers. The results showed that in 50% of the onboards without pingers with trammel net fishers showed signs of depredation, however depredation seemed to decrease with both DiD 01 and DDD 03X pingers with 18.2% and 29.4% respectively, of onboards observations with trammel net fishers, showing signs of *T. truncatus* depredation. Hence a significant decrease in depredation was recorded. Onboard observations were also carried out without trammel nets and without pingers. These onboards were carried out in three chosen areas with high depredation activity occurring close to fish farm areas.

Cetacean depredation specifically carried out by *T. truncatus* seems to be quite a common phenomenon in Maltese waters, however due to time constraints only a few of these onboards were carried out. Although, the preliminary results achieved through this study could act as insight on which larger scale projects could work on. However, it is highly clear, that further analysis needs to be carried out to ensure that fisheries are not solely managed in the traditional aspect, however a more ecosystem-based fisheries management approach should be taken in order to tackle such an issue. This project was the first of which, depredation statistics were recorded in Malta. According to Gilman *et al.* (2007), these statistics are vital in proper fisheries management since this is a type of natural mortality that should be taken into consideration to ensure that correct methodologies are utilized to carry out stock assessments.

Throughout the study researchers had a number of limitations due to limited funds and time, however all these limitations can be tackled through further studies. One of the aspects that was very well received from fishers was the trammel nets that were given to the fishers who participated in the study. Even though they were interested in trying out the pingers, several fishers stated that it would be cheaper to provide them with more material to construct their depredated trammel nets rather than providing them with pingers since the latter are more expensive to purchase than the former. The researchers also recommend that more pingers would be provided rather than just two pingers per fisher, since each pinger only covers approximately 500m of fishing gear. According to EC 2019/1241, fishers fishing in the Mediterranean Sea are allowed to tow approximately 6000m of trammel net fishing gear, therefore the 2 pingers provided only covered 1000m of gear.

Throughout this project data was also collected data on GPS coordinates of the exact sightings and depredation locations, however due to time constraints and limited human resources this data was not analysed. The researchers recommend that future studies on spatial distribution of cetacean hotspots should be carried out. This will provide fishers with a better understanding of commonly inhabited locations by cetaceans, hence decreasing the chances of depredation and cetacean injury from fishing gears.

In order to ensure that a more holistic research study is carried out, researchers suggest that acoustic recordings and the installation of underwater cameras are employed so as to identify any cetaceans in close proximity which are not sighted and to collect data in real-time. Since the first phase of the study seemed to indicate that pelagic long-line fisheries seem to also be one of the main targets for depredation, the researchers suggest that future studies could also focus on this fishery. Even though both sets of pingers seemed to work, the researchers suggest that low-cost devices such as shiny compact disks and visual deterrent devices such as green LEDs or UV LEDs.

ACKNOWLEDGEMENTS

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ANNEXES

Annex 1: Trammel Net Specifications

15 pcs Fishing nets 210d/4 33mmsq 50 md 230 metres Grey
15 pcs Fishing nets 210d/9 150mm^2 6.5 md x 430 metres Grey
4500 pcs Fishing floats (300 pcs per net) for deep water
15 pcs nylon rope 5mm x 220 metres (one for each net)
15 rolls of leaded rope, one for each net (22kgs each)
15 pcs Fishing nets 210d/4 33mmsq 50 md 230 metres Grey
15 pcs Fishing nets 210d/9 150mm^2 6.5 md x 430 metres Grey
Highlighter repair monofilament nylon Rolls of 500g nylon twine in size 210d/15 or 18

Annex 2: Fishing effort per sampling port

<table>
<tr><th colspan="7">Fishing effort per sampling port</th></tr>
<tr><th colspan="7">Malta</th></tr>
<tr><th></th><th colspan="2">Longliners</th><th colspan="2">Small-scale vessels</th><th colspan="2">Purse-seiners</th></tr>
<tr><th>GSA 15</th><th>Total number of vessel in the port</th><th>Fishing days</th><th>Total number of vessel in the port</th><th>Fishing days</th><th>Total number of vessel in the port</th><th>Fishing days</th></tr>
<tr><td>St. Paul's Bay</td><td colspan="6" rowspan="8">Not available during the time of study.</td></tr>
<tr><td>Marsaxlokk</td></tr>
<tr><td>St. Julian's</td></tr>
<tr><td>Xemxija</td></tr>
<tr><td>Mellieha</td></tr>
<tr><td>Imsida</td></tr>
<tr><td>Lapsi</td></tr>
<tr><td>Marsalforn</td></tr>
</table>

Annex 3: Onboard Observations data sheet

Onboard Observations with Trammel Net Fishers without Pingers

General Information

Name of Observer	
Date	
Time	
Port Location	
Weather	
Moon phase	
Gear Type and Material	
Gear Dimensions	
Soaking Time	

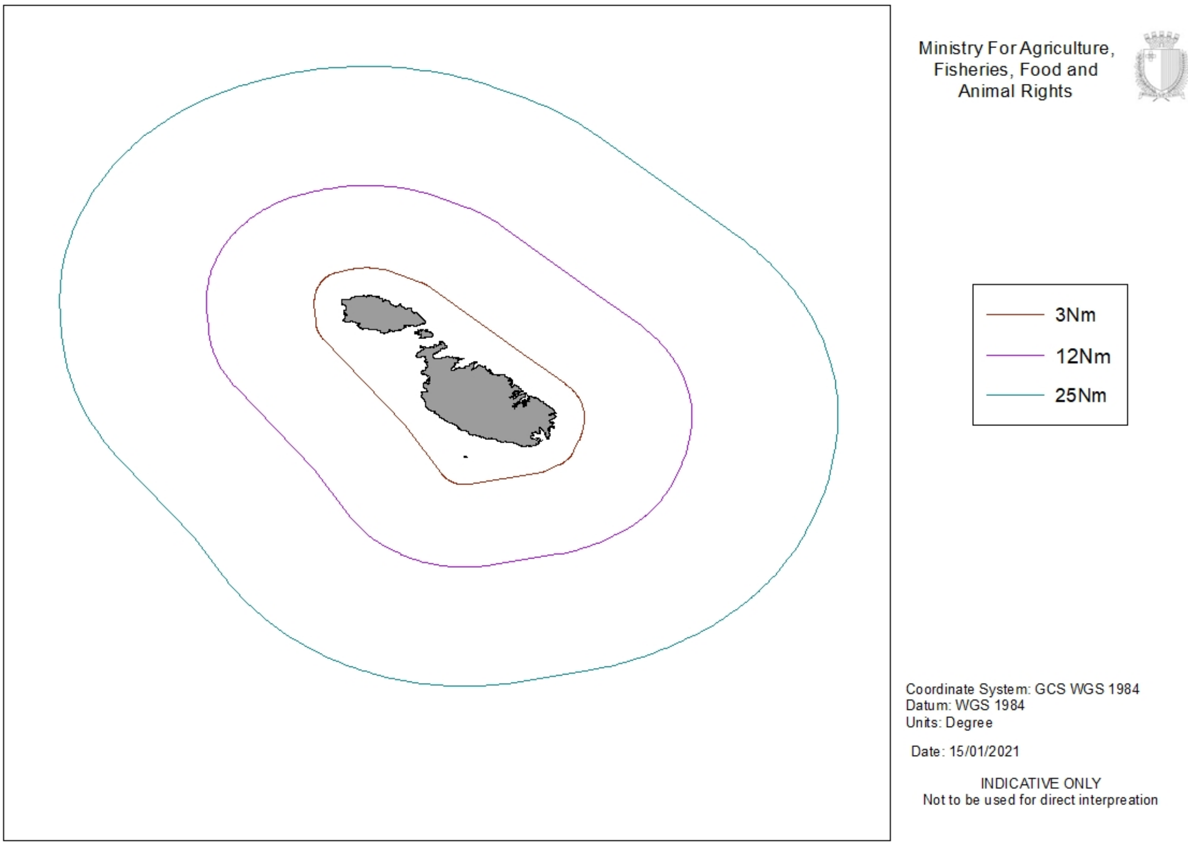
Cetacean Observations

Cetacean Species	✓	Number of Cetacean Pods	Approximate Number of Cetaceans in a Pod
Common bottlenose dolphin			
Cuvier's whale			
Sowerby's whale			
Striped dolphin			
Rough toothed dolphin			
Fin whale			
Minke whale			
Killer whale			
Sperm Wale			
False killer whale			

Other Cetacean Species	✓	Number of Cetacean Pods	Approximate Number of Cetaceans in a Pod

Location of Cetacean Hotspots

Place location on the Map below:



Coordinates of location of cetacean hotspots:

Cetacean Species Name	Coordinates

Environment, Depth and Distance from Mainland

Cetacean Species Name	✓	Type of environment	Depth of Vessel when Cetacean were observed	Distance from Mainland when Cetaceans were observed	Monetary Value Lost	Type of Depredation	No. of Holes
Common bottlenose dolphin							
Cuvier's whale							

Sowerby's whale							
Striped dolphin							
Rough toothed dolphin							
Fin whale							
Minke whale							
Killer whale							
Sperm Wale							
False killer whale							

Other Cetaceans	Type of environment	Depth of Vessel when Cetacean were observed	Distance from Mainland when Cetaceans were observed	Monetary Value Lost	Type of Depredation	No. of Holes

Species Captured	Catch in Kilograms

Annex 4: Licenses for Marine Scientific Research on the Continental Shelf of Malta

MINISTERU GĦALL-FINANZI
U X-XOGĦOL

Dipartiment Blata Kontinentali

MINISTRY FOR FINANCE
AND EMPLOYMENT

Continental Shelf Department

Our ref: CSD/11/2017/3

14 November 2021

Mr Bjorn Callus
Director General
Department of Fisheries and Aquaculture
Ministry for Agriculture, Fisheries, Food and Animal Rights
Gfiammieri Farm, Triq l-Ingiered
Luqa

Licence for Marine Scientific Research on the Continental Shelf of Malta

'Monitoring the interaction between cetaceans and fisheries in the Maltese Management Fisheries Zone'

The Continental Shelf Department (CSD) within the Ministry for Finance and Employment has evaluated the request received on 4th November 2021 from EcoMarine Malta Ltd. on behalf of the Department of Fisheries and Aquaculture within the Ministry for Agriculture, Fisheries, Food and Animal Rights (DFA-MAFA) and the MAVA Foundation to undertake marine scientific research having cruise name 'Monitoring the interaction between cetaceans and fisheries in the Maltese Management Fisheries Zone'.

In terms of Regulation 6 of the Continental Shelf Regulations (S.L. 535.02) of the Laws of Malta, CSD is granting a licence to DFA-MAFA to carry out the proposed research subject to the following conditions:

(a) DFA-MAFA is bound by the provisions of Regulation 6 of the Continental Shelf Regulations;

(b) The marine research shall only be carried out for the objectives defined in section 2.1 of the application namely to record and identify cetacean species in Malta's territorial waters by means of six onboard observations;

(c) This licence is only being granted for the scientific measurements described in section 4.5 of the application for consent and shall be carried out solely with the vessel and instrumentation described in sections 4.1 and 4.5 respectively of the said application

Block F, Triq Antonio Maurizio Valperga, Floriana FRN1700, Malta
Tel : (356) 2292 2114 E-mail: dgcs.csmalta@gov.mt
http://continentalshelf.gov.mt

MINISTERU GĦALL-FINANZI U X-XOGĦOL

Dipartiment Blata Kontinentali

MINISTRY FOR FINANCE AND EMPLOYMENT

Continental Shelf Department

Our ref: CSD/11/2017/3

13 May 2022

Mr Bjorn Callus
Director General
Department of Fisheries and Aquaculture
Ministry for Agriculture, Fisheries and Animal Rights
Għammieri Farm, Triq l-Ingiered
Luqa

Licence for Marine Scientific Research on the Continental Shelf of Malta

'Monitoring the interaction between cetaceans and fisheries in the Maltese Management Fisheries Zone'

The Continental Shelf Department (CSD) within the Ministry for Finance and Employment has evaluated the request received on 10th May 2022 from EcoMarine Malta Ltd. on behalf of the Department of Fisheries and Aquaculture within the Ministry for Agriculture, Fisheries and Animal Rights (DFA-MAFA) and the MAVA Foundation to undertake marine scientific research having cruise name 'Monitoring the interaction between cetaceans and fisheries in the Maltese Management Fisheries Zone'.

In terms of Regulation 6 of the Continental Shelf Regulations (S.L. 535.02) of the laws of Malta, CSD is granting a licence to DFA-MAFA to carry out the proposed research subject to the following conditions:

(a) DFA-MAFA is bound by the provisions of Regulation 6 of the Continental Shelf Regulations;

(b) The marine research shall only be carried out for the objectives defined in section 2.1 of the application namely to record any sightings of cetacean species in Malta's territorial waters by means of twelve onboard observations;

(c) This licence is only being granted for the scientific measurements described in section 4.5 of the application for consent and shall be carried out solely with the vessel and instrumentation described in sections 4.1 and 4.5 respectively of the said application namely, visual sightings and passive acoustic tracking by means of two 150m long towable hydrophone arrays using the sailing vessel *Max*. The survey shall be carried out within the internal and territorial waters of Malta extending up to 12 nautical miles measured from the baselines (Cap. 226);

(d) The licence for this survey is being granted without creating a precedent for the licensing of any future similar work that may be proposed. Any other survey which involves the acquisition of additional data requires a new licence from the CSD;

(e) This licence is valid within the period 15th May 2022 to 30th September 2022. The specific survey dates shall be notified to the CSD according to condition (f);

(f) Notification of survey commencement and completion is to be provided in writing to the CSD on dgcs.csmalta@gov.mt in advance of survey commencement and within a week of the survey's completion;

(g) The CSD is to be notified in advance of any major change in the marine survey as proposed in the application. Such major changes in survey operations shall only be carried out subject to an amendment in the licence terms and conditions by the CSD;

(h) A final report is to be submitted to the CSD by 30th June 2023. This report is to summarise all scientific activities carried out during the survey and any assessment and interpretation undertaken on the data gathered;

(i) All data gathered (raw and processed) and any reports are to be provided to CSD on an external USB hard disk as they become available or at the latest with the final report. Diagrams and files provided should be geo-referenced to WGS 84 datum. Geographic Information Systems (GIS) data must be provided in ArcGIS compatible format and attributed with the corresponding metadata;

(j) The CSD is hereby indemnified and held harmless from any third-party claims for damages, costs or losses that such third parties may suffer as a result of DFA-MAFA's conduct of any operations contemplated by this licence;

(k) It is the responsibility of DFA-MAFA to ensure that the vessels and scientific equipment being used in this marine survey, details of which are given respectively in application, have the necessary certifications and authorisations from other competent authorities to conduct this work;

(l) This licence does not relieve DFA-MAFA of the requirement to obtain any other necessary permissions and/or licences from any other relevant competent authority(s) in Malta;

(m) This licence is not transferable.

Dr Albert Caruana
Director General

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ACCOBAMS-MOP8/2022/Inf39

MITIGATING DOLPHIN DEPREDATION IN MEDITERRANEAN FISHERIES
JOINING EFFORTS FOR STRENGTHENING CETACEAN CONSERVATION AND SUSTAINABLE FISHERIES

Bottlenose dolphin interactions with purse seine fishery in the Moroccan Mediterranean Sea

Pilot study report

المعهد الوطني للبحث في الصيد البحري
INSTITUT NATIONAL DE RECHERCHE HALIEUTIQUE

Authors

Mohamed MALOULI IDRISSI, Ayman JGHAB, Aurélie MOULINS, Karim EL MGHOUCHI, Greta DEMONTIS

Date

MAVA FONDATION POUR LA NATURE

29 September 2022

Bottlenose dolphin interactions with purse seine fishery in the Moroccan Mediterranean. Sea pilot study report (summary report)

Study conducted in collaboration with:

ACCOBAMS Secretariat
Jardin de l'UNESCO
Les Terrasses de Fontvieille
MC 98000 MONACO

GFCM Secretariat
Palazzo Blumenstihl
Via Vittoria Colonna 1
00193, Rome, Italie

Regional Activity Centre for Specially Protected Areas (RAC/SPA)
Boulevard du Leader Yasser Arafet
B.P. 337
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Low Impact Fishers of Europe
https://lifeplatform.eu/

And funded by:
Fondation MAVA
Rue Mauverney 28
1196 Gland, Suisse

Responsible for the study :
Name and position of the Coordinator of the Pilot Action

Persons in charge of the study :
Names, position and origin of the other participants

Study reference :
Memorandum No.

With the participation of :
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Karim El Mghouchi, INRH-Nador
Kenza Moukhtar Jamaai, INRH-Agadir
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Nouh Lahmam, INRH-Tanger
Abdelhak Benchakroun, INRH-Tanger

Youness Saidi, INRH-Tanger
Ayoub Ennouar , INRH-Nador
Faysal Lissaoui, INRH-Nador
Khalid Belkadi, INRH-Agadir
Mohamed Salfati, INRH-Nador
Greta Demontis, Fondation CIMA
Abderrazaq Amar, INRH-Tanger
Mostafa Ouamira, INRH-Tanger

Photo credit :
JGHAB AYMAN, KHAILI AYMANE, SARA BENCHAKROUN, NAOUFAL TAMSOURI, NOUH LAHMAM, SAIDI YOUNESS, AYOUB ENNOUAR, FAYSAL LAMSAOUI, KENZA MOUKHTAR JAMAAI, KARIM EL MAGHOUCHI, MOHAMMED IAAZA, KHALID BELKADI, ABDELHAK BENCHAKROUN

This report should be cited as:

Authors(s), Date. Title. MoU ACCOBAMS No. XX/2016, Nb of pages.

Bottlenose dolphin interactions with purse seine fishery in the Moroccan Mediterranean Sea pilot study report (summary report)

1. Context and objectives of the study

The aims of this project are to study bottlenose dolphin depredation on purse seiner fishery on the Moroccan Mediterranean coast and to collect data to protect this specie. This study enfolds a series of actions and small pilot projects such as:

· Close monitoring of the interaction between bottlenose dolphins and purse seiners through questionnaires and scientific observer on board;
· Study of the abundance and distribution of bottlenose dolphins and cetaceans in the Mediterranean through Photo-id and line transect methods;
· Experimentation of the new reinforced seine as a mitigation measure.
· Study of the population of bottlenose dolphins and cetaceans in the Mediterranean through passive acoustic monitoring;

2. Introduction

The Mediterranean Sea is a well-known hotspot for biodiversity, yet is a very human population dense area with very intense human marine activity (marine traffic, industrial production, and high fishery pressure). These activities stress and are susceptible to threats a very large population of marine mammals living in this area (coll et al., 2010; Abdulla & Linden, 2008).

Dolphin depredation and interaction has become a major problem in the Mediterranean Sea, and especially caused by Bottlenose dolphins (*Tursiops truncatus*) and Short-beaked common dolphins (*Delphinus delphis*) in the Mediterranean Sea, and are taking place mostly in areas where distribution is preferred, an easily accessible prey by marine mammals, overlaps with the distribution of target species in the fishery (Azzali & Virno Lamberti, 1993; Kaschner et al., 2004; Bearzi et al., 2008).

This study is conducted in the South Alboran Sea, mainly in two areas M'diq Region and Al Hoceima region (see figure 1). These two regions host the most depredations dolphin on purse seine fishery in the Moroccan Mediterranean coast.

The depredation is strictly caused by bottlenose dolphins, this species attacks the purse seine while hauling the fish banks. The main targeted species are small pelagic fish (Sardine, Mackerel, and Sardinelle). These species are caught in the purse seine and the bottlenose group attacks it while inside. Until now, there is no such specific evidence that dolphin attacks have a certain well-known behaviour, time or place preference, this phenomenon could due to the growing decrease of small pelagic stocks in the region.

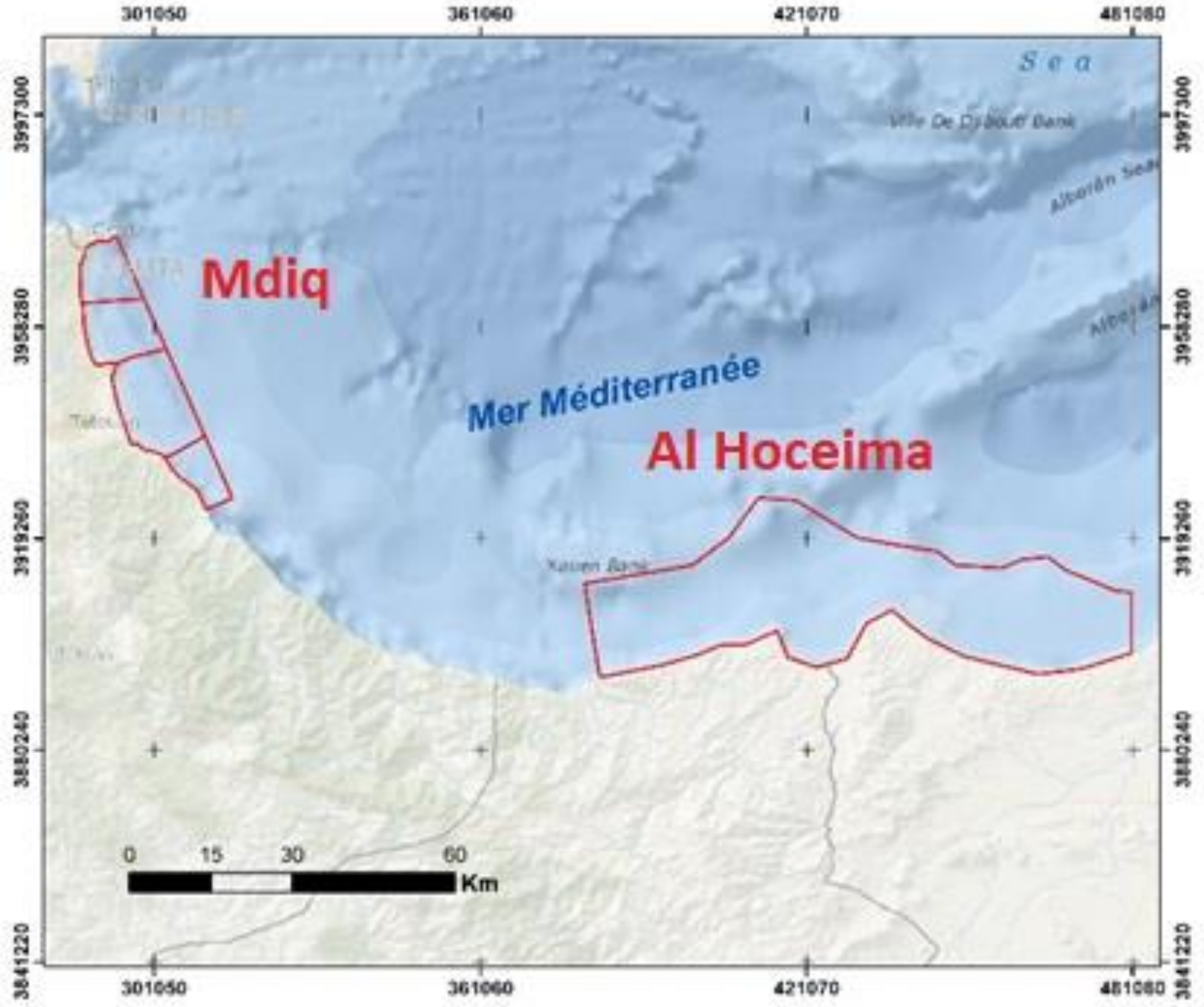


Figure 1: Study areas

3. Materials and methods

The study encompasses three different components (1. Depredation monitoring, 2. Bottlenose dolphin monitoring and photo-id, 3. Mitigation trials).

3.1 Depredation Monitoring

Since April 2017, a monthly monitoring program is being carried out through field surveys with fishers and on board purse seiners observations in the two main ports (Al Hoceima and M'diq).

During the surveys and on board observations, the scientists ans observers collect data on the fishing operations, information about fishing area, catch composition, time of fishing operation, size of the purse seine used, soaking time, etc. Furthermore, they collected also data on the depredation by bottlenose dolphins (number of individuals observed, position, time, number of tears, sizes of the tears...).

3.2 Bottlenose Dolphins monitoring and photo-identification

Bottlenose dolphin monitoring is conducted using two different approaches, line transects to study the Abundance and distribution of bottlenose in the study area. The second approach concern the use of photo-identification which dolphin dorsal photographs, ID catalog, and capture-recapture method to estimate the number of dolphins in the study area.

Data collection protocol

The excursion route is divided in two modes:

- When actively searching for cetaceans, *on-effort*
- When not looking for animals, *off-effort*

At sea data collection

The *off-effort* is attributed when you stop for lunch, you collect waste or during an observation, (the focus is on the group of animals sighted and not on searching for additional specimens in the surrounding area). This subdivision is necessary to quantify the sighting effort during the campaign.

The track of each vessel was recorded with two instruments:

- GPS outdoor Garmin "etrex";
- Tablet (with Android OS and application called *IlogWhales*).

To collect and annotate the data, the application *IlogWhales* was used. The Department of Informatics, Bioengineering, Robotics and Systems Engineering (DIBRIS) of the University of Genoa developed the application. The track of the survey is recorded continuously with an automatic writing of the vessel coordinates associated with time (in UTC+1), speed and direction. Other additional information is collected and automatically associated to specific coordinates of the track. In particular:

- Weather conditions;
- Sightings of cetaceans;
- Sightings of other species (e.g., seabirds, fish, marine turtles)
- Maritime traffic information.

During the *on-effort,* two observers scan the 180° ahead diving it in two sectors partially overlapping of 120° each. A third person insert the additional data in the tablet. There is a rotation of observer' roles every half an hour to limit the tiredness. The animal search was carried out visually with naked eye and with the binoculars, with magnification and diameter of 7x50, equipped with an internal compass and graduated grid used to estimate the distance with the detected object.

In the case of a cetacean sighting, on the detection moment, the data entered in the tablet are the azimuth and distance of the animals, and the direction of the boat. Both angles are acquired using the compass of the binoculars. This data are mandatory in order to estimate the position of the animals on the detection moment, before interacting with them. Moreover, this data is used to analyze the distance sampling.

Cetaceans are successively approached in order to confirm the species, estimate the size of the group and to photo-identify the individuals encountered, with digital SLR cameras Canon 90D.

The observers applied the rules of the Code of Good Conduct defined by ACCOBAMS and considering the needs to the scientific activities conducted for the monitoring.

Data archive

The collected data are exported from *IlogWhales* in the form of a text file with extension in *.csv (comma separated values). Two files are exported for each survey:

1) Data on all coordinates associated with the "time stamp", the speed and direction of the boat;
2) Data related to additional information called "events".

The tables resulting from these two files have been placed on an ad hoc database in *PostgreSQL* managed with *PgAdmin* software. The GPS Garmin is used only as a backup in case of malfunction of *IlogWhales.* Each type of event is stored in different tables and associated with its respective coordinates.

Only bottlenose dolphin photographs were analyzed (other species photos will be analyzed separately as this species is the primary objective of this study). All photographs taken during a sighting were used to select the frame describing the best each individual of the sightings. They are viewed in chronological order to identify each individual looking at the dorsal fin on both sides of each animal. In addition, the best frames of the head, the anterior and the posterior parts or any other distinguished marks per individual and per side are selected when available. Each selected frame is cropped and stored in the catalog of photo-identification on the software *File Marker Pro*. The cropping and eventual edits (contrast and exposition) were done with the software *paint.net.*

In the database *File Marker Pro*, for both side of the identified individual per survey, an entry is created when available. If not, only one side is inserted. The entry describes for one side, at least the dorsal fin, and in some case other section of the body. Additional information is inserted: the individual identifier, the side, the relative survey, the quality and the marking level. The quality is a frame rating related only to the picture of the dorsal fin; the value goes from 1 to 5 (with 1 for bad quality pictures and 5 to good dorsal pictures and the value is given according to the focus, angle of the animal relative to the sensor plane, portion of fin showing and the exposure). The marking level refers to the quantity of marks on the dorsal fin; the value goes from 1 to 3 (1 for unmarked individuals and 3 for individuals with more than 3 long lasting marks). The quality rating is independent of the marking level.

Data archive is done chronologically and the “matching” between photo-identified individuals consists to compare any new entry from a specific side to every entry of the catalog of the same side. When a matching is found with a previous entry, the individual identifier given corresponds to the one of the previous entry.

Data analysis

The maps of tracks and sightings are created on QGIS in order to describe the distribution of the effort and sighting. To weight the effort influence over the quantity of sightings, the value of species per unit effort (SPUE) is calculated over a grid on 1km resolution.

The photo-identification analysis consists to extract data from Files Maker Pro and create the capture and recapture matrix over months and over seasons. The frequency of capture is calculated and the discovery curve is plot. Finally, the Chapman estimate is calculated to determine the local abundance.

3.3 Spatial analysis and depredation modeling

3.3.1 Depredation spatial analysis

Fisheries data

Fisheries data collected through questioners and onboard observation were reorganized and were transferred and processed in an Excel database. Maps and pre-analyses of the spatial distribution of several parameters were made within ArcGis 10.3 software and its Spatial Analyst extension for mapping and GIS analysis.

Spatial distribution maps were generated on a grid of 2 km^2 side (2*2km) and 1 km^2 (1*1km), to avoid penalizing the mapping with false cells missing due to a too low effort and also taking into account the size of the study area.

Different parameters were calculated for each grid cell:

- Fishing effort (equivalent to the number of fishing operations)
- Number of dolphin depredation (equivalent to the number of depredations by bottlenose dolphins for each operations)
- Depredation rate (equivalent to the ratio of the number of attacks divided by the effort).

These data cover the four periods studied from 2017 to 2020 for the Al-Hoceima area and between 2018 and 2021 for the M'diq area.

To map these parameters, we performed the following steps:

- Creation of sampling grid on our study area

- Coding the pixels by an identification code.

- Projecting data points (catch and fisheries operations data- georeferenced) on the sampling grid using spatial join tool, which allows to automatically counting the number of points projected in each pixel

- Export of the layer contains pixels have the total number of points counted (projected) that correspond to the total number of fishing operation per pixel.

- Selection of the points recorded depredation after the projection of these by the same tool (spatial join) on the sample grid and then the export of the second layer that contains the numbers of bottlenose attacks in each pixel.

- Mathematical operations in each cell to calculate the variables that will be used in this study (% of depredation, Number of bottlenoses observed, catches, mean depth, mean length of used purse seine.

- After removing missing data (NA) data. We applied more detailed processing on the final data base to make the statistical analysis.

Environmental Parameters:

Environmental parameters (Sea Surface temperature, Sea surface salinity, and Chlorpyll A) retrieved from Copernicus open data access hub were used in this study. The main objective is to understand the possible impact of environmental parameters of the likelihood of possible interaction of bottlenose dolphin with the purse seiners.

In Each grid cell (used in section 3.3.1), we calculated the mean values of these environment factors for the same study period.

3.3.2 Modeling Bottlenose depredation and anthropic factors

To find the parameters that can influence the probability of bottlenose dolphin depredation. We used quantitative and qualitative variables. This statistical analysis was carried out using the R software. The modeling was carried out using the R software (64 bits, version 3.3.3). The packages used were (car, questionr, broom, broom.helpers, GGally, effects, ggeffects, ggplot2).

We used stepwise-backward procedure, which consists of using all parameters together in a full model and evaluating p-value and then removing parameter by parameter that has p-value > 0.05, the highest to find the reduced model that best describes our data.

A Generalized Linear Model (GLM) was used to model the probability of interaction of bottlenose dolphins with the fishing variables, the distribution of this variable being binomial, the variables tested are, duration of the fishing operation, length of the net, number of active boats, type of species caught and its quantity in kg, depth of the net, number of purse seiners.

GLMs allow for flexible relationships between the response variable (i.e. % of depredation) and explanatory variables (Hastie and Tibshirani, 1990; Wood, 2006). In the current study, binomial GLMs with a logit relationship were employed. This model fit our binary data type (presence or absence of depredation).

3.3.3 Modeling Bottlenose depredation and environmental factors (spatial analysis)

Modeling the impact of environmental factors on fisheries data was done using spatial regression and Ordinary Least Square (OLS) analysis in Arcmap and Qgis.

The predictive variables used were: (environmental factors: SST, SSS, CHL-A, Depth), and fisheries factors (soaking time, mean length of the purse seine, number of active boat, number of fishing operations, catches and species). We applied Spatial regression to select the most significant predictors (at $p>0.5$) and applied OLS analysis to construct the best predictive models.

The selection process was done in five steps, selecting from one explanatory significant variable to five variables. In each step, best models were classified using Adjusted R^2 and variable's significant levels. We decided to keep a maximum of three explanatory variables.

3.4 Mitigation trials

In order to reduce bottlenose attacks and their economic impact, a new prototype seine was using a new fish net of pure nylon polyamide with a density of 1.14, and with a design very similar to the purse seine used in the Moroccan Mediterranean. This net has perfect elasticity and a very good resistance, which allows it to be more rigid to bottlenose attacks.

To respond to the technical characteristics of the purse seiners making up the Moroccan Mediterranean fleet in relation to the drop and tonnage of the purse seine, three reinforced purse seines have been manufactured by INRH in collaboration with a private French company:

-Large reinforced purse seine of 521 m in length with a drop of 121 m and a weight of about 5.7 tons;

-Medium reinforced seine of 439 m in length with a drop of 110 m and a weight of about 4 tons;

-Small reinforced purse 369 m in length with a drop of 100 m and a weight of about 3 tons.

Furthermore, following the results of the tests of the large reinforced seine, improvements were added during the design and manufacture of the medium and small-reinforced seines. Thus, the following improvements should be highlighted:

- The use of a stronger wire to compensate for the relative importance of the damage caused by bottlenose dolphin attacks, mainly in the central slicks near the pocket

- The lightening of the slicks which are very far from the pocket and which present a weak degree of attack.

An appropriate rate of arming and blurring between the assemblies of the different parts of the seine net and the head ropes, mainly the lead rope, have been applied to ensure a better distribution of the efforts exerted on all the parts of the gear and to increase the resistance strength of the net.

Figure 2: Picture of large strengthened purse seine while hauling

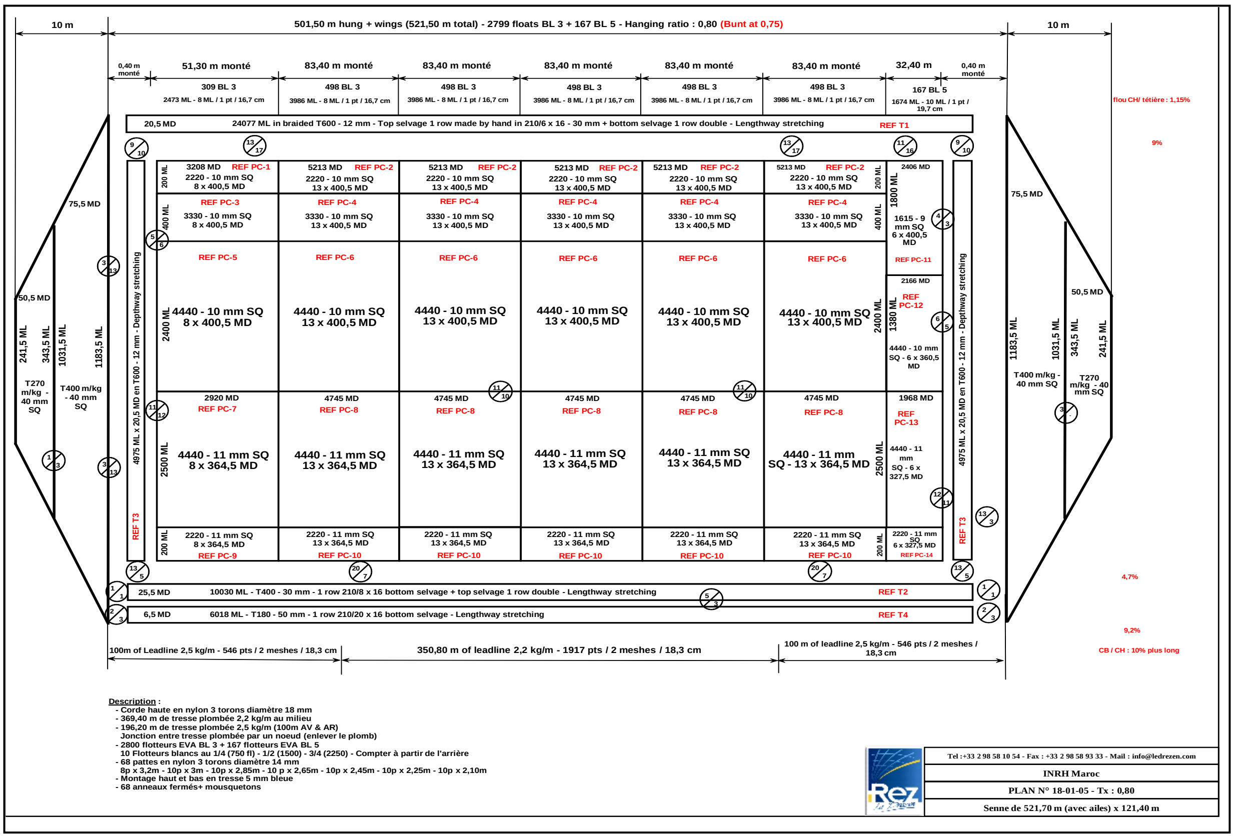


Figure 3: Scheme of Large strengthened purse seine

4. Results and discussion

4.1 Depredation monitoring

Bottlenose dolphin depredation data shows a negative trend during 2021 for the attacks on M'diq purse seiners where the contrary was observed in Al Hoceima purse seiners as an increase in the depredation percentage (see figure below).

This increase in Al Hoceima depredation can be explained by the fact that only a few purse seiners are still fishing in this area which increases the probability of dolphin encounter for each purse seiner, and thus more attacks, while for Mdiq, there is more purse seiners which create a dispersion effect on the specie.

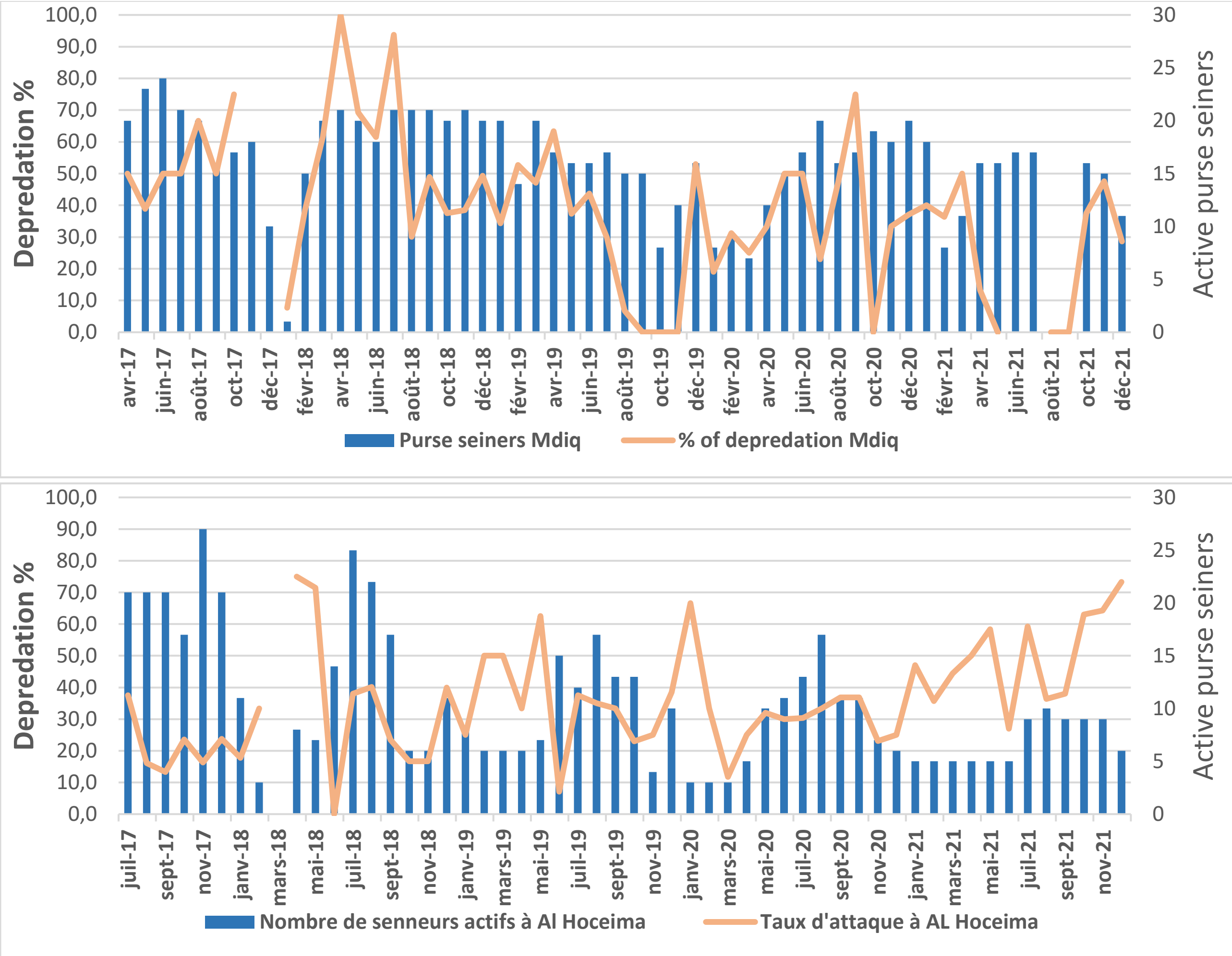


Figure 4: Depredation percentage in orange versus active purse seiners at the main depredation ports (The percentage is the number of attacked fishing operations divided by the total number of operations for each purse seiner).

4.2 Bottlenose dolphin depredation distribution

<u>M'diq region:</u>

<u>Fisheries effort distribution</u>

Fishing effort (in number of fishing days) is relatively distributed in all the study area, while some areas represent a high fishing effort concentration (Large of M'diq, and Martil) (see figure below).

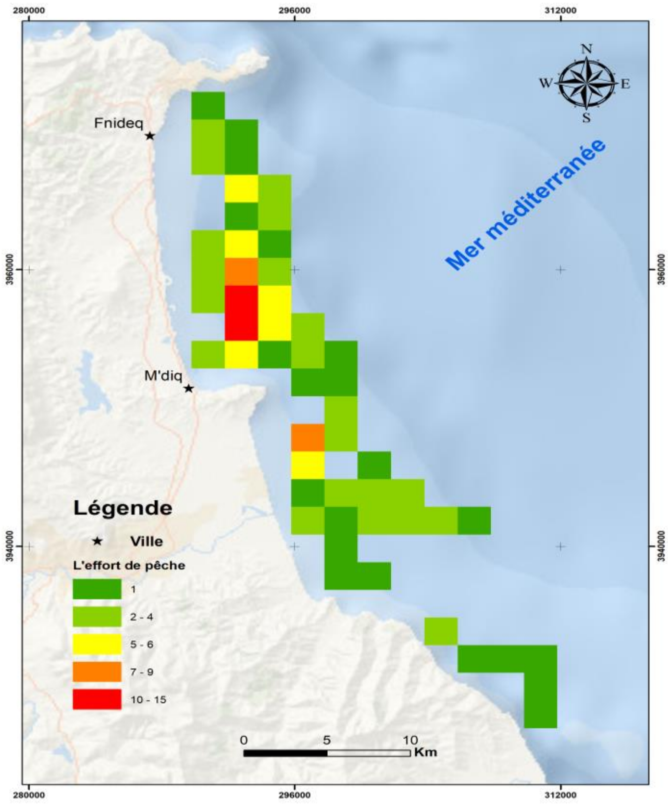


Figure 5: Purse seine effort (fishing days) in M'diq region

Depredation distribution

Depredation events are distributed in almost all the M'diq area, but a high concentration were observed in the large of Martil, and in the large of Capo Negro (see figure below).

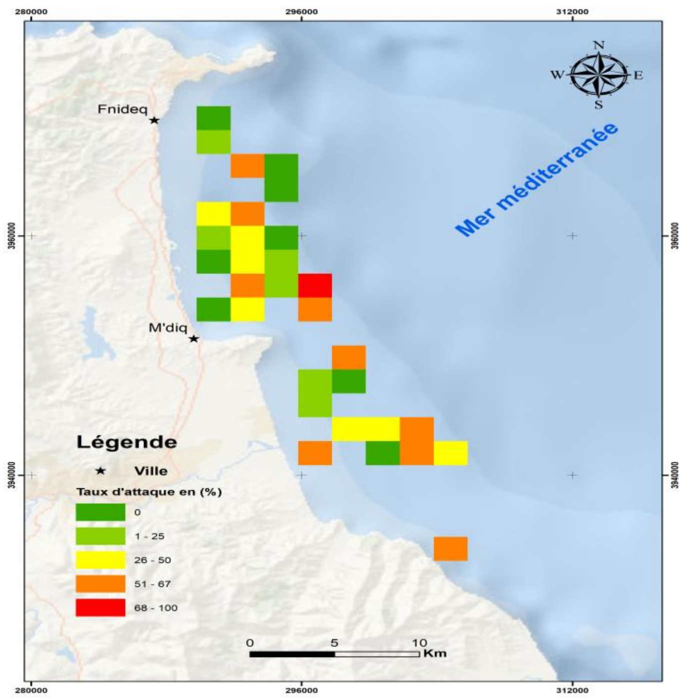


Figure 6: Depredation percentage (bottlenose depredation by fishing operations) in M'diq region

Al Hoceima region:

Fisheries effort distribution

Purse seine activity is distributed along the study area all around the bay of Al Hoceima. Nonetheless, some fishing hotspot was observed in the large of Cap Quilates and Oued Amakrane.

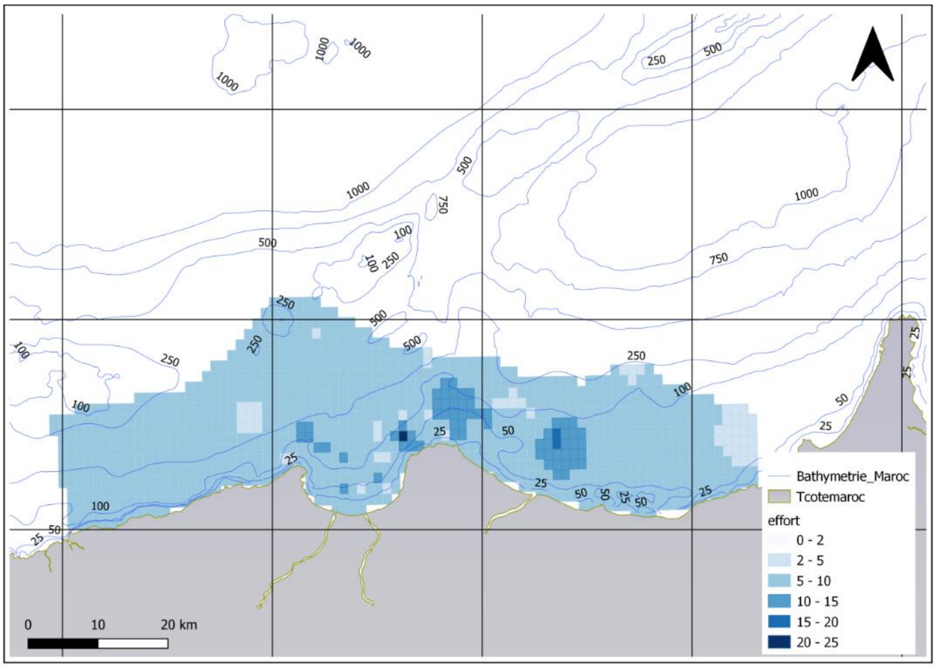


Figure 7: Purse seine effort (in fishing days) in Al Hoceima region

Dolphin distribution

The Bottlenose distribution map and the probability of encounter was calculated using the number of observed or pointed by fishers during questionnaires. It has appears that bottlenose dolphin is highly observed in the large of cap Quilates and in the bay of Al Hoceima.

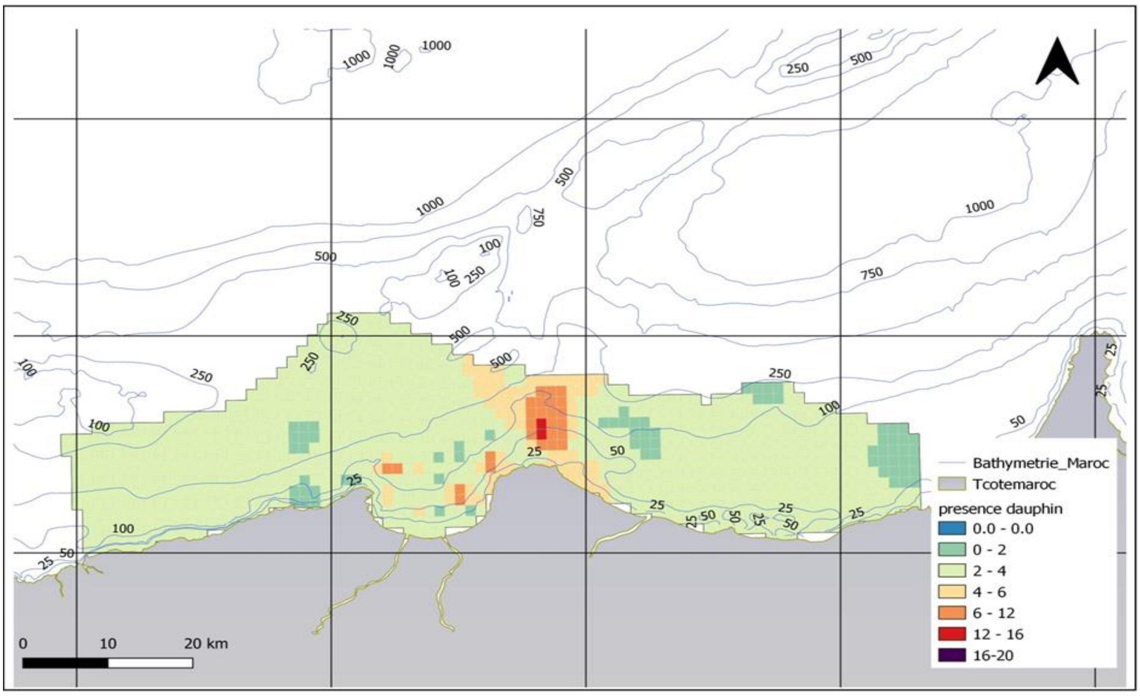


Figure 8: Bottlenose dolphin distribution in Al Hoceima region

Depredation distribution

Depredation events were distributed along the fishery effort zones, but especially in the large of cap Quilates (the area of high encounter of bottlenose dolphins).

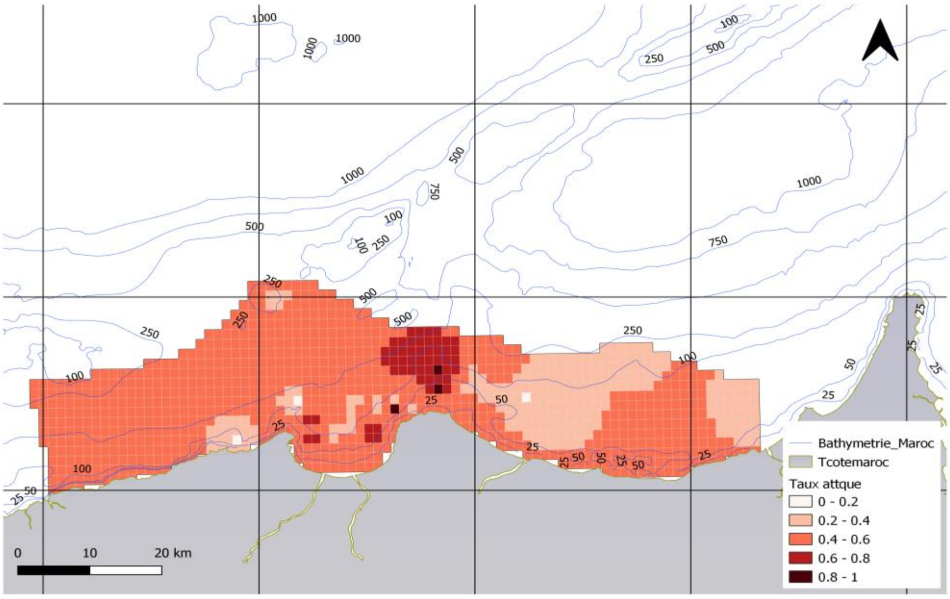


Figure 9: Probability of depredation (bottlenose depredation by fishing operations) in the region of Al-Hoceima

4.3 Impact of fisheries on dolphin depredation

The best predictive model encompasses (effort (Lf), soaking time (DO), and number of active purse seiners (NS), Saison factor, and the catch of Besuge, Mackerel, and sardine). Some factors had a positive influence on the probability of depredation such as (Soaking time, Mackerel, length of the purse seine used) while others have a negative relationship (Sardine, Besuge, and number of active purse seiners). (Table 1 and figure 10).

The predictive model explained more than 63.42 of the variance, and all the variables were statistically significant (p>0.5).

<u>Table 1:</u> *Predictive model estimates and significance*

Variables	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	-7.224643	1.793263	-4.029	5.61e-05 ***
Auxilary Beam	-3.468081	1.735559	-1.998	0.0457 *
Atlantic Horse Mackrerl	3.154681	1.427389	2.210	0.0271 *
Saisons	1.264851	0.519632	2.434	0.0149 *
Number of purse seiners	-0.930602	0.194904	-4.775	1.80e-06 ***
Sardine	-2.017186	0.789529	-2.555	0.0106 *
Soaking time	0.029786	0.014598	2.040	0.0413 *
Length of the purse seine	0.010474	0.004097	2.557	0.0106 *

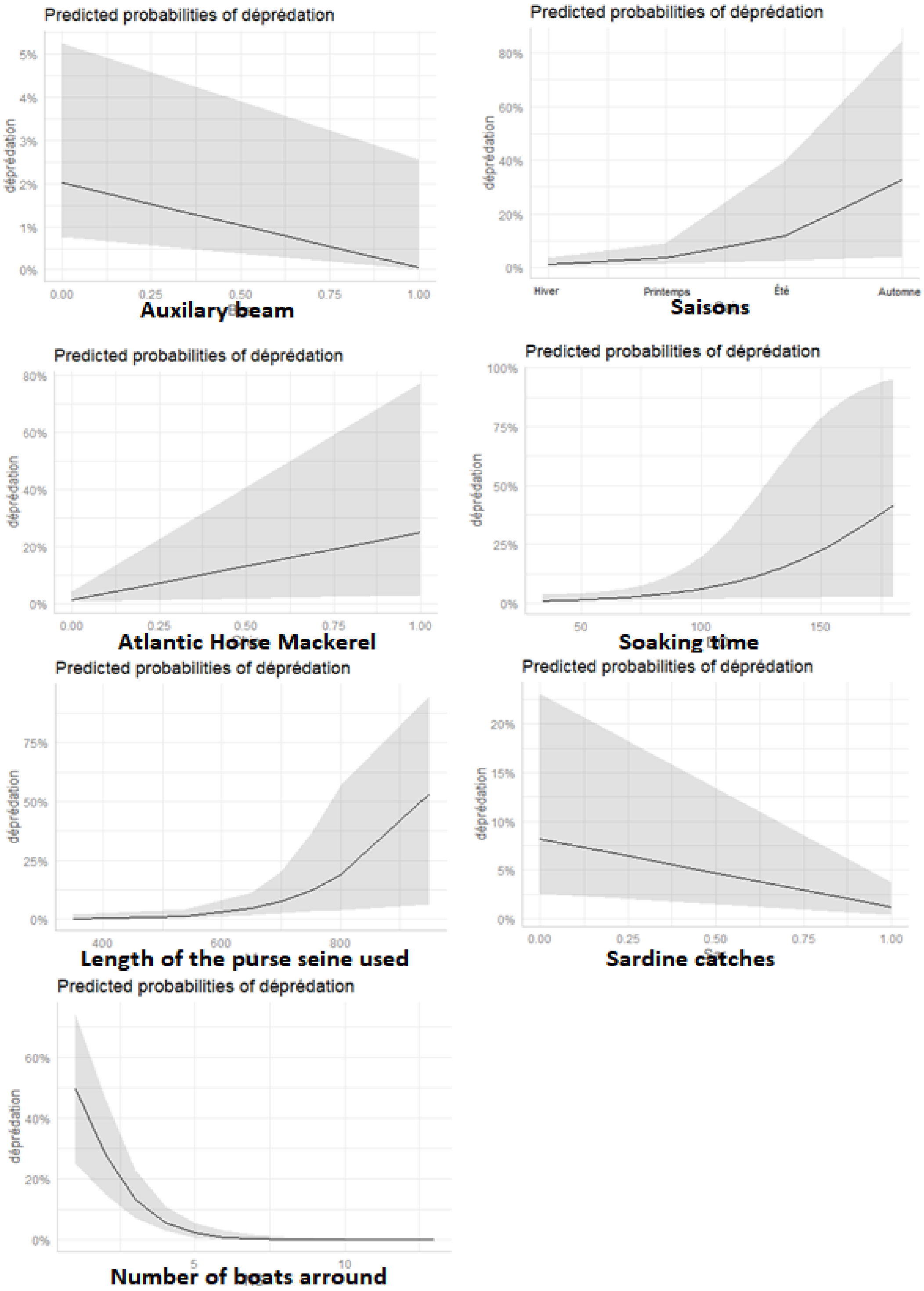


Figure 10: Best predictive models GLM results

4.4 Impact of environmental factors on depredation

After the carry out of the selection process, we decided to keep for three best models generated, the models (1, 2, and 3) explained 46%, 91%, and 91 % of the variance respectively in the spatial distribution of depredation in the study area.

We can write the models as:

Table 2: Best significant models

Models	Models formula	Adjusted R2	AICc	P value
1	*Depredation = Log (bottlenose dolphin presence)*	0.46	-39.4	<0.05
2	*Depredation= Log (bottlenose dolphin presence)- log(effort)*	0.91	-191.9	<0.05
3	*Depredation= Log (bottlenose dolphin presence)- log(effort)- log(chlorophyll A)*	0.91	-192.9	<0.05
4	*Depredation= Log (bottlenose dolphin presence) - log(effort) + log(temperature)*	0.91	-192.4	<0.05

The models result, show that although chlorophyll and temperature represent a significant relationship with depredation (temperature positive effect, and chlorophyll A negative effect), which can be explained as more chlorophyll a concentration, more nutrient rich and more small pelagic presence can lead to a reduction in depredation, and a rise in sea surface temperature can positively affect depredation. These two factors selected in models 3 and 4, still could not explain more variance as it was in model number 2.

This model has as explanatory variables the presence of the bottlenose dolphin and fishing effort, these two variables explained more than 91% of the total depredation variance. The positive effect of bottlenose dolphin's presence and the negative relationship of the fishing effort can be explained as bottlenose dolphins concentration areas where there is a high encounter of the dolphins are the most likely the area of high depredation rate, while the more purse seine boats are fishing simultaneously could lead to the reduction of the probability to be depredated (dispersion effect).

The three models were significant, but models 2 and 3 showed a significant consistency related to the prediction of depredation, especially for the areas of high depredation rates (see figures below).

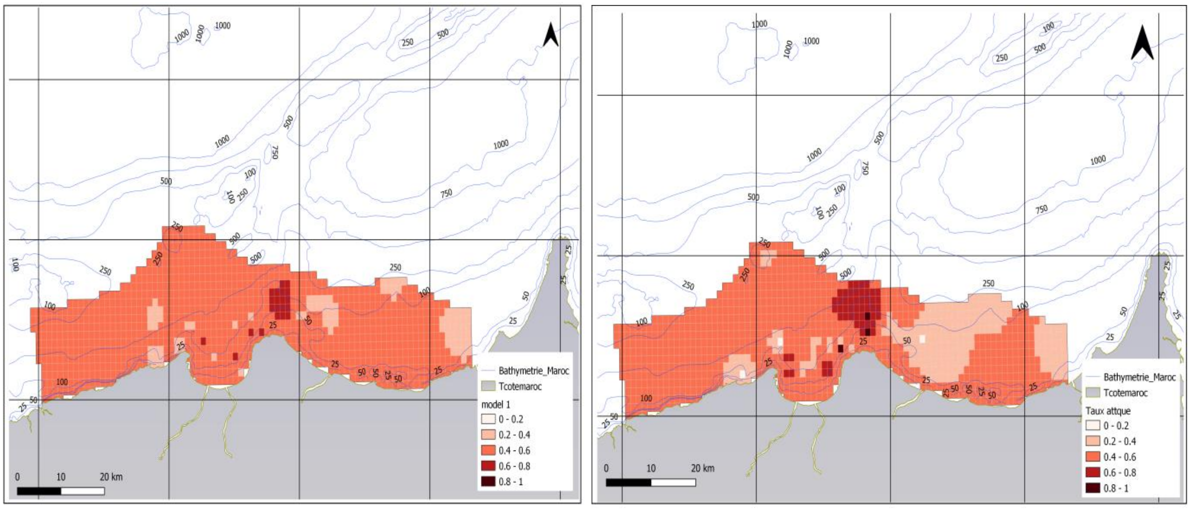


Figure 11: predicted model 1(left map) versus depredation rate (right map)

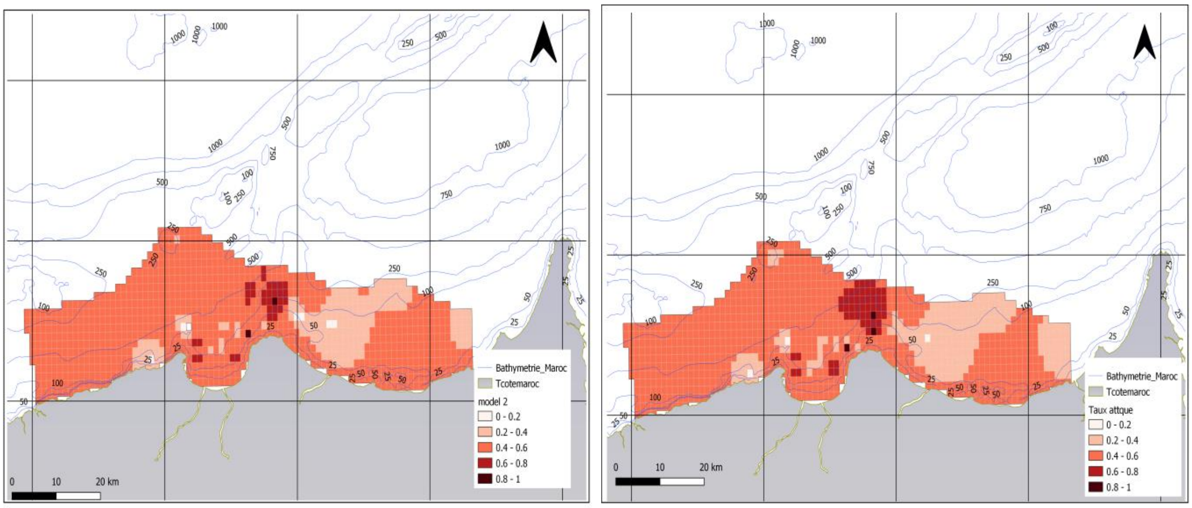


Figure 12: predicted model 2 (left map) versus depredation rate (right map)

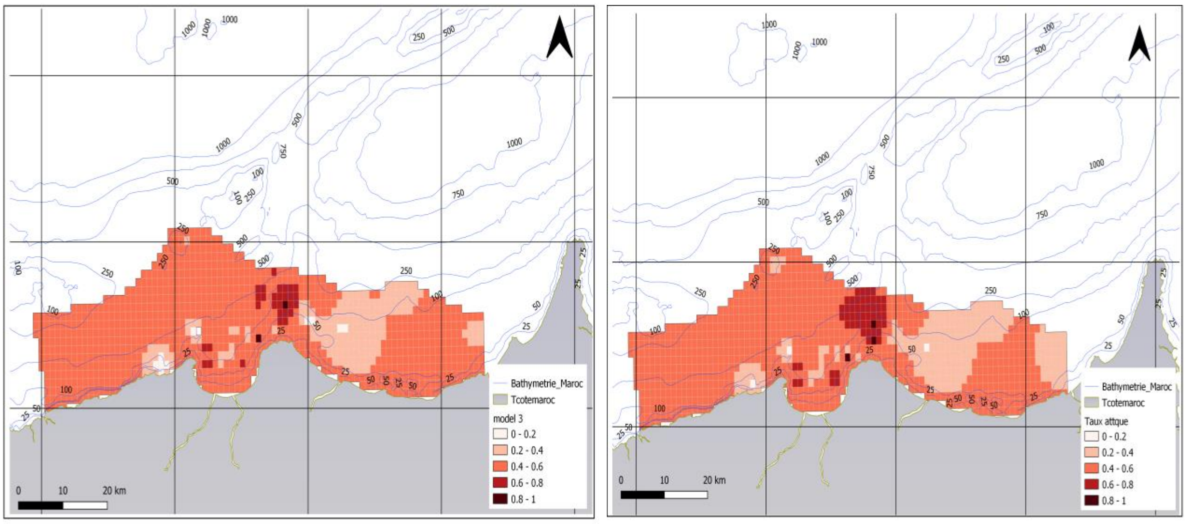


Figure 13: predicted model 3 (left map) versus depredation rate (right map)

4.5 New strengthen purse seine

The performance of this reinforced seine (in three different prototype dimensions: Big, Medium and small) was evaluated according to two criteria: fishing efficiency and resistance to bottlenose dolphin attacks (by the average number of tears per tide and their size). These two parameters are calculated for the reinforced seine, and are compared with the data collected for purse seiners operating with ordinary seines during the same period and at the period and at the same areas.

<u>Resistance to Bottlenose attacks</u>

Concerning to the resistance to bottlenose dolphin attacks, the reinforced purse seine (3 dimensions) suffered on average less tears than the regular purse seine. The average number of tears than the regular seine. The large reinforced seine suffered 19 tears compared to 47 tears per tide attacked for the regular seine. For the medium-sized reinforced seine 18 tears against 91 for the regular seine. Finally seven (7) on the small reinforced seine against 19 on the regular seine.

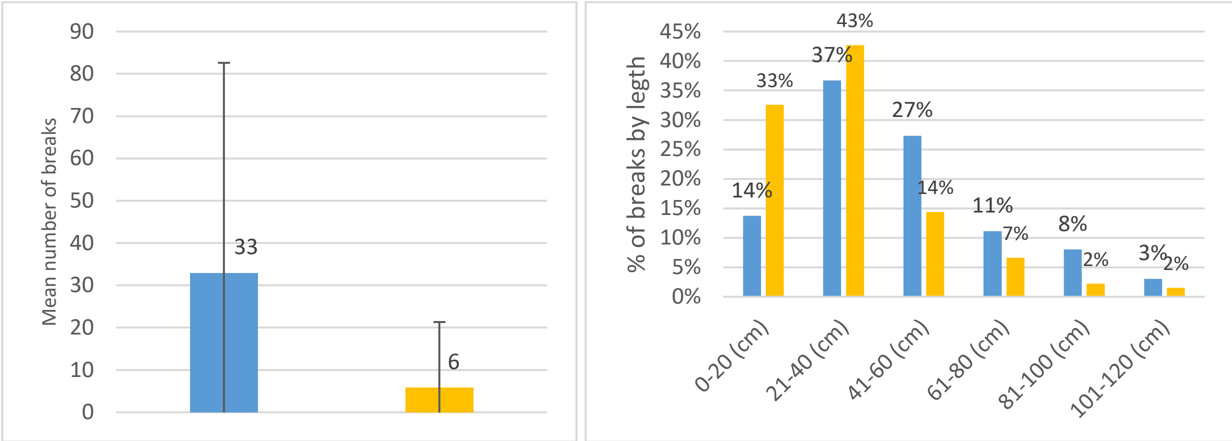


Figure 14: numbers of breaks caused by Bottlenose dolphins by type of purse sine (left plot), types of length breaks by type of purse seine (right plot), (ordinary purse seine in blue and big strengthened purse seine in yellow)

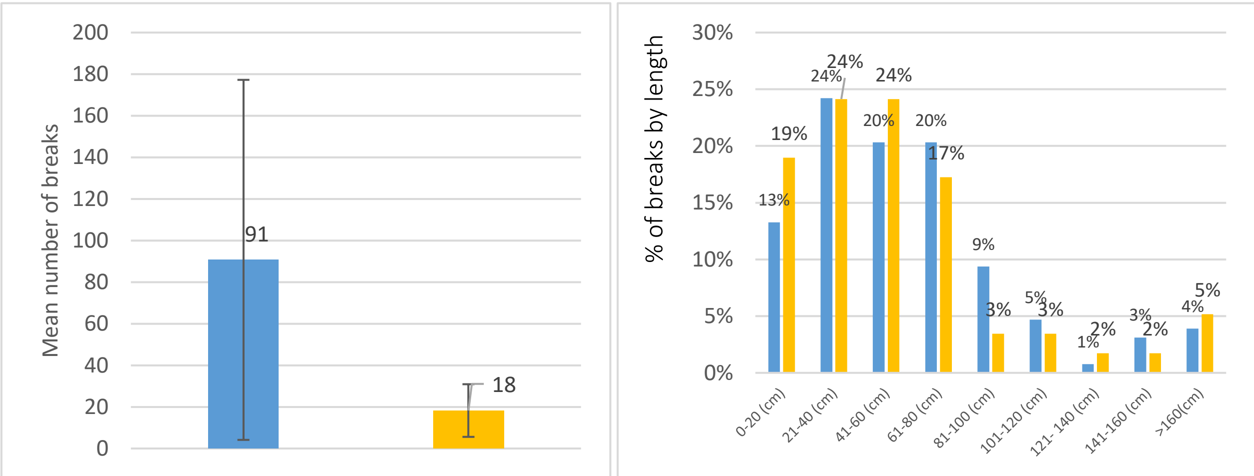


Figure 15: numbers of breaks caused by Bottlenose dolphins by type of purse sine (left plot), types of length breaks by type of purse seine (right plot), (ordinary purse seine in blue and average strengthened purse seine in yellow)

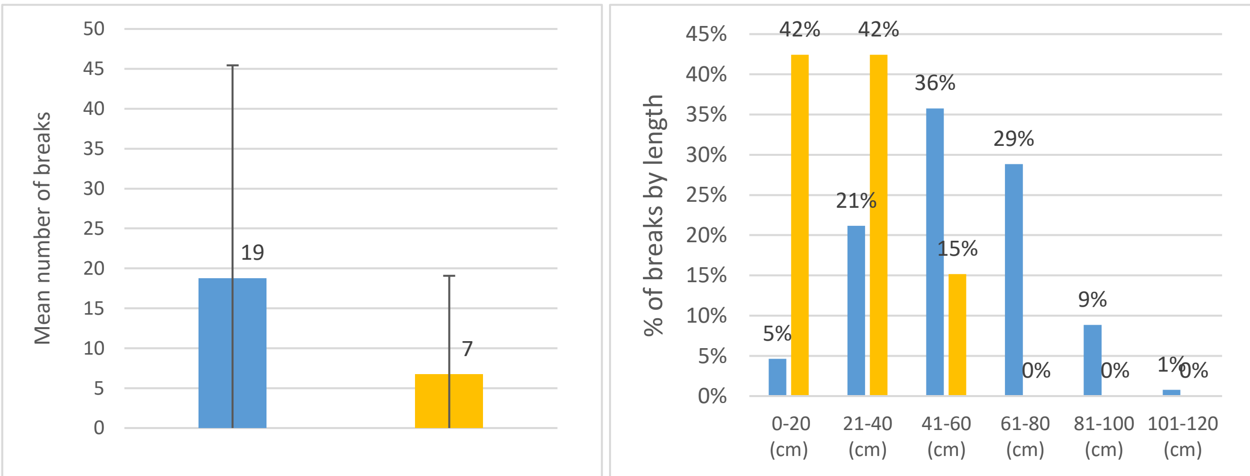


Figure 16: numbers of breaks caused by Bottlenose dolphins by type of purse sine (left plot), types of length breaks by type of purse seine (right plot), (ordinary purse seine in blue and small strengthened purse seine in yellow)

Fishing efficiency

The average catch per fishing day for the large and medium-sized reinforced seine was almost twice as then the catch of the regular seine. While the average catch of the small-reinforced purse seine was lower than the regular one. The small-reinforced seine has a length of 369 m. It is much smaller compared to the average length of the regular seines used by the other purse seiners during the experiment.

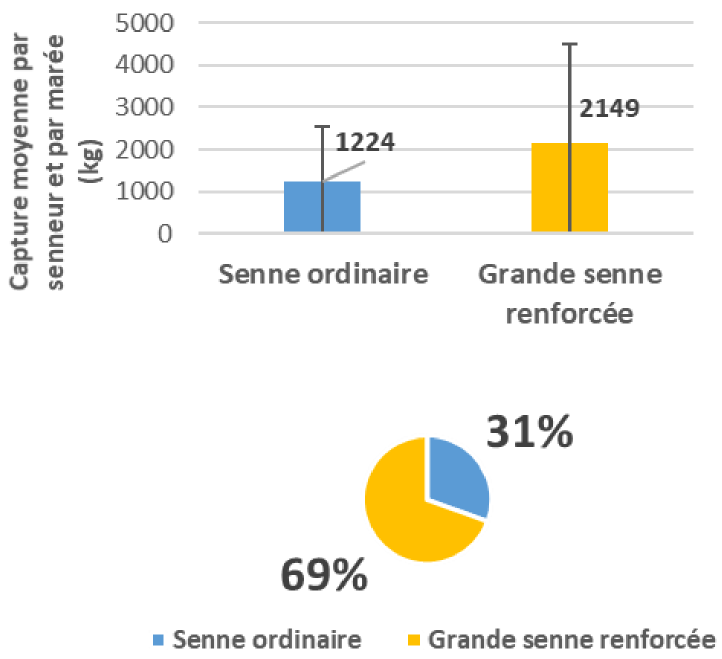


Figure 17: Catches of ordinary purse seine (blue) versus catches of large strengthened purse seine (yellow)

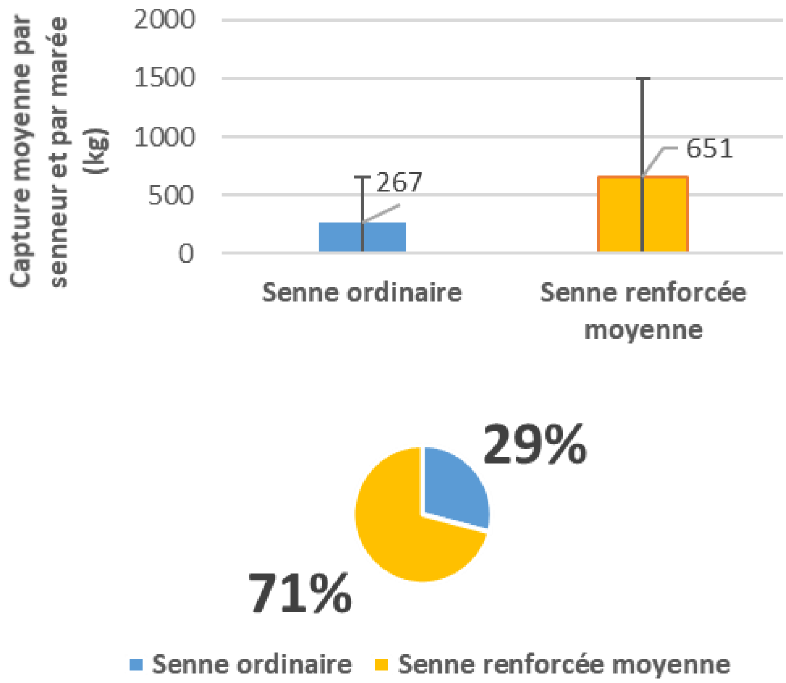
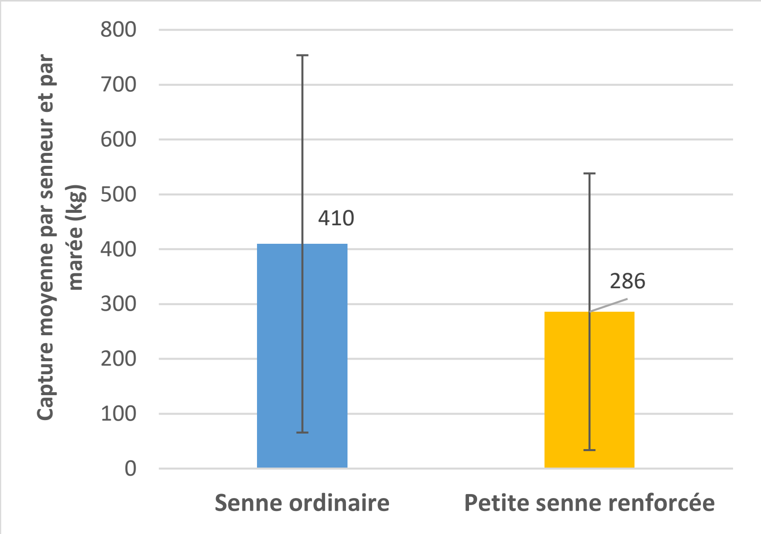


Figure 18: Catches of ordinary purse seine (blue) versus catches of medium strengthened purse seine (yellow)



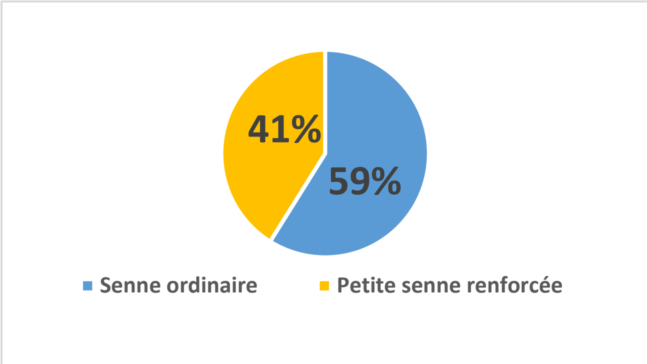


Figure 19: Catches of ordinary purse seine (blue) versus catches of small strengthened purse seine (yellow)

5. Conclusion and recommendations

5.1 Conclusion

This study has shown some very interesting outcomes regarding bottlenose dolphin distribution, abundance and behavior. We will present the publication of all the analyses and results in the end of 2022. The close monitoring of the depredation displays a decrease in M'diq depredation and an increase in Al Hoceima. This is mainly due to the fact that only reduced purse seiners are still active in Al Hoceima.

Spatial distribution of depredation shows that these phenomenon is mainly encounter in a places of high encounter probability of bottlenose dolphins (Cap Quilates and inside the bay in Al Hoceima region, and Kabila, Martil and Capo Negro in M'diq region).

The influence of environmental factors seems to be very small on the depredation, while the fishing behavior was much correlated with the depredation rate. The soaking time, length of the purse seine and the type of specie captured were likely to increase the depredation, while

The results of the experiment show that the reinforced seine is a reliable solution to the problem of interaction with bottlenose dolphin problem of interaction with bottlenose dolphins. This seine is more rigid to attacks and its repair cost is lower than the cost of repair than the regular seine used by the purse seiners in both regions (fewer tears and tears and much smaller sizes).

5.2 Recommendation

Bottlenose dolphin monitoring and observation actions should be maintained as photo-identification study had shown some very interesting results, and this type of study take need several years (beyond the timeframe of this study).

Spatial analysis suggests that fishers should avoid fishing in the regular fishing hotspot and in the region of high encounter rate of bottlenose dolphins.

Soaking time and the length of the purse seine should be reduced in order to decrease the depredation rate.

6. Acknowledgments

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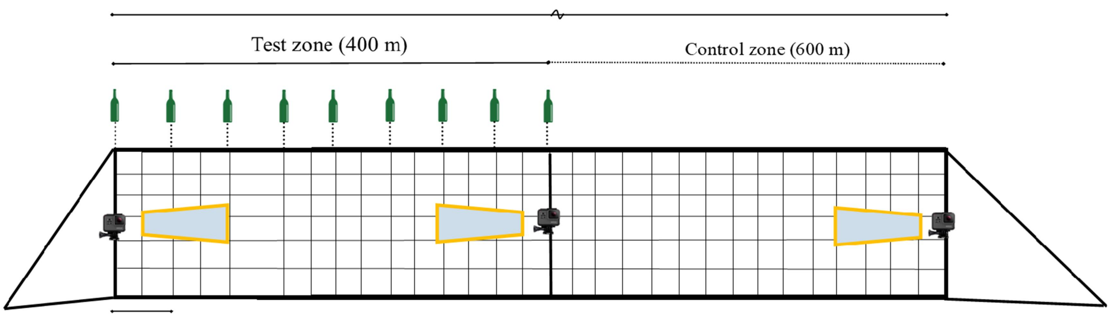
ACCOBAMS-MOP8/2022/Inf39

MITIGATING DOLPHIN DEPREDATION IN MEDITERRANEAN FISHERIES

JOINING EFFORTS FOR STRENGTHENING CETACEAN CONSERVATION AND SUSTAINABLE FISHERIES

Interactions between air breathing marine vertebrates, particularly cetaceans, and artisanal fisheries in northern Alboran Sea (CETAFISHBE)



Asociación Herpetológica Española

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August, 2022

MAVA Fondation pour la nature

TECHNICAL REPORT TITLE

Interactions between air breathing marine vertebrates, particularly cetaceans, and artisanal fisheries in northern Alboran Sea

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Interactions between air breathing marine vertebrates, particularly cetaceans, and artisanal fisheries in northern Alboran Sea

Executive Summary (3 pages maximum)

Interactions between cetaceans and fisheries have become a major problem worldwide, which is reflected in the increasing number of reported cases together with the difficulties in quantifying the impacts on cetacean in fisheries economy. These interactions occur when there is a spatial overlap between cetaceans' habitat and fishing grounds, in most cases because both cetaceans and humans share the same target species (such as the European pilchard and anchovies).

Interactions can be negative or positive, and beneficial effects would involve dolphins "co-operating" in fishing operations, increasing the chances of success in the capture of prey. Nonetheless, most interactions have negative consequences for fishers, including breaking of fishing nets and loss of capture. The main types of fishing gears affected by interactions between cetacean and fisheries in coastal Mediterranean waters include artisanal bottom-set trammel nets and gillnets, as well as purse seine.

Main interaction between fisheries and dolphins consists in the total or partial depredation of the catch. This behaviour produces the break of parts of the gear that can result in reducing the catchability and important economic losses. Coastal dolphins, particularly common bottlenose (*Tursiop truncatus*) are often claimed to damage the catch and the fishing gear in order to steal the capture, also scaring the potential preys away. *Tursiops* can be observed in a wide variety of habitats, being a common marine mammal in the continental shelf of the Alboran Sea, also on the slope and in deep waters between 200 and 500 meters depth. This species exhibits a highly varied diet throughout its distribution range, including mainly Sparidae species and a mixture of other species including European hake, mackerels, European conger and European pilchard.

The bottlenose dolphin is, according to the IUCN Red List of Threatened Species, a vulnerable species. Furthermore, it is included within the Annexes II (animal species of Community interest) and IV (strictly protected species) of the EU Habitats Directive (Council Directive 92/43/EEC), within the Barcelona (endangered or at-risk species) and Bern (strictly protected fauna) Conventions and the ACCOBAMS agreement (Bonn Convention), and locally within the Spanish National Catalogue of Threatened Species.

This work is part of the Action CETAFISHBE which studies the Interaction between cetaceans and small-scale fisheries in southern Spain. The main aims of this study are to show the existence of dolphin-fisheries interaction in the northern margin and particularly:

i. To improve knowledge of the behaviour and interactions of cetaceans and fishermen;
ii. Monitoring cetacean interactions in the fishing areas of Caleta de Velez and Fuengirola;
iii. Analyse the interaction between cetaceans, small scale fisheries and small pelagic purse seiners;
iv. To implement and test different low cost mitigation methods to reduce bottlenose interactions in SSF in northern Alboran Sea.

Finally, it will support a better understanding on gear depredation dynamics in order to provide further information on possible mitigation measures to be used, hopefully moving beyond the use of pingers, and to raise awareness among the administrations and decision-makers on the issue and to find practical solutions.
This report presented by AHE to ACCOBAMS is the deliverable derived of two Memorandum of Understanding Nº 01/2021/LB 6411 and Nº 03/2022/LB 6411 signed between the Secretariat of the Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean and

Contiguous Atlantic Area (ACCOBAMS) and the Chairperson of the Spanish Herpetological Association (AHE) to carry out the project Interactions between airbreathing marine vertebrates, particularly cetaceans, and artisanal fisheries in northern` Alboran Sea.

During the first step in 2021 we have collected information on 938 sets (fishing operations) of artisanal fishing with nets, of these sets 205 have been damaged by dolphins (22%) with an average cost for repairing the nets of 1200 € (including the hand work and replace the material). Moreover, in this phase, four cameras were installed on the nets of two boats and two mullet trammel net fishing operations were recorded in two different fishing areas. We hypothesize that the set most depredated by dolphins are close to the coast, at shallow depths and with clear waters, areas where bottlenose dolphins are commonly observed. The number of net units, and therefore the larger the net, the more likely it is that increase the captures and that dolphins will prey on these nets. The results of the analysis indicate that approximately 30% of the monitored sets suffered a net damage due to unwanted interaction with non-target wildlife species (alien seaweeds or dolphins).

During the second step in 2022, we focused our efforts in trying to find and apply a low-cost solution/mitigation to dolphin depredation through the design of two over four proposed low-cost mitigation devices: Mitigation based on recycled glass bottles used as acoustic deterrents and mitigation based on Compact Disks (CDs) based on acoustic and light reflection device. We also tried pingers as high-technology devices for dolphin mitigation as alternative solution but without positive results.

A total of 56 experiments with low cost material were carried out: 19 experiments using recycled glass bottles, 34 experiments using CDs, complementary three experiments used pingers. Recycled glass bottle-based devices (a system previously tested in South America) showed to have a negative effect on finfish captures and no conclusive effect on dolphin mitigation. CDs-based device showed no conclusive effects on dolphin mitigation too. Pingers showed a clear “dinner bell” effect on the experiments carried out, experiments using this device had to be terminated. As conclusion of the experimentation phase we obtained a low level of statistically valid data by problems with the collaborators to use the devices provided by us.

As part of the approach to the problem, fishermen were surveyed about the economic impact dolphins have on their economic activity. The economic value of the repair time of a net on each interaction is between €50 and €60 per net plus the equivalent value of the fish not caught by that area of net with a hole in it and the losses by depredation. The economic situation of the fishermen is in a critical state due to the need to reinvest the few profits in repairing the nets.

We conclude that the number of experiments with the different devices should be increased to obtain better statistical results. And to do that, the number of fishermen collaborators should also increase, but many fishermen answer that they have new additional problems that cause new losses (the presence of invasive algae *Rugulopteryx okamurae*) as to prioritise and be involved in experimental actions.

1. Context and objectives of the study

This report presented by AHE to ACCOBAMS is the final deliverable of the Memorandum of Understanding Nº 01/2021/LB 6411 signed between ACCOBAMS and the Spanish Herpetological Association (AHE) to carry out the Action “Interactions between air-breathing marine vertebrates, particularly cetaceans, and artisanal fisheries in northern’ Alboran Sea (CETAFISHBE)”. This report includes additional activities and results obtained under a second MoU Nº 03/2022/LB 6411.

Although interactions can be negative or positive, most interactions have negative consequences for artisanal fishers, including breaking of fishing nets and loss of capture and revenues. The interactions between cetaceans and fisheries usually occurs when there is spatial overlap between cetaceans' distribution and fishing areas, in most cases because both cetaceans and humans share the same target species (Zappes et al., 2016; Revuelta et al., 2018).This kind on human-dolphin interactions have become a major problem worldwide (Harwood, 1983; Goetz, 2014; Goetz et al, 2014). The problem becomes more serious because some of these target species represent an important feeding resource for dolphins inhabiting Mediterranean coastal waters, and at the same time they are largely caught by small-scale fisheries and some present overexploited stocks (Tudela, 2004). Currently, the types of vessel groups with the greatest rates of interactions with marine mammals seem to be those using set gillnets and trammel nets in coastal areas (FAO, 2020), as well as trawl nets and purse seines to some extent (Bearzi, 2002).

The main interaction between fisheries and dolphins consists in the total o partially depredation of the catch, which is concentrated in the fishing nets and represents an easy to exploit food resource for these cetaceans, this is particularly the case of fixed fishing gears with long soak times (Goetz, 2014). Coastal dolphins, particularly common bottlenose (*Tursiops truncatus*) are often claimed to damage the catch and the fishing gear in order to steal the capture, also scaring the potential preys away (Notarbartolo di Sciara, 2002). In this line, most of the documented cases of predation of catch from fisheries in Mediterranean coastal water are due to the attack of bottlenose dolphins (Bearzi et al., 2010). This species can be observed in a wide variety of habitats, being the most common marine mammal in the continental shelf of the Mediterranean Sea (Notarbartolo di Sciara, 2002; Gonzalvo et al., 2014).

In the Alboran Sea, the bottlenose dolphin can be found in the continental shelf and the slope and in deep waters between 200 and 500 meters depth (Forcada et al., 2004; Cañadas et al., 2005). This species exhibit a highly varied diet throughout its distribution range, including mainly Sparidae species and a mixture of other species including European hake (*Merluccius merluccius*), mackerels (*Scomber* spp.), European conger (*Conger conger*) and European pilchard (*Sardina pilchardus*) (Giménez et al., 2017). The bottlenose dolphin is included in the IUCN Red List of Threatened Species (Bearzi et al., 2012), in the category Least Concern (Natoli et al. 2021). Furthermore, it is included within the Annexes II (animal species of Community interest) and IV (strictly protected species) of the EU Habitats Directive (Council Directive 92/43/EEC), within the Barcelona (endangered or at risk species) and Bern (strictly protected fauna) Conventions and the ACCOBAMS agreement (Bonn Convention), and locally within the Spanish National Catalogue of Threatened Species as vulnerable (Real Decreto 139/2011).

Although conflict with fisheries has been reported worldwide (Gearin et al., 1994; Barlow & Cameron, 2003; Powell & Wells, 2011; Reeves et al., 2013; Rechimont et al., 2018), the literature suggests that the problem is severe throughout the Mediterranean area (Bruno et al., 2021).

The previous project on the depredation-SSF issue carry out by AHE was "Mainstreaming Small-scale Fisheries in the Mediterranean, 2018-2020" coordinated by Low Impact Fishers of Europe (LIFE), supported by the MAVA Foundation and implemented in northern Alboran Sea . It was a multiregional pilot research project to assess the socio-economic and ecological impacts linked to the cetacean - SSF fishery interactions in the Mediterranean, and to search for potential measures to mitigate the problem.

The current ACCOBAMS-AHE Action "Interactions between cetaceans and artisanal fisheries in northern Alboran Sea (CETAFISHBE), could be considered a second step of the AHE research in collaboration with ACCOBAMS to better understand both the causes of the negative interaction and its magnitude in the north of Alboran Sea. Some possible low-cost solutions have also been explored. The main aims of the current Action are:

i. To improve knowledge of the behaviour and interactions of cetaceans and fishermen;

ii. Monitoring cetacean interactions in the fishing areas of Caleta de Velez and Fuengirola;

iii. Analyse the interaction between cetaceans, small scale fisheries and small pelagic purse seiners;

iv. To implement and test different low cost mitigation methods to reduce bottlenose interactions in SSF in northern Alboran Sea.

2. Introduction

2.1. State of the knowledge interactions between cetaceans and artisanal fisheries in the area

The main results of the previous AHE-LIFE project "Mainstreaming Small-scale Fisheries in the Mediterranean" (2018-2020) are related to:

i. Predation by *Tursiops truncatus* on captures in SSF gears, confirming that the most affected gears were red mullet and cuttlefish trammel nets , bullet tuna, sardine and set gillnets (several target species);

ii. Red mullet (*Mullus surmuletus*) and cuttlefish (*Sepia officinalis*) trammel nets in Caleta de Vélez and Málaga ports declared the highest number of gears affected;

iii. Most respondents considered that the presence of the bottlenose dolphin has increased in the last 5 years;

iv. Negative interactions occurred on average in 46% of the operations and the percentage of the gear damaged can reach 76% on average. Depredation produce holes: small (0-30 cm), medium (31-80 cm), big (81-120 cm), very big (>120cm);

v. An emergent problem associated to SSF is the presence of the alien brown seaweed *Rugulopteryx okamurae*, detected in 2015 in southern Gibraltar strait. Since then it has shown a surprising growth and dispersion displacing the native biota and producing negative effects on the local fishermen in northern Alboran Sea. Fishermen from Tarifa, Algeciras Estepona, Marbella and Fuengirola claimed the fall of their catches.

vi. A total 88% of fishermen reported to had negative interactions, representing 46% of fishing days working with gillnet affected and an with an average total losses reported of 871€ (SD = 1130) per event with interaction, and that losses have a larger impact by the expansion of *Rugulopteryx okamurae*.

The current ACCOBAMS-AHE Action was adopted to be implemented during the period October 2020-August 2022. In this phase, the area of activity is the same (Fig. 1) although we concentrate the activities in two ports, Caleta de Vélez and Fuengirola. The area considered is situated in northern Alboran Sea, in the Mediterranean coast of Andalucia, that in whole include 13 fishing ports and is, for fisheries management purposes, shared among the regional government (Junta de Andalucía), the national government (General Secretary for Fisheries) and the FAO-General Fisheries Commission, corresponding the northern Alboran to the Geographical Subarea nº 01 (GFCM GSA 01).

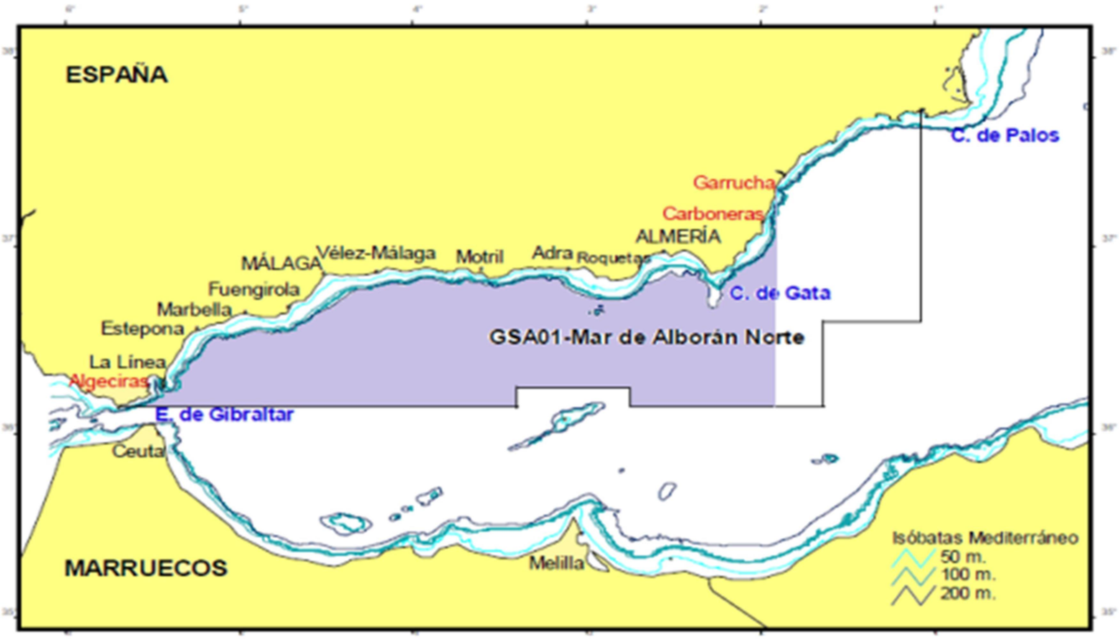

Figure 1. Main fishing ports in the Spanish area of the ACCOBAMS/AHE (2020-2022) project

Moreover, currently this region is important for observing cetaceans and therefore whale watching companies are established in the area. Three Important Marine Mammals Areas (IMMAs) overlapping in this area (Fig. 2), which is considered the most relevant area for marine mammals from Western Mediterranean Sea (Báez et al., 2019).

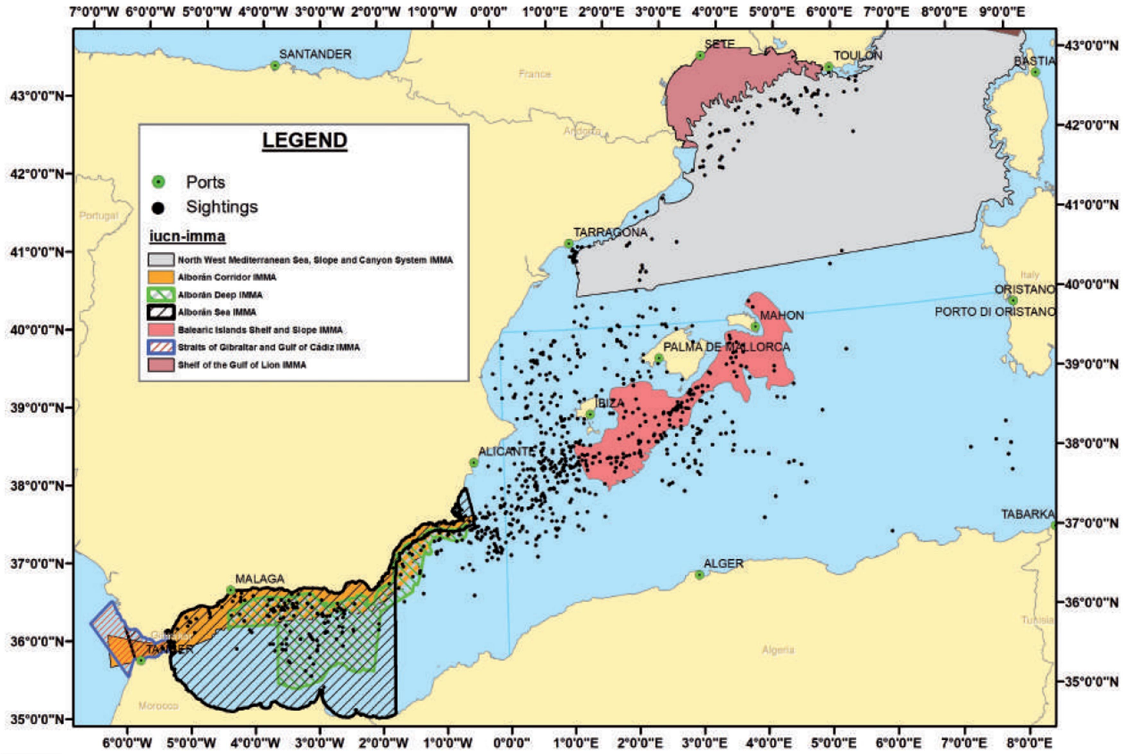

Figure 2. Spatial distribution of IEO opportunistic sightings (1997-2014) by IMMA from Western

2.2. Artisanal trammel net fisheries from the selected area and ports selection

The most important fishing ports in the Alboran Sea in relation to the number of vessels are Estepona, Caleta de Vélez, La Linea de la Concepción and Almería, which provide more than 50% of the Andalusian small-scale fleet that operates in the Mediterranean Sea. Situated in the centre of the region, Caleta de Velez is the major landing port of the fleet of small scale fisheries. The small scale fleet uses a great variety of gears targeting bivalve molluscs, crustaceans, fishes and cephalopods. With 42 active small scale vessels Caleta represents 11.2% of the regional fleet. Main net gears used by this small scale fleet include set gillnets and trammels nets. Set gillnet are named and used depending on the target species and fishing area (métieres): they can use Bonitera targeting Atlantic bonito *Sarda sarda*, Sardinal targeting European sardine, *Sardina pilchardus*, Melvera targeting Frigate tuna *Auxis* spp. Trammel nets most used are those targeting Cuttlefish (*Sepia officinalis*) and Red Mullet (*Mullus* Spp).

According to Aguilera et al. (2020) the main artisanal gears used and the period of activity in the Caleta de Velez port are in Table 1.

Table 1. Main trammel net gears used in northern Alboran Sea and main fishing period used (Aguilera et al., 2020).

Gear	Period of use
Cuttlefish trammel net	February-June
Red mullet trammel net	June-August
Sardine set gillnet	June-August
Bonito set gillnet	All year

Moreover in the port of Caleta de Velez there is a fleet of 16 purse seiners targeting small pelagic (mainly Sardine and Anchovy) also affected by documented interactions with dolphins producing depredation and holes in the fishing gear.

The second selected port is Fuengirola, situated in the western part of the area, represent the 7, 4% of the regional small scale fleet, with 28 vessels that alternate different artisanal gears targeting bivalve molluscs (bivalve dredges), crustaceans (traps), fishes and cephalopods (nets) and Octopus fishing traps. These small scale vessels use different nets types, mainly cuttlefish and red mullet trammel nets during some periods of the year. In this port it is also situated the Oceanographic Centre of Malaga (IEO), where different teams have been working on small scale fisheries since the XX century (Camiñas & Rey, 1984; Camiñas et al., 1988; 1990; Baro et al., 2021). Moreover, since 1993, another team of the Oceanographic Centre of Malaga (IEO) compiled opportunistic observations of cetaceans in the western Mediterranean and Alboran Sea building data set containing information of nine species of cetaceans (Torreblanca et al., 2016; 2019). In summary two of the most active fishing ports in southern Spain, that are important because using artisanal gears including trammel nets and other nets types, Caleta de Vélez and Fuengirola, are involved in this Action with the collaboration of the two Cofradias de Pescadores, and covering approximatively a half of the GFCM GSA 01, northern Alboran Sea, with the activity of the small scale fleet of the two ports.

The current Action has been subdivided into two parts. In the first, interactions between marine cetaceans and artisanal fishermen in the study area are monitored through daily surveys at the fishing port. In the second, we tried to find and test, with the cooperation of artisanal fishers, low-cost dolphin mitigation devices to deal with these interactions.

2.3. General objectives

Our main goal, following the MoU includes:

- To estimate, in selected pilot ports - Caleta de Velez and Fuengirola, Málaga- the depredation caused by cetaceans (in particular bottlenose dolphins) in artisanal nets fishery and to ascertain the number of vessels involved, main period and the marine areas (hot spots) where most interactions occur.

- Based on the current state of play obtained during phase 1, our main aim is to improve existing information and its quality on the interactions, depredation of catches by cetaceans and the main effects of dolphins/fishers encounters on the fishing activity (effort/fishing days balance), the fishing gears (number and size of the holes produced in the nets during the interactions) and the losses provided by the fishing activity (comparing attacked and non-attacked vessels), through monitoring SSF (at landing and with on-board activities) during the main fishing period with artisanal nets (spring and summer months).

- As the information obtained during phase 1 suggests the incidence of dolphins also in purse seiners targeting small pelagic species from the same ports, and one of the partners, ANSE works directly with this fleet, our team address a part of our efforts to complement information on main periods/areas of interaction.

- Complementarily we'll look into the bycatch aspect of other air breathing marine vertebrates, particularly marine turtles and sea birds and other by-caught species in the target SSF and PS fleets.

As in practice it was not easy to carry on some of the previous goals as will be comment later, we selected and discussed with fishermen and Cofradias de Pescadores a series of low-cost devices and techniques designed to test the mitigating interactions.

3. Progress of activity during the Action

Following the Annex I of the AHE Project Proposal to ACCOBAMS, the activities foreseeing in the Workplan during the Action (October 2020—July 2022) are summarised in Table 2.

Table 2. Summary of activities carried out during the Action CETAFISHBE.

Activities in the Workplan	Date of implementation	Main difficulties
Preparatory phase	2020	Select and expert to the project Contacts with Cofradias Contacts and election of collaborative fishermen
Coordination and meeting with partners in Spain	2020	Univ. Huelva Partner retired Agreement with ANSE Partner
Monitoring of SSF fleet (Caleta and Fuengirola)	2021	Reticence of several skippers of SSF to collaborate
Monitoring on PS fleet in Caleta	2021	Reticence of skippers of PS to collaborate.
Analysis of results of first phase. Progress report	2021	Analysis based on preliminary questionnaires.
Port questionnaires (on attacks)	Febr. 2021 – Febr. 2022	Difficulties derived of *Rugulopteryx* extension and dolphins interactions
Fishing production/fleet	Jan. 2021 – Febr 2022	Reticence of skippers to share data. Problems not solved to obtain official data
Climatic data collection	Febr.- July 2021	
On board SSF deterrents trials	Jan. 2022 - June 2022	Less collaboration than foreseeing. No experts onboard
Hot spots SSF-cetaceans detect	All year	Few location of depredation events
Visual mitigation trials	Febr. 2021-June 2022	Less collaboration than foreseeing
Chemosensory repellents trials	------------	Not done. No fishermen collaboration
Acoustic deterrent trials	Jan. 2022 – June 2022	Less collaboration than foreseeing. Low cost trials
Cameras on nets check cetaceans behave	Jan. 2022 - June 2022	Difficulties to obtain good recordings. Recording time not cover the entire daily activity
Contribution to a project brochure	All year	Contribution pending of project coordinator

Activities in the Workplan	Date of implementation	Main difficulties
Meeting fishers and Cofradias	Mar. 2021 - June 2022	Retards in some meetings Few collaborative fishermen
Final report	August 2022	Finished draft to ACCOBAMS

3.1. Step one: Monitoring of fishing activity and depredation[1]

3.1.1. Specific objectives

The main aim was to improve existing information and its quality on the interactions, depredation of catches by cetaceans and the main effects of dolphins/fishers encounters on the fishing activity (effort/fishing days balance), the fishing gears (number and size of the holes produced in the nets during the interactions) and the losses provided by the fishing activity (comparing attacked and non-attacked vessels), through monitoring small scale fisheries (at landing and with on-board activities) during the main fishing period with artisanal nets (spring and summer months).

3.1.2. Meeting and Consultation with Partners and Stakeholders

During the first months of the project, activities were focused on contacting the port authorities and Cofradia's chairperson to inform them of the results of Phase I, the projected activities during Phase II and to request the authorizations, to work inside the fish landing port following the established protocols.

In a first step three meetings were held in the ports of Caleta de Velez and Fuengirola. After learning about the project and receive the annexed Spanish summary, the Cofradias responsible in each port informed the fishermen of the artisanal fleet about our activities and gave us authorization to access the port to communicate directly with the target fishermen. The Spanish summary was distributed to collaborators too.

The Phase II has been coordinated with a national partner, ANSE. This is an NGO that has experience in working with cetaceans and fishermen. ANSE is carrying out a project in the port of Caleta, so it was necessary to share information to avoid overlapping. During 2021 they are implementing a nationally project to estimate bottlenose dolphin populations and interactions with purse seiners and small scale fisheries in an area that partially overlaps with the AHE Action. Both AHE and ANSE are collaborating to share their information, improve results and facilitate synergies. We held two meetings before starting the data collection, a live meeting and an online meeting. The first meeting was in the port of Caleta de Velez. As the information obtained during Phase 1 suggested the incidence of dolphins in purse seiners targeting small pelagic species from the same ports and as ANSE work directly with this fleet from Caleta de Vélez, AHE will address a part of the effort to complement ANSE information, mainly on the main periods/areas of interaction with that fleet.

3.1.3. Monitoring artisanal fisheries/fleets interacting with bottlenose dolphins in Caleta de Vélez and Fuengirola, GSA 01

[1] This part was included in the Progress Report delivered to ACCOBAMS in October 2021.

The small scale fleet was monitored in Caleta de Vélez and Fuengirola during six months (mid-February – mid-August) in 2021. In addition, from March to July we collected environmental data (air temperature, sea state, sea surface temperature, wind strength and direction, etc.) in Caleta de Vélez. A total of 64 days of data collection were distributed throughout the monitoring period, in order to have complementary environmental information to help us the detection of temporal and spatial hot spots. The collected information/data improved our knowledge on the interactions of SS fisheries with cetaceans: species involved, behaviour with the gears and capture as well as the characteristics of the fleet (target species, fishing area, fishing period, fishing effort, daily number of interactions, type of interaction effects, catch losses, etc.).

Daily visits were carried out in the two ports. Complementary were conducted surveys to the fishermen at the landing sites, when the fishermen are repairing the fishing gears and maintaining their boats, considering that many fishermen have limited time (Moore et al. 2010). Twenty-two visits were made in Caleta and 18 in Fuengirola. Due to those fishermen's preferences, suggestions and work schedules, we complemented the questionnaires with telephone calls (a total of 100) in order to obtain daily information on the fishery, number of interactions and to quantify economic losses.

Two vessels of the artisanal fleet are collaborating to install cameras (GoPro Hero7 Black) on the fishing nets during fishing operations to help understand the cetaceans approach to the captures. The first recordings were obtained during the fishing operations of two vessels based in Caleta and Fuengirola. The cameras were placed on the upper part of the nets (on the floating rope, Fig. 3), using two different tools to fix them.

Figure 3. A GoPro Hero7 Black camera (red circle) on the rope in a trammel net.

Video recordings were obtained from two fishing trips, used to check the species of cetaceans causing damage to the gear (Fig. 4), the type of damage to the nets, how many fish are removed or damaged, the behaviour of the dolphins or duration of the interactions.

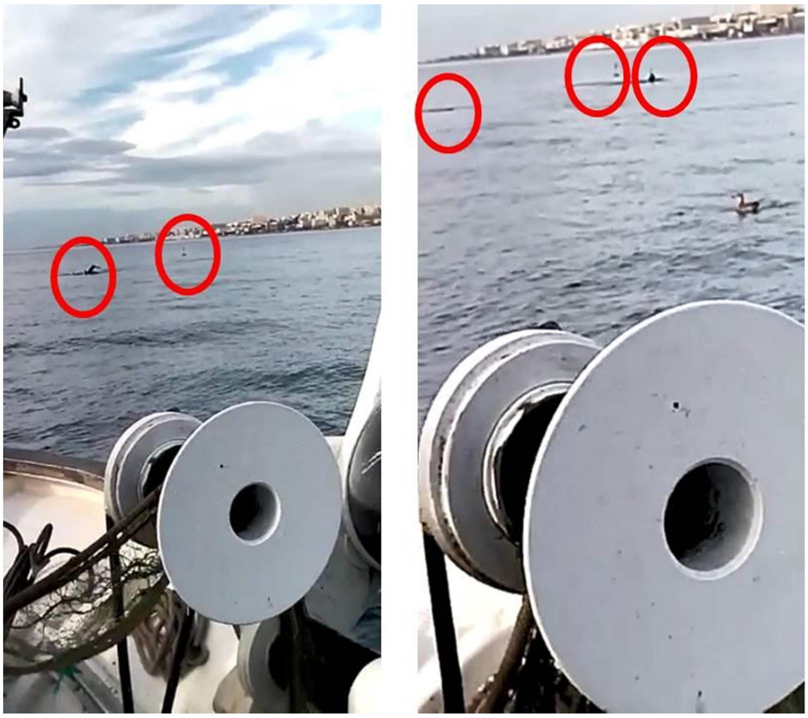

Figure 4. Picture taken from onboard. The red circles show dolphins preying on the trammel nets.

3.1.4. Difficulties and lessons learned during this phase

3.1.4.1. Preparatory phase

During the preparatory phase we had contacted port authorities to organize informative and discussion meetings; however, on several occasions we had problems to meeting the responsible, because they said to be very busy with fishery issues. This situation delayed starting the first activities on the ports and landing halls until obtain the corresponding authorizations. Later, we introduce the project to the fishermen and meet with them. Due to COVID protocols it was not possible to have a joint meeting to explain to them what the project was about, and we had to go one by one, delaying the start.

3.1.4.2. Data collection

First contact with the fishermen was not easy; many of them are tired of collaborating in projects, without getting results or feedback. Although the data collection improved with the commitment of the fishermen, two boats did not go to appointments and they didn't answer the calls. Another difficulty has been the sexism of some fishermen towards the biologist in charge of direct data collection, a woman. We believe that we must continue working on social education in order to solve the problems of labour discrimination due to gender. We solved these problems with the new incorporations of more fishermen.

Concerning doubts about the accuracy of the information on the fishing area and the fishing strategy, it was solved by consulting the green boxes of the vessels. It has been possible to know the number of vessels, the fishing grounds of the artisanal fleet, the fishing effort (fishing days) and its distribution, both by area and by month. The green boxes are the Andalusian

Fishing Vessel Monitoring System (SLSEPA), used for tracking and monitoring fishing vessels under 15 m in length (Aguilera et al., 2020).

Data collection forecasts were established based on the results of the first phase of the project. This planning has changed for different reasons, the fishermen have been forced to modify their fishing strategy, and working less and less with gillnets and trammel nets. In Caleta de Vélez few boats fish with nets in summer, to avoid economic losses due to interactions with bottlenose dolphins. As more than 80% of the fleet is licensed to fish for octopus (pots) and shellfish (fishing dredgers), they can change the active fishing gear depending on their needs and unforeseen events. In addition, some boats have even interrupted their activity to take advantage of subsidies, avoid losses and take advantage of this time period to repair or manufacture the new gears.

3.1.4.3. The invasive algae *Rugulopteryx okamurae*

An additional inconvenience, which has made the small scale fishermen modify their strategy, has been the increasing presence of the invasive algae (*Rugulopteryx okamurae*) (Fig. 5) underlined as a growing problem during our previous project. This problem is growing at present, pressing fishermen to move to other fishing areas and even change the fishing gear (trammel or set nets used). To solve those problems, we have interrupted data collection in August 2021, and continued in January 2022, a period when a large part of the artisanal fleet is back actively fishing with nets.

Figure 5. A trammel net clogged with the alien algae *Rugulopteryx okamurae* coming back

3.1.4.4. Using cameras to prospect cetacean's behaviour with nets and catches

An important problem was the availability of boats to carry out this trial. By one side these cameras have a limited autonomy (2 hours), and record fishing operations of short duration (e.g. red mullet trammel nets). Also there were very few boats active with this type of nets able to collaborate. Additionally some captures (e.g., cuttlefish trammel nets) are used to be robbed at sea increasing the possibility of cameras to disappear, reducing the collaboration.

Four cameras were installed in two boats. Two red mullet trammel net fishing operations were recorded in two different fishing areas. One of the cameras was used at dawn and the images are not useful. To avoid problems, the second recording was made in the afternoon, and the images obtained close to the gear are clear, but only a few minutes of the fishing operation were recorded, probably something went wrong with the system. It is necessary to continue using the cameras when the boats are available, to detect errors, and select the most effective system and moment of the day to obtain positive recordings of the interactions.

Finally we verify the lack of interest of the fishermen to put cameras and use it to find possible solutions to dolphin's interactions; we have only obtained two recordings, despite the fact that the cameras have been in their possession for months.

3.1.5. Achievements obtained during this phase

- Responsible of the Cofradia de Pescadores from Caleta de Velez and Fuengirola fishing ports, the authorities in both fishing ports, agree with AHE to involve SS vessels from these two ports in the project.
- The project team prepares a summary document for distribution to Cofradias and SS fishermen to inform on the results obtained during phase I of the project.
- Fishermen and Cofradias receive a document in Spanish with main achievements on interactions. We gave publicity to the results.
- The team AHE-IEO is working under a collaborative spirit to solve the problems
- ANSE, a NGO working also with cetaceans and fisheries in the region (western Mediterranean) agreed to collaborate with the ACCOBAMS/AHE project
- Data collection is obtained at landing ports and by phone calls including captures, target species, fishing areas, fishing periods and interactions (species of dolphins, number of interactions and number of holes , where the interactions, effects, losses) and is building up a data base.
- Environmental data are regularly obtained.
- In both ports, Caleta and Fuengirola, there are fishermen (few) that collaborate with the project and that are able to on board experts to check some mitigation measures.
- Despite a reduced collaboration of artisanal fishermen, we have been able to install cameras in trammel fishing gear
- The recordings of the cameras, although they do not show interactions with dolphins at the moment, they begin to provide recordings.
- The *Rugulopteryx* alga continues to expand its area of distribution and affecting even more to the artisanal fleet and other activities.

We have collected information on 938 sets (fishing operations) of artisanal fishing with a net, of these sets 205 have been damaged by dolphins (22%) with an average cost for repairing the nets of €1200 (including the hand work and replace the material).

3.1.6. Statistical analysis

The information from the 938 fishing operations was analysed. Two different target variables were studied: (i) the damage to gear due the clogging of the artisanal fishing trammel nets by seaweed (abbreviated as CNS, thereafter), and (ii) the breaking of the nets by dolphin predation (abbreviated as BND, thereafter). CNS was assessed when the skipper, after hauling the trammel net onboard, returned to port for cleaning. This could mean the hasty end of the fishing day and the loss of net capture during that set. On the other hand, a BND event was considered when a net break occurred. As possible explanatory factors affecting the local incidence of CNS or BND we analysed both environmental and technological variables. The values of environmental variables were obtained by direct sampling of sea water beside the base port.

We grouped the explanatory variables into three different factors: A) Spatial-temporal, B) Oceanographic-Environment and C) Technical features of the fishing. Thus, each factor is represented by a set of variables, in total 14 independent variables (Table 3).

Table 3. List of factors and explanatory variables checked to perform the logistic model. The type of variables and units are included

Factor	Variables	Acronym	Type	Units
Spatial-temporal	Month	MO	Ordinal	Dimensionless
	Longitudinal gradient	LG	Ordinal	Dimensionless
Oceanographic-environment	Sea Surface Temperature	SST	Quantitative	ºC
	Air Temperature	AT	Quantitative	ºC
	Wind direction	WD	Qualitative	Dimensionless
	Moon phase	MP	Qualitative	Dimensionless
	Cloudiness*	CL	Qualitative	Dimensionless
Technical of the fishing operation	Soak time	ST	Quantitative	h
	Number of net units	NNU	Quantitative	Dimensionless
	Mesh size	MS	Qualitative	Dimensionless
	Fishing ground depth	FGD	Quantitative	m
	Target species	TS	Qualitative	Dimensionless
	Gross register tonnage	GT	Quantitative	Dimensionless
	Length overall	LOA	Quantitative	m

* denoted variable only used in the BND (Breaking of the Nets by Dolphin predation) model.

A) The variables included as spatio-temporal factors are: month, and longitudinal gradient. Both variables are ordinary and dimensionless. The month variable refers to the month when the fishing was done, in the interval between the value 3 (March) and 7 (July). The longitudinal gradient refers to the order of the location in the West-East gradient following the coast, and the range of the variable goes from 1 (further west) to 23 (further east).

B) The Oceanographic-environment factor included the variables: air temperature, cloudiness, moon phase, Sea Surface Temperature, and wind direction. Air temperature ranged between 11 ºC and 25 ºC, and was taken directly in the port at 09:00 a.m. Cloudiness is a qualitative variable with four states: (i) sky covered with clouds, (ii) sky without clouds, (iii) cloudy intervals, and (iv) slightly cloudy. Moon phase also is a qualitative variable with six states: (i) New Moon, (ii) First Quarter, (iii) Full Moon, (iv) Last Quarter, (v) Growing Moon, and (vi) Waning Moon. Sea Surface Temperature range was 11 ºC to 25 ºC, and was taken directly in the port at 09:00 a.m. Wind direction is a qualitative variable with six states: (i) North, (ii) South, (iii) Northeast, (iv) Northwest, (v) Southeast, (vi) Southwest, and (vii) East and West.

C) The Technological features of the fishing operation included the variables: soak time, number of net units, mesh size, fishing ground depth, target species, Gross register tonnage, and Length overall. Soak time is the time the net remains in the water, with 1 hour soak time being the most frequent, involving 148 sets. Number of net units is the number of net setting pieces, and is an estimation of the total length of the trammel nets, ranging between 6 and 34 net units, being the sets with 15 net units the most frequent with 191 sets. For the Mesh size, we use the commercial categories with which the fishermen build the nets. Fishing ground depth, varied between 1 and 110 meters. Target species is a qualitative variable with 8 different states (see the groups of species of each state in Table 4), each different state (i.e. group of target species) representing a different fishery strategy. Gross register tonnage was ranked between 0.71 and 4.79, and Length overall ranged between 6 and 10.5 m.

Table 4. Checklist of the target species (TS), with 8 different states, each state represents a different fishery strategy and a different metier.

Fishery strategy (metier)	**Species common name**	**Scientific name**
TS 1	Common cuttlefish	*Sepia officinalis* Linnaeus, 1758
TS 2	Striped red mullet	*Mullus surmuletus* Linnaeus, 1758
TS 3	Red mullet	*Mullus barbatus* Linnaeus 1758
TS 4	Tiger prawn	*Penaeus kerathurus* (Forskål, 1775)
TS 5	Common sole	*Solea solea* (Linnaeus, 1758)
TS 6	Atlantic bonito	*Sarda sarda* (Bloch, 1793)
TS 7	Slender rockfish; Greater forkbeard; European lobster; Common spiny lobster	*Scorpaena elongata* Cadenat, 1943; *Phycis blennoides* (Brünnich, 1768); *Homarus gammarus* (Linnaeus, 1758);

		Palinurus elephas (Fabricius, 1787)
TS 8	Common seabream; Common pandora; Common dentex; Redbanded seabream; Greater amberjack; Shellfish	*Pagrus pagrus* (Linnaeus, 1758); *Pagellus erythrinus* (Linnaeus, 1758); *Dentex dentex* (Linnaeus, 1758); *Pagrus auriga* Valenciennes, 1843; *Seriola dumerili* (Risso, 1810); ---

Two different statistical models were performed for each variable (CNS and BND). We used logistic binary stepwise forward/backward regression to obtain the probability of occurrence of at least one local CNS and BND event in a particular set in function of the three explanatory factors (Spatio-temporal, Oceanographic-Environment, and Technical) together (final model) and separately for individual factors or pairs of factors (partial models). The partial models were performed using the variables related to each factor that were included in the final model. Model coefficients were assessed by means of an Omnibus test and the goodness-of-fit between expected and observed proportions of positive events along ten classes of probability values was evaluated using the Hosmer & Lemeshow test (which also follows a Chi-square distribution; low p values would indicate lack of fit of the model) (Hosmer and Lemeshow 2000).

In addition, the discrimination capacity of the model (trade-off between sensitivity and specificity) was evaluated with the receiving operating characteristic (ROC) curve. The area under the ROC curve (AUC) provides a scalar value representing the expected discrimination capacity of the model (Lobo et al. 2008).

In a similar way to Muñoz et al. (2005) we performed a variation partitioning to assess as percentages the relative contribution in the explanatory model of each factor included to explain the damage to the trammel nets by seaweeds (CNS) or dolphin predation (BND). The main aim of this analysis is to assess the pure effects of each factor (Borcard et al. 1992; Muñoz et al. 2005). Therefore, the part of the variation in each final model explained by each factor was obtained by correlating the values obtained from the final model and the partial models, using Spearman rank correlation coefficient and the squared correlation values. Then, the pure independent effect of each factor was assessed by subtracting from 1 (the whole variation) the variation explained by the partial model of the other factors (for example:

$$R^2_{\text{(Spatio-temporal pure)}} = 1 - R^2_{\text{f(Oceanographic-Environment+Technical of the fishing)}}).$$

Favourability function (F)

Regardless of the goodness-of-fit of the model, logistic regression is sensitive to the presence/absence ratio (Hosmer and Lemeshow 2000). The favorability function (Real et al. 2006; Acevedo and Real 2012) adjusts the model to inform about the degree to which the Spatio-temporal, Oceanographic-Environment and Technical factors favor the event, regardless of the presence/absence ratio of CNS or BND. The threshold 0.5 from the favorability model is easier to interpret, as it indicates neutral environmental conditions, i.e., neither favourable or unfavourable for CNS or BND.

Favorability (F) was calculated from the probability obtained by the logistic regression according to the expression:

$$F = \frac{\frac{P}{(1-P)}}{\frac{n_1}{n_0} + \frac{P}{(1-P)}}$$

where P is the probability of a CNS or BND event occurring, n_1 is the number of observed events of net damage for each CNS or BND, and n_0 is the number of observed sets with no net damage. Because F removes the effect due to the ratio of presences/absences, the CNS and BND models can be directly compared (Real et al. 2006; Acevedo and Real 2012). Thus, we plotted F of CNS and BND in the same range of the explanatory variables. These plots help us to interpret the response of each Favorability function to the same variables.

3.1.7. Results

The results of the analysis indicate that approximately 30% of the monitored sets suffered a net damage due to unwanted interaction with non-target wildlife species (alien seaweeds or dolphins). This obviously leads to economic losses of the small-scale fisheries fleet both due to a reduction in captures, because of the cost of repairing/substituting the whole net or damaged units, to which must be added the time in hours of repairing or mounting a new net on land. Moreover, the percentage of total sets with traces of seaweeds in the nets regardless of damage was 33.8%, while the percentage of sets with damage by seaweeds was 12.4% (CNS). In relation to the damage caused by dolphin predation (BND), 17.9% of the sets suffered damage. Only 4 monitored sets suffered both CNS and BND at the same time (0.73%), and 3.65% of total sets showed damage from BND and traces of seaweeds (Fig. 6).

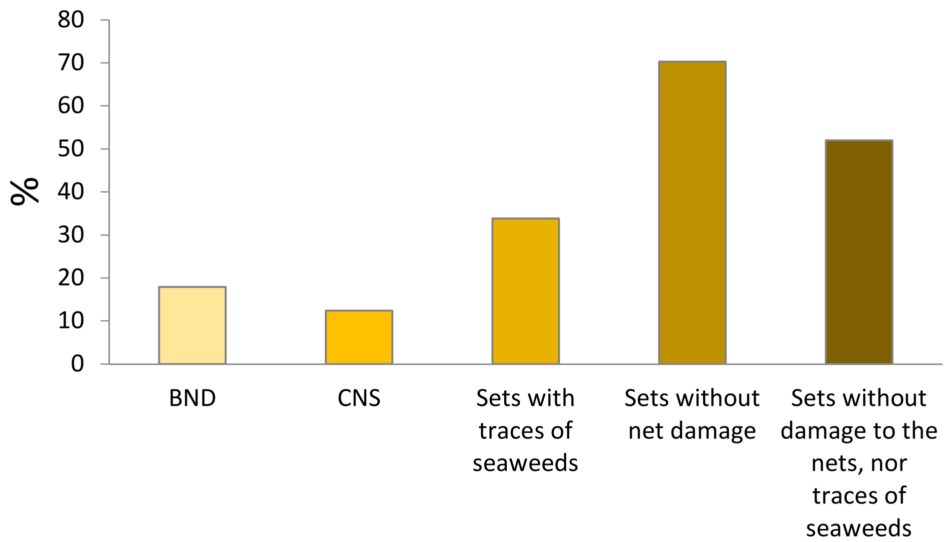

Figure 6. Percentage of sets by CNS (clogging trammel nets by seaweeds), BND (breaking of the nets by dolphin predation), Sets without traces of seaweeds, Sets without net dame, and sets without damage to the nets, nor traces of seaweeds

Two statistically significant logistic models were obtained for the target variables CNS (clogging trammel nets by seaweeds), and BND (breaking of the nets by dolphin predation). The models were significant according to the Omnibus test, and their discrimination capacities were good (Table 5). The breaking of the nets by dolphin predation (BND) model showed poor goodness of fit, according to the Hosmer and Lemeshow test.

Table 5. Explanatory factors and variables included in both final models CNS (clogging trammel nets by seaweeds) and BND (breaking of the nets by dolphin predation), and goodness-of-fit. Key: R^2_N, Pseudo-R-squared Nagelkerke; 2LL, less than twice the natural logarithm of the likelihood; AUC area under the ROC (receiving operating characteristic) curve. Variables in CNS model: LG, longitudinal gradient; WD, wind direction; MP, moon phase; MO, month; TS, target species. Variables in BND model: NNU, number of net units; TS, target species; GTR, gross register tonnage; CL, cloudiness; MP, moon phase; LG, longitudinal gradient.

Factors	CNS Model	BND Model
Omnibus Test	175,145 (P<0.0001)	115 (P<0.0001)
Hosmer & Lemeshow Test	5.879 (P= 0.661)	22.014 (P= 0.005)
-2LL	201.860	384.698
AUC	0.922	0.809
Factors	Spatio-temporal, Oceanographic-Environment and Technical of the fishing	Spatio-temporal, Oceanographic-Environment and Technical of the fishing
Variables	LG; WD; MP; MO; TS	NNU; TS; GTR; CL; MP; LG

We performed 12 different partial models (Table 6 and 7). In the CNS model, the partial model with highest Spearman correlation with the final model involved the factors Oceanographic-Environment+Spatio-temporal (Table 8), but in the BND model, the partial model with highest correlation with the final model involved the factors Technical features of the fishing + Oceanographic-Environment (Table 9). The percentage of relative contribution in the explanatory model of each factor included explaining the damage to gear due or clogging trammel nets by seaweeds (CNS), or breaking of the nets by dolphin predation (BND) are presented in Table 10.

Table 6. Goodness-of-fit of CNS (clogging trammel nets by seaweeds) partial models. Key: -2LL, minus twice the natural logarithm of the likelihood; AUC area under the ROC (receiving operating characteristic) curve.

Partial Model	-2LL	AUC
Technical of the fishing+ Oceanographic-Environment	294.229	0.854
Oceanographic-Environment+Spatio-temporal	261.207	0.898
Technical of the fishing+Spatio-temporal	273.630	0.892
Technical of the fishing	340.820	0.781
Oceanographic-Environment	365.263	0.736
Spatio-temporal	294.817	0.867

Table 7. Goodness-of-fit of BND (breaking of the nets by dolphin predation) partial models. Key: -2LL, minus twice the natural logarithm of the likelihood; AUC area under the ROC (receiving operating characteristic) curve

Partial Model	-2LL	AUC
Technical of the fishing+ Oceanographic-Environment	410.017	0.790
Oceanographic-Environment+Spatio-temporal	472.509	0.703
Technical of the fishing+Spatio-temporal	420.855	0.784
Technical of the fishing	431.013	0.773
Oceanographic-Environment	485.559	0.657
Spatio-temporal	507.768	0.578

Table 8. Spearman correlation coefficient (Rho-Spearman) between the probability CNS model (clogging trammel nets by seaweeds), and partial models.

Partial Model	Rho-Spearman
Technical of the fishing+ Oceanographic-Environment	0.873
Oceanographic-Environment+Spatio-temporal	0.914
Technical of the fishing+Spatio-temporal	0.231

Table 9. Spearman correlation coefficient (Rho-Spearman) between the probability BND (breaking of the nets by dolphin predation), and partial models.

Partial Model	Rho-Spearman
Technical of the fishing+ Oceanographic-Environment	0.958
Oceanographic-Environment+Spatio-temporal	0.537
Technical of the fishing+Spatio-temporal	0.774

Table 10. Percentage of relative contribution in the explicative model of each factor included to explain the damage to gear due or clogging trammel nets by seaweeds (CNS), or breaking of the nets by dolphin predation (BND).

Factor	% Relative contribution CNS	% Relative contribution BND
Technical of the fishing	16.5%	70%
Oceanographic-Environment	30.9%	20%
Spatio-temporal	23.8%	8%

The variables, target species, month, and longitudinal gradient, were significant in both CNS and BDN models. Thus, we plotted the average value of favorability, for each state of these variables for both CNS and BNS (Fig. 7-9).

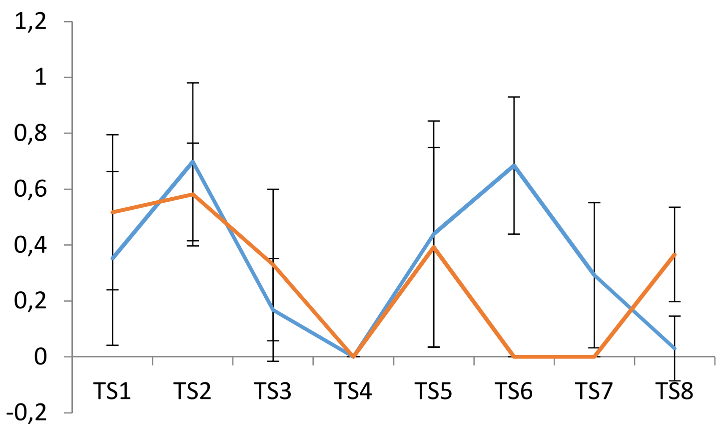

Figure 7. Average value of favorability, for each state of the target species (TS) variable for both CNS and BNS. The confidence interval of the standard deviation is shown. Key: Blue, CNS (clogging trammel nets by seaweeds); and Red, BND (breaking of the nets by dolphin predation). Key as in Table 4.

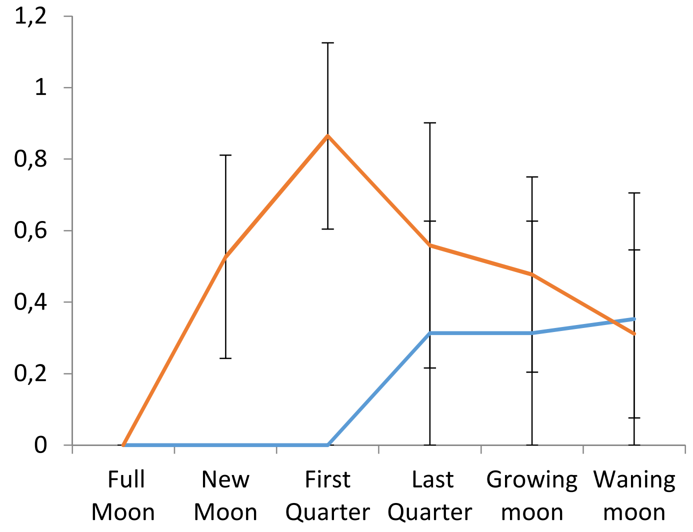

Figure 8. Average value of favorability, for each state of the month (MO) variable, for both CNS and BNS. The confidence interval of the standard deviation is shown. Key: Blue, CNS (clogging trammel nets by seaweeds); and Red, BND (breaking of the nets by dolphin predation)

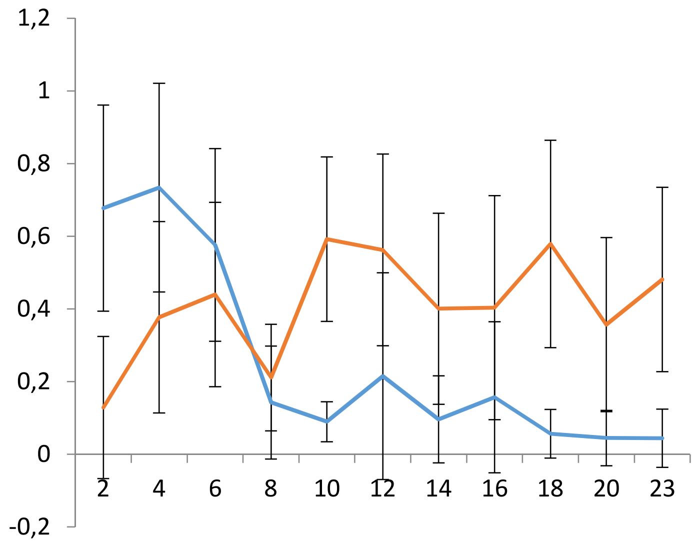

Figure 9. Average value of favorability, for each state of the longitudinal gradient variable (LG) for both CNS and BNS. The confidence interval of the standard deviation is shown. Key: Blue, CNS (clogging trammel nets by seaweeds); and Red, BND (breaking of the nets by dolphin predation).

3.2. Step two: Testing low-cost dolphin mitigation measures

NOTE. For MAVA and ACCOBAMS information: the bulk of activities and results included in part 3.2 were funded with the additional budget of the MoU ACCOBAMS-AHE Nº 03/2022/LB 6411.

3.2.1. Background

During the second phase of the Action put the focus on thinking and designing low-cost devices that could reduce the interactions dolphins-artisanal fishermen.

Although our work was focused on the use of low-cost devices, we acquired ‘pingers’, an acoustic mitigation device. Pingers were used to monitor changes in dolphin behaviour to reduce the frequency of interactions with the nets (Dawson et al. 2013). However, although the perception of the use of pingers by fishermen is good (because it does not require substantial changes to their fishing strategy or gear), the price of these devices is not affordable for everyone. Still, fishermen compromised of buying these devices if our experiments proved them to be effective.

We focused on the artisanal fleet of Caleta de Vélez and Fuengirola, although further expansion to other ports was necessary due to the lack of enough collaborators.

In the first instance, all the fishermen who collaborated during the first phase were contacted. A meeting with the Caleta de Velez Cofradia’s chairperson (January 2022) started this phase and all the fishermen surveyed during the first phase were contacted by telephone. Most of them showed pessimism and lack of interest towards the experiments. One group was not fishing at the beginning of this phase, so they reported not being able to help or collaborate. Other fishermen showed interest in carrying out the experiments at first, but subsequent calls showed that they were not willing to invest their time in collaborations for innovation.

Finally four collaborators in three ports, two fishermen in Caleta de Vélez, one in Nerja and one in Fuengirola, agreed to carry out the experiments we proposed to reduce depredation. The experiments started in Fuengirola.

3.2.2. Specific objectives

The main objective during this phase was to find a low-cost solution to dolphin interactions mitigation/reduction of the depredation that could be easily used by artisanal fishermen with a low investment of budget and time. Two types of low-cost devices were tested:

- Recycled 33cl glass bottles with a marble included inside simulating acoustic devices.
- Compact Disks (CDs) simulating scarecrows as used in surface longlines to reduce seabirds bycatch.
- A third mitigation option, the use of chemosensory deterrents included as bait (acidic, spicy) that cetaceans can reject, was not carried out due to lack of collaborators

Discussions with the fishermen about their affordability also showed their desperation to find a solution to the interactions. Therefore, they accepted the use of a commercial high-tech device to try to find a solution even if the cost was not easy to bear, and multi-frequency pingers were also tested on the small scale fisheries nets.

3.2.3. Dolphin mitigation based on recycled glass bottles

The use of bottles to reduce interactions was inspired in Berggren et al. (2020). Since experiments based on mitigation devices with electronic alarms (pingers) do not have a clear positive outcome (Dawson et al. 2013; Mangel et al., 2013), Berggren et al. (2020) they tried to find a mitigation device that was not limited to fishermen due to its high cost.

They designed a device costing no more than \$0.50 per piece of net to mitigate interactions between cetaceans and artisanal fishermen, and thus reducing the amount of by-catch of this faunal group. These devices were tested between 2019 and 2020 on artisanal fishermen's driftnets in Puerto Salaverry, Perú (8° 12' S, 78° 58' W) whose target species were mainly elasmobranchs.

These acoustic mitigation devices were based on 350 ml glass bottles with a bolt suspended on a string inside the bottle, attached by a screw to a rubber stopper. These bottles were mounted on the buoyancy line of the driftnet, producing a sound with the natural movement of the sea currents and thus preventing cetaceans from approaching the nets that originates the acoustic waves. The trial conducted in the driftnet fishery off Salaverry Ports targeting elasmobranchs suggests that glass bottle alarms do not significantly reduce bycatch of dolphins or turtles in gillnets.

3.2.3.1. Methods

Empty green 33cl glass bottles used to contain beer were selected. These bottles were donated by a waiter from a nearby bar, so there was no cost for the material. The bottles were washed and dried. They were corked and a screw tied to a monofilament fishing line was left inside to be used as a pendulum. In addition, a marble was included inside to maximise its sound capacity underwater. The cork was coated with a layer of silicone and vulcanised insulating tape to waterproof the bottle (Fig. 10).

Figure 10. Design og the mitigation device based on recycled glass bottles.

The experimental design for this trial is shown in Fig. 11. We selected a professional trammel net divided into two zones: a test zone including the glass bottles adapted as a mitigation devices placed every 25 meters, and a control zone with no mitigation devices installed. Go-Pro cameras were placed to record the approach of fauna and the behavior of the devices/bottles installed.

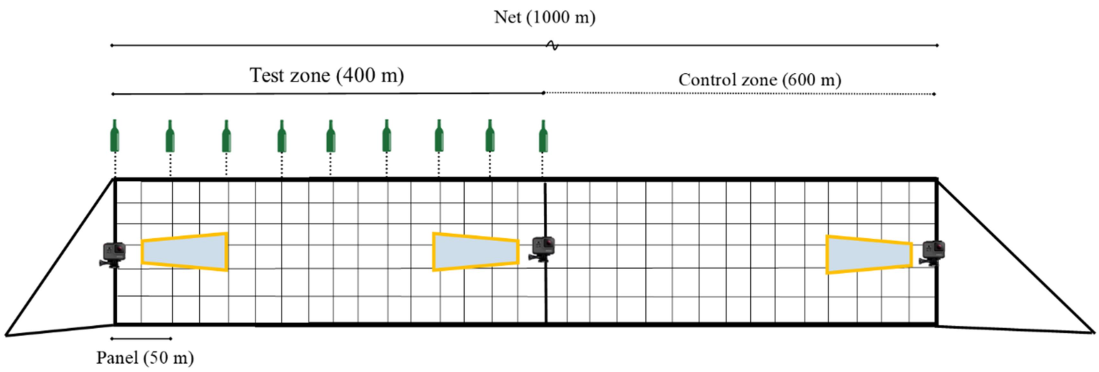

Figure 11. Experimental design of the experiment based on recycled glass bottles.

3.2.3.2. Results

We performed experiments in different fishing areas and depths. The results of the experiments of the acoustic mitigation devices based on bottles are summarised in Table 11.

Table 11. Results of the experiment based on recycled glass bottles.

Experiment code	Date	Collaborating boat code	Fishing area	Depth (meters)	Experimental net	I (test zone)	I (control zone)	Other nets (number)	I (non-experimental nets)
BO01	09/02/2022	FU01	Cala de Mijas	4,57	Nylon	0	0	-	-
BO02	17/05/2022	CA01	Nerja	6,69	Nylon	0	0	-	-
BO03	18/05/2022	NE01	Maro	6,69	Nylon	1	1	-	-
BO04	25/05/2022	CA01	Algarrobo	21,94	Monofilament	1	1	Monofilament (1)	1
								Nylon (2)	1
BO05	26/05/2022	CA01	Lagos	8,23	Nylon	1	1	Monofilament (1)	0
								Nylon (1)	1
BO06	26/05/2022	NE01	Nerja	8,23	Nylon	0	0	-	-
BO07	27/05/2022	NE01	Nerja	8,23	Nylon	0	0	-	-
BO08	31/05/2022	NE01	Nerja	9,14	Nylon	0	0	-	-
BO09	01/06/2022	NE01	Nerja	9,14	Nylon	0	0	-	-
BO10	31/05/2022	CA01	Lagos	5,49	Nylon	0	0	Nylon (1)	0
BO11	31/05/2022	NE01	Nerja	9,14	Nylon	0	0	-	-
BO12	01/06/2022	NE01	Nerja	9,14	Nylon	0	1	-	-
BO13	02/06/2022	NE01	Nerja	9,14	Nylon	0	0	-	-
BO14	05/06/2022	NE01	Nerja	9,14	Nylon	0	1	-	-

Experiment code	Date	Collaborating boat code	Fishing area	Depth (meters)	Experimental net	I (test zone)	I (control zone)	Other nets (number)	I (non-experimental nets)
BO15	06/06/2022	NE01	Nerja	9,14	Nylon	0	0	-	-
BO16	07/06/2022	NE01	Nerja	9,14	Nylon	0	1	-	-
BO17	09/06/2022	NE01	Nerja	8,23	Nylon	0	0	-	-
BO18	13/06/2022	NE01	Torrox	8,23	Nylon	1	1	-	-
BO19	14/06/2022	NE01	Nerja	10,05	Nylon	1	1	-	-

A total of 19 experiments with recycled bottles were conducted. In three experiments, interaction with dolphins was found only in the control area (no interaction in the test area). One experiment showed interaction in the test zone and no interaction in the control zone. Interaction in both zones was found in four experiments. A total of 11 experiments were found with no interaction.

The results of the first experiment using glass bottles (Fig. 12) showed that no interaction was found in the nets used during the fishing operation. The onboard camera used by the fishermen recorded the fishing operation with the experiment (**https://youtu.be/uWnvRcef54c**). However, the fisherman reported that he had a high amount of catches all along the net, except in the test area (where the experimental glass bottles were located). In addition, all bottles were found to be partially filled with water (Fig. 13). This resulted in the cessation of collaboration by the fisherman. Despite financial compensation for the experiment, his collaboration could not be recovered.

Figure 12. Sequence of frames extracted from the video recorded by the on board GoPro camera. A: Beginning of net setting; B-C: Crew collaboration to ensure safety of the glass bottles; D: Setting the bottles; E: Bottles set.

Figure 13. Glass bottle partially filled with sea water. Water filtered through the cork due to the water pressure.

The bottles had to be redesigned to prevent further water leaks. For this purpose, a thin layer of silicone was added around the cork and the insulating tape was replaced by vulcanised tape (this tape is widely used by electricians in swimming pool work). From the second experiment with recycled glass bottles, the problem with water leaks was solved and experiments continued ongoing (Figure 14). However, new collaborators who agreed to test the experiments with recycled bottles reported a decrease in finfish catches in the area where the bottles were located. This effect was not seen when the bottles were deployed at shallower depths, in which case the target species was cephalopods.

Figure 14. Collaborating boat setting up the experiment using recycled glass bottles.

3.2.4. Dolphin`s interactions mitigation based on Compact Disks (CDs)

This experiment is based on the use of CDs for computer as reflectors of the sound emitted by the dolphins and as visual scarecrows . This would make it difficult to locate the nets and make the dolphins wary of them.

3.2.4.1. Methods

Computer CDs are attached to the flotation line of the trammel net every 25 meters (Fig. 15).

Figure 15. Design of the mitigation device based on CDs.

The experimental design is shown in Fig. 16. As in the other experimental device we use Go-Pro cameras always to try to record the approach of the dolphins and target species and the behavior of the dolphin when take the captures and break the nets.

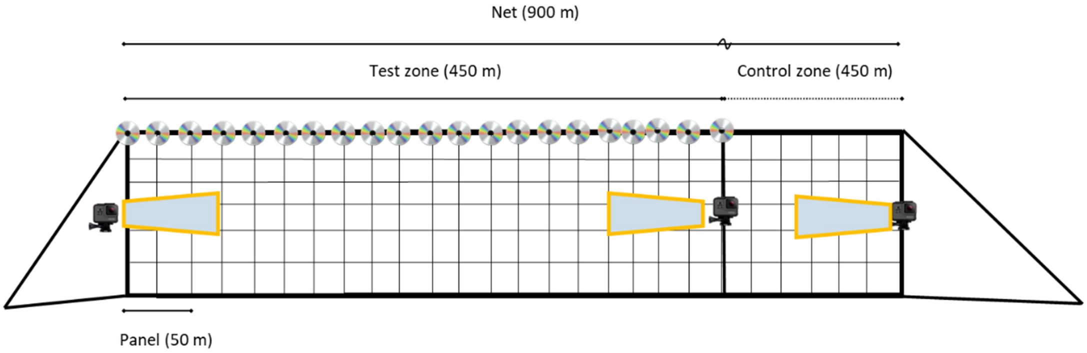

Figure 16. Experimental design with trammel net based on CDs.

3.2.4.2. Results

The results of the CD-based mitigation device experiments are summarised in Table 12.

Table 12. Results of experiment based on CDs.

Experiment code	**Date**	**Collaborating boat code**	**Fishing area**	**Depth (meters)**	**Experimental net**	**I (test zone)**	**I (control zone)**	**Other nets (number)**	**I (non-experimental nets)**
CD01	22/02/2022	CA01	Maro	6,40	Nylon	0	0	Monofilament (2)	1
CD02	05/03/2022	CA01	Maro	6,40	Nylon	1	1	Monofilament (2)	
CD03	08/03/2022	CA01	Lagos	23,77	Monofilament	0	0	Monofilament (1) Nylon (1)	0
CD04	14/03/2022	CA01	Lagos	22,86	Monofilament	0	0	Monofilament (3)	0
CD05	17/03/2022	CA01	El Morche	21,94	Monofilament	1	1	Monofilament (2)	1
CD06	18/04/2022	CA02	Lagos	17,37	Nylon	1	1	-	-
CD07	18/04/2022	CA01	Chilches	21,94	Monofilament	0	0	Nylon (2) Monofilament (1)	0
CD08	25/04/2022	CA01	Benagalbón	13,72	Monofilament	1		Monofilament (1) Nylon (2)	1
CD09	25/04/2022	NE01	Nerja	8,23	Nylon	0	1	-	-
CD10	26/04/2022	CA01	Benajarafe	19,20	Monofilament	1	1	Monofilament (1) Nylon (2)	1
CD11	26/04/2022	NE01	Maro	10,05	Nylon	0	1	-	-
CD12	27/04/2022	NE01	Maro	9,14	Nylon	1	1	-	-
CD13	28/04/2022	NE01	Maro	8,23	Nylon	1	1	-	-

Experiment code	Date	Collaborating boat code	Fishing area	Depth (meters)	Experimental net	I (test zone)	I (control zone)	Other nets (number)	I (non-experimental nets)
CD14	01/05/2022	NE01	Nerja	9,14	Nylon	0	1	-	-
CD15	28/04/2022	CA01	Almayate	29,3	Monofilament	1	1	Monofilament (1) Nylon (2)	1
CD16	01/05/2022	CA01	Lagos	6,40	Monofilament	1	1	Monofilament (1) Nylon (2)	1
CD17	03/05/2022	CA01	Maro	10,97	Nylon	1	1	Monofilament (1) Nylon (1)	1
CD18	03/05/2022	NE01	Nerja	8,23	Nylon	1	1	-	-
CD19	04/05/2022	NE01	Nerja	8,23	Nylon	0	0	-	-
CD20	05/05/2022	NE01	Maro	7,31	Nylon	0	0	-	-
CD21	05/05/2022	CA01	Nerja	5,49	Nylon	0	0	Monofilament (1) Nylon (1)	1
CD22	08/05/2022	NE01	Nerja	9,14	Nylon	1	1	-	-
CD23	16/05/2022	NE01	Nerja	6,69	Nylon	0	1	-	-
CD24	15/05/2022	CA01	Torrox	30,09	Monofilament	NA	NA	Monofilament (1) Nylon (2)	NA
CD25	17/05/2022	CA01	Nerja	15,88	Monofilament	NA	NA	Monofilament (1) Nylon (2)	NA

Experiment code	Date	Collaborating boat code	Fishing area	Depth (meters)	Experimental net	I (test zone)	I (control zone)	Other nets (number)	I (non-experimental nets)
CD26	31/05/2022	CA01	Mezquitilla	20,12	Monofilament	0	0	-	-
CD27	01/06/2022	CA01	El Morche	8,23	Nylon	1	1	Monofilament (1) Nylon (2)	1 0
CD28	02/06/2022	CA01	Mezquitilla	10,97	Nylon	1	1	Nylon (2) Monofilament (1)	1 0
CD29	05/06/2022	NE01	Benajarafe	10,97	Nylon	0	0	Nylon (2) Monofilament (1)	0
CD30	06/06/2022	CA01	Benajarafe	10,97	Nylon	1	1	Nylon (2) Monofilament (1)	1
CD31	07/06/2022	CA01	Benajarafe	10,97	Nylon	1	1	Nylon (2) Monofilament (1)	1
CD32	08/06/2022	CA01	Benajarafe	25,60	Monofilament	1	1	Nylon (3)	1
CD33	09/06/2022	CA01	Chilches	7,32	Nylon	1	1	Nylon (2) Monofilament (1)	1
CD34	12/06/2022	CA01	Benajarafe	8,23	Nylon	0	0	Nylon (2) Monofilament (1)	0 NA

A total of 34 experiments using monofilament and nylon trammel nets in different fishing areas and depths were conducted based on CDs for computer. In six experiments, interaction with dolphins was found only in the control area (no interaction in the test area). No experiment showed interaction in the test zone and no interaction in the control zone. Interaction in both zones was found in 18 experiments. A total of eight experiments were found with no interaction. Interaction with the invasive alga *R. okamurae* caused two experiments to be invalid (NA) due to clogged nets.

In the recordings using Go-Pro cameras attached to the net, fish can be observed swimming around the nets with the CDs (Fig. 17), that suggest has not negative effect on the target.

Figure 17. Fishes swimming around the CDs installed on the trammel net.

Following the next links, different experiments recorded can be seen: **https://youtu.be/wYQGtwTmtBU; https://youtu.be/X46u26s7lxk**.

A dolphin was recorded during the experiment (Fig. 18). According to the sailors, the dolphin swam along the nets in search of food (Link to the video recording of the dolphin: **https://youtu.be/V6VZZwBXxpY**).

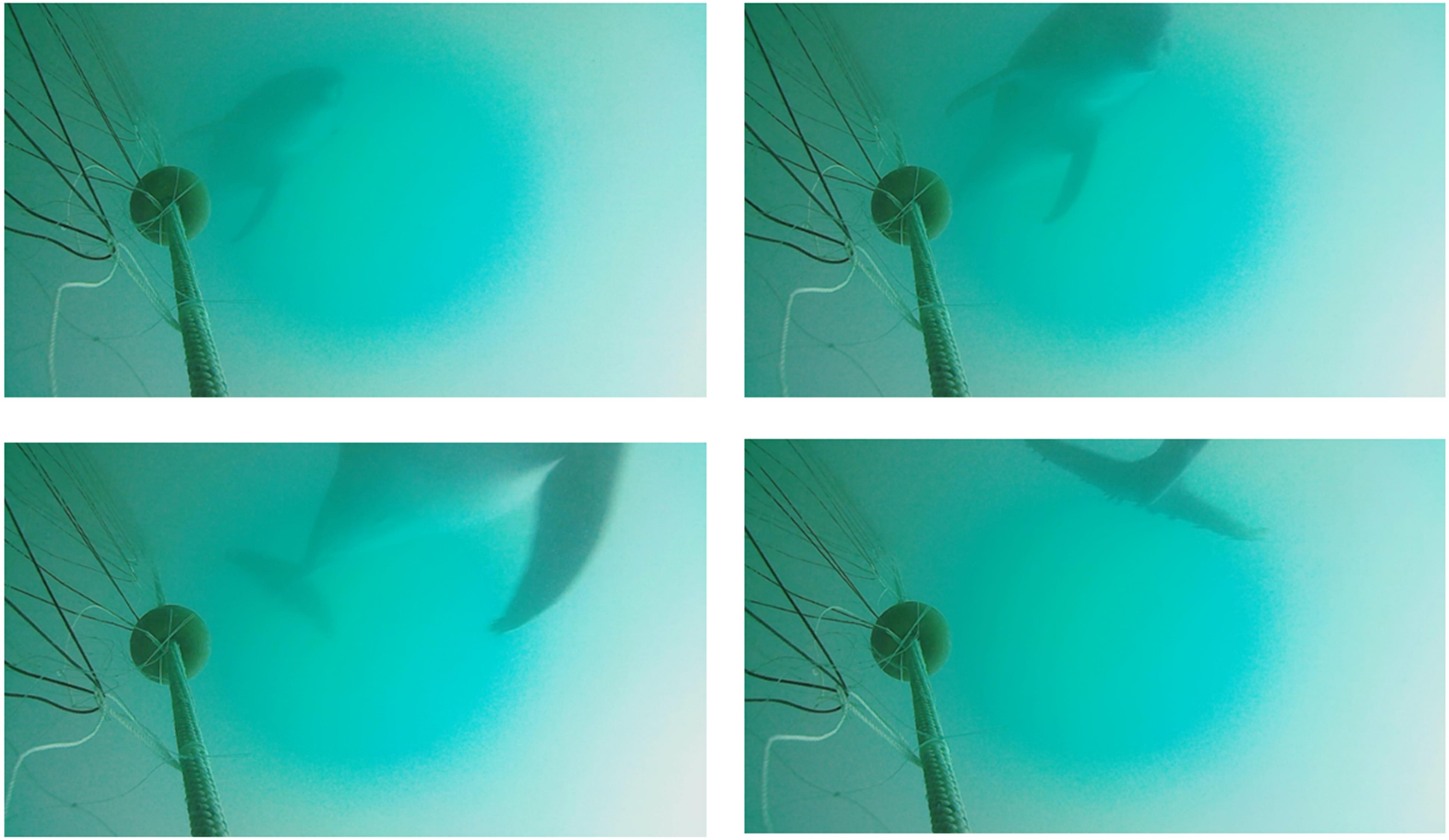

Figure 18. Sequence of images of the dolphin swimming along the net

Due to the wear and tear of the CDs at sea, the devices required replacement every 5-8 experiments (Fig. 19).

Figure 19. Images of the wear and tear of the CDs after their installation in the nets.

3.2.5. Dolphin mitigation using commercial pingers

3.2.5.1. Methods

Pingers are commercial devices that act as acoustic alarms. A total of eight pingers model NETSHIELD (company Future Oceans, https://www.futureoceans.com/buy-pingers/) were purchased and used. These pingers produce sound at a variable frequency of 70 kHz with a sound pressure level of 175 decibels. The device is capable of operating at depths of up to 1000 meters in both fresh and salt water. It is activated on contact with water.

In a similar way that in the visual mitigation experiment, the used net was divided into test and control zone. In the test zone, pingers were installed approximately 100 m apart. The control zone had no mitigation devices installed.

3.2.5.2. Results

The results of the pinger-based acoustic mitigation device experiments are summarised in Table 13.

Table 13. Results of the experiment using pingers.

Experiment code	Date	Collaborating boat code	Fishing area	Depth (meters)	Experimental net	I (test zone)	I (control zone)	Other nets (number)	I (non-experimental nets)
PI01	09/05/2022	CA01	Nerja	30,09	Monofilament	1	1	Monofilament (1) Nylon (2)	1
PI02	10/05/2022	CA01	Torrox	30,09	Monofilament	1	1	Monofilament (1) Nylon (2)	1
PI03	11/05/2022	CA01	Torrox	30,09	Monofilament	1	1	Monofilament (1) Nylon (2)	1

A total of three experiments were performed with pingers in professional trammel nets. All experiments showed interactions in both zones of the net. The interactions registered during the experiments were massive.

The fishermen recorded the situation from the boat on the first day of the experiment. On this day, the fishermen picked up the experimental net on board in Nerja and were chased by the dolphins to the town of Torrox (approximately 10 km). According to the fishermen, they had never experienced such a situation in more than 25 years of their profession. It is thought that the dolphins continued to listen to the pingers on board because the humidity allowed them to continue to function even when out of the water.

On the second and third day of the experiment, interaction with the nets was also reported (Fig. 20). However, on these days the dolphins were not around the fishing area during the net retrieval operation. Recordings of the dolphin sighting during the fishing operation can be accessed via the following link: **https://youtube.com/shorts/Z1odNEdb7T0**.

Figure 20. Traces of catch after interaction/depredation of dolphins.

3.2.6. Main obstacles and difficulties

The main problem encountered during the preparatory phase of this experiment was again the lack of interest by the fishermen in collaborating. Even so, and knowing that they would receive financial compensation for the time invested in setting up the experiments, only two collaborators could be found at the beginning of second step. On the other hand, this phase started in January 2022, a date when many fishermen had not started the fishing season or even opted to target another species (e.g. octopus (*Octopus vulgaris*)).

Experiments

Negative results during the first experiment (based on recycled bottles) resulted in the loss of a partner boat. This slowed down the development of the experiments because the project did not have any collaborating fishermen. In order to solve this problem, it was necessary to expand the number of ports where collaborators could be found.

The visit to the port of Motril in search of collaborators did not have results because the only remaining trammel net fisherman decided to stop fishing due to the high number of interactions he had.

The visit to the fishermen of Nerja got the only local artisanal fisherman to collaborate with the project, becoming one of the fishermen who helped to carry out the most experiments.

Search for collaborators was due to the fact that the capacity of the artisanal fishing boats is very limited. Therefore, according to the current regulations, the scientific staff in charge of the experiments could not embark with the fishermen to set up the experiments themselves, and this led to an even greater lack of interest in their collaboration.

Weather conditions

In the Alboran Sea, intense spring westerlies are characteristic. By inducing upwelling, they cause an increase in primary production and agitation of the waters. The arrival of bad weather caused by westerly winds did not allow fishermen to go fishing from 31 March until the third week of April because artisanal fishermen's boats (Fig. 21) are very vulnerable to sea conditions (Ramírez et al., 2021). The disappearance of the storms coincided with the Easter holidays taken by the fleet. Experiments resumed on 18 April, but the bad weather returned two days later. On the last week of the month, experiments were resumed again.

Figure 21. Picture of the main small scale vessel collaborating with the Action during a fishing operation.

During summer, the wind intensity decreases considerably and the wind direction changes to an easterly direction (Vargas-Yáñez et al., 2021), so experiments could be conducted more frequently during May and June 2022. Weather conditions are so variable in the area that only a strong collaboration of fishermen with scientists, aiming to reduce or avoid interactions with dolphins, during good weather periods can solve the implementation of the experiments and tests with artisanal vessels from the selected fishing ports.

An additional constraint: The invasive algae *Rugulopteryx okamurae*

The invasive alga *Rugulopteryx okamurae,* confirmed since July 2016 (Altamirano et al., 2016; Ocaña et al. 2016) in the strait of Gibraltar, and extended soon by northern Alboran (Aguilera et al., 2020), clogs the fishing nets and eliminates or reduce drastically the commercial captures. This fact has aggravated the situation for artisanal fishermen complicating their involvement to collaborate.

In Fuengirola the interaction between small scale fisheries and the invasive algae is a recurrent problem (Fig. 22). These interactions occurred to a lesser extent in Caleta de Vélez until the last month of experimentation.

Figure 22. Cleaning artisanal trammel nets collapsed by *Rugulopteryx okamurae*.

3.3. Fishers involvement, collaboration and perception

The fishermen are tired, if not contrary, of collaborating with different groups of experts (NGOs, Universities, Research Institutes, Cooperatives, Administrations, etc.,) who request their time, knowledge, data and information without later reverting to them the results of the investigations or without results that could improving their livelihoods. From the beginning of the project they were against an open collaboration. Finally, they agree in a small financial compensation related to the time they dedicated to the activities of the action to encourage some of them to develop the experiments, but it was insufficient to recover their collaboration after some negative results with the test and experiments.

All fishermen agreed that they need a subsidy to repair the nets broken by the dolphins in order to continue artisanal fishing with trammel nets. They complain that the purse seine and trawl fishermen in the area have subsidies (even for fuel) and make themselves feel economically marginalised.

Although some partners showed a good involvement during practically the whole action, they repeat that the profession will disappear without subsidies and the search for a solution to the interactions.

3.4. Main obstacles and lessons learned during this phase

As mentioned, the big obstacle to the development and implementation of the experiments was the collaboration. A second problem was the bad weather conditions at sea, resulting in very few experiments carried out. These final collaborating ships were from Caleta de Vélez (2) and Nerja (1). The partner boat from Nerja is the only artisanal fisherman still operating in the port.

In addition, an approaching trip was made to the port of Motril (Province of Granada, to the east of the action area) to look for new collaborating boats. In this port there is only one active artisanal fisherman left who, due to the interactions with the dolphins, has stopped setting the trammel net to change his activity with pots to catch common octopus, *Octopus vulgaris* (Baro Domínguez et al., 2021).

As general conclusion and lessons learned during the action, future projects in the area should include a stronger collaboration of the local fishermen's Cofradía based on a previous agreement to encourage fishermen to collaborate. To be honest, we started the project by having meetings and involving the Cofradias, but the support of these organisations has been not as effective as we planned.

4. Economic Impact Analysis

The interactions between artisanal fishermen and dolphins in northern Alboran Sea are causing huge economic losses among fishermen, as underlined in previous projects (Aguilera et al., 2020). Therefore, a complementary survey and the analysis of the new data to estimate the cost of the interactions was carried out again, not only taking into account the cost of repairs the gears, but also the time spent on these repairs without fishing.

4.1. Specific objectives

The main goal is to estimate the total cost of the interactions between dolphins and artisanal fishermen in selected fishing ports.

4.1.1. Economic survey results

A total of twelve fishermen were surveyed about the economic impact dolphins have on their economic activity. These fishermen are based in five ports, four in Malaga province (Caleta de Vélez, Fuengirola, Nerja, Málaga) and one in Granada province (Motril). The 66% of fishermen surveyed set between 3 and 4 trammel nets per fishing operation. Each net has on average 20 pieces.

The 75% of the surveyed fishermen report interactions with dolphins 3-4 days per week. The remaining 25% report more interactions, 6 - 7 operations per week.

The trammel nets, build by several units, are always exposed to natural wear and tear due to their frequent use and time passed under the sea, where the greatest damage is caused by rubbing against rocks or deterioration by snags. According to our surveys, nets may have a lifespan of between 2 and 20 years. Currently, interaction with dolphins results in nets lasting between 1 day and one fishing season (2-7 months depending on the target species and the number of interactions).

The extent of the damage depends on the number of dolphins feeding and breaking the net. When there are few dolphins (2-5 individuals), their behaviour related to the capture in the nets and their feeding behaviour is selective and the damage is minor. When there are a group of between 5-10 individuals, they interact more aggressively generating more damage/breaks to the nets that can produce the loss of the total capture and leave the gear out of use.

The 83% of respondents said they repaired the nets when damage was minor (50 cm in average diameter). These holes require between half an hour and one hour to repair. Approximately, a net with minor damage requires between 8 and 9 hours. Given the minimum wage in Spain (1000 €/month), each hour of work is equivalent to 6.25 €. Therefore, the economic value of the repair time of a net is between

€50 and €60 per net plus the equivalent value of the fish not caught by that area of net with a hole in it and the losses by depredation.

The 100% of the fishermen reported that the damage is severe when dolphins go in groups of several individuals. When this happens, they would rather buy a new piece for substitution the damaged than repair it, because of the time it would take. Major damages are not treated until the piece is unusable, then it is replaced by a new one. Each new piece costs between 100 and 300 € already assembled. An unassembled piece costs around €50, but requires several hours of work to assemble. Replacing a complete trammel net by a new one costs around 6000€.

The half of the fishermen reported more damage when the gear is assembled to target Red mullet (*Mullus surmuletus*). Questions about the economic impact of these interactions showed that fishermen in the last three years have suffered a 30-50% reduction in profits. In some cases, the destruction of the trammel nets has meaning that profits have not exceeded losses due to the purchase of new gear, leading to the fishermen having to stop fishing for the remainder of the season. The few profits made are being reinvested in new nets. The situation has led some respondents to declare that they are considering selling the boat and changing their trade.

4.1.2. Fishes involvement, collaboration and perception

The fishermen were very cooperative in responding to the surveys. They are generally very involved when it comes to showing their real problems and the economic impact and loss of capital invested as interactions with dolphins increase.

4.1.3. Main obstacles and lessons learned

In general, all artisanal fishermen contacted or collaborators agree on the need for subsidies given the seriousness of their economic situation. Given their need to show this severity, there were no obstacles to collecting information on economic impact. As main lesson, start the activity of a project on interactions like this by preparing and collecting information and problems that suffer the artisanal fishermen using affected gears through any survey can facilitate the collaboration in other aspects of the project as experiments and test to reduce the interactions by applying deterrents or new tools.

5. General Discussion

An additional problem to consider but that has not evaluated during this action, is the conflict between Ukraine and Russia that is the shifting the prices of carburant and as consequence increase the investment to fishing. As this problem of carburant appears at the end of the action we don't evaluate the impact of the increase of the fuel prices in the revenues of the fishermen involves in the survey.

During the present Action, trammel nets were identified as being depredated by dolphins. The critical economic situation of fishermen in the southeast of Andalusia due to interactions with dolphins and the invasive alga *Rugulopteryx okamurae* motivated our Association to analyse these interactions and look for a solution. The economic situation of these fishermen has been aggravated by the rise in fuel prices (Ruíz, 2022). Our study is the first to evaluate the effectiveness of low-cost devices in mitigating dolphin depredation in the southeast Andalusian coast.

Firstly, we evaluated the damage to gear due the clogging of the artisanal fishing trammel nets by seaweed (abbreviated during this report as CNS). In the particular case of the CNS, this study is the first approach to its damage on the trammel net. The main variables and factors that explain the damage to the net are fundamentally related to the oceanographic-environmental and spatio-temporal factors that, on the one hand, determine the marine currents (as is also the case of lunar phases and wind direction) and, on the other, reflect the distribution and abundance of the alien seaweed *Rugulopteryx okamurae*.

Subsequently, we evaluated the breaking of the nets by dolphin predation (abbreviated during this report as BND). In the case of the BNS, the technical features of the fishing operation are the most important (up to 70% in the present study) as was also the case in previous studies (Pennino et al. 2015; Snape et al. 2018; Pardalou and Tsikliras 2020).

Target species, month, and longitudinal gradient were important variables for both clogging trammel nets by seaweeds (CNS), or breaking of the nets by dolphin predation (BND), but due to the fishing strategy they had different effects, and in some cases opposite, for the two types of damage. For example, in the case of longitudinal/coastal gradient, the interaction with dolphins increased from west to east, while the presence of algae increased in the opposite direction. The different fishing strategies used, depending on the target species, also had a differential effect in both cases, although when the fishermen went in search of the tiger prawn (*Penaeus kerathurus*) they did not suffer damage to their nets in either case. This could be due to the fact that the trammel net in these cases is set in deeper waters (>18 meters depth). Depending on the target species, in the case of CNS, the nets suffered more damage when the target was striped red mullet and Atlantic bonito, while in the case of BNS higher damage was associated to common cuttlefish (*Sepia officinalis*) and striped red mullet (*Mullus surmuletus*). In fact, of 40 observed sets targeting striped red mullet, 62.5% suffered serious net damage. During the red striped mullet fishery season from Sardinia, Díaz López (2005; 2006) observed net damage for 68.7% of fishing days in trammel fishery, which is very similar to the damage observed in our area. Moreover, many studies (for example, Gazo et al. 2008; Pardalou and Tsikliras 2020) reported highest net damage in trammel fisheries targeting striped red mullet, in a similar way of our findings. However, other studies also observed that the cuttlefish nets were less predated by dolphins (Lauriano et al. 2004; Pardalou and Tsikliras 2020), in opposition to our findings. This is a point to highlight, because perhaps the fishermen of the south of Spain use some fishing strategy when using the trammel net targeting cuttlefish, different from other parts of the Mediterranean, or simply that the dolphins of the Alboran Sea have become familiar with the taste of the cuttlefish.

The fishing strategy during trammel fisheries targeting striped red mullet, imply setting the net in shallow water and near stones. The shallow waters close to the coast were found to be the areas where interactions with dolphins were most frequently observed, and these shallow water areas are also where drifting seaweed is concentrated. Moreover, it is the most exposed area to the effect of tidal currents towards the coast. On the other hand, dolphins could feel a special attraction for stripped red mullet perhaps for three different reasons: i) its taste, because this species contains some component that dolphins need to complement the daily diet, ii) lower energy cost to prey on these specific nets, and iii) due to the better visibility of shallower depth, where they find the entangled fish more easily. In the case of the predation on cuttlefish captures the reasons could be similar.

Other differential effect between CNS and BND was that of the different lunar phases. Here we must bear in mind that the moon will determine the tidal regime, and therefore the current that occurs with the rise and fall of the sea.

In the case of the CNS model, other variables analysed were wind direction and month. In general, the North components of the wind direction tend to increase the probability of CNS, versus the South components, which decrease the probability. This may be due to the fact that the direction of the flow takes the opposite direction to that which it had on the surface when reaching a certain depth (Pond and Pickard 1983). The months of summer, with better conditions for the growth of seaweeds (Ravaglioli et al. 2022), were the months with the highest probability of CNS.

In the BND model other significant variables were the number of net units used, and the gross tonnage (GT) of the ship, both with a negative effect in the probability. *A priori*, the higher the number of net units, and therefore the larger the net, the more likely it is that increase the captures and that dolphins will prey on these nets. In a similar way, higher GT implies larger ships with higher fishing effort, so they could be more likely to be affected. However, the observed effect was the opposite. This may be explained because the fishermen set near the coast fewer parts of the net, and similarly, ships with higher GT tend to set in areas further away from the coast (because they have more autonomy) or the base port. Therefore based on the analysis, we hypothesize that the set most depredated by dolphins are close to the coast, at shallow depths and with clear waters, areas where bottlenose dolphins are commonly observed. After surveying the skippers who have collaborated about this possibility, they all agreed with this hypothesis.

According to Pardalou and Tsikliras (2020), the mesh size of the net had a negative relationship with the increase in predations, because the net mesh size could increase its selectivity, and possibly the dolphins are attracted to nets with greater variety of capture/preys. In our study, the mesh size was not significant, and had no effect neither in the CNS nor in the BND events.

Possible options to reduce depredation: Low-cost devices and pingers

This study evaluated the potential mitigation effects of the low-cost devices as well as the use of pingers.

Experiments using recycled glass bottles based on Berggren et al. (2020) gave a negative result in the first experiment resulting in the loss of one cooperating fisherman. The finfish deterrent effect continued to be reported in subsequent experiments conducted when the net was set deeper. Just as anthropogenic noise can prevent bycatch of marine mammals, it can also reduce interactions with fishing gear by masking its location (Weilgart 2007). However, in general, fishes are very acoustic animals, using sound to perceive their environment, for mating, communication, and predator avoidance (Popper 2003). It has been shown that anthropogenic noise could cause a reduction in catches of 40-80% (Weilgart 2007), so the bottles would be detected as an unnatural sound. This effect was reported by Berggren et al. (2020), although our results show that fishing for cephalopods such as cuttlefish (*Sepia officinalis*) is not affected by the noise produced by the bottle. Given the results obtained from the experiments with recycled glass bottles in our experimental Alboran Sea area, no conclusive results regarding the mitigation of dolphin interactions are observed, recommending more experimental trials before to conclude on the validity of this method.

The experiments with Compact Disks (CDs) did not show a negative effect on finfish or cephalopods. This was demonstrated by the recordings of the GoPro cameras that monitored the experiment underwater during the first two hours. This experiment started from the hypothesis that the aluminum coat of the CD could have a potentially mitigating effect due to its capacity to reflect the sound from echolocation. Given the results obtained by the experiments with the CDs, no conclusive positive result is observed with regard to the mitigation of dolphin interactions.

Finally, pingers were used as commercial mitigation device. Although multiple studies have used pingers to mitigate interactions between marine mammals and fisheries (Reviewed in Dawson et al. 2013), our results show that there is a clear “dinner bell” effect. The dinner bell effect is the name given to the effect of attracting marine mammals to pingers. In these cases, the sound of pingers is used by dolphins to locate where fishing nets are located, so they will be attracted to them (Bruno et al. 2021).

Pingers are a widely used method of reducing dolphin predation (Snape et al. 2018). Pingers have attracted much attention as a possible method to mitigate these problems (Dawsons et al. 1998). However, despite their widespread use, the economic effectiveness of these devices is relatively scarce (Maccarrone et al. 2014; Snape et al. 2018). Moreover, due to the highly adaptable behavior of this species of dolphin, although at first the pingers can produce deterrence in the animals, after getting used to the sound it indicates exactly where there is a net. In addition, pingers contribute to noise pollution in the sea (Kastelein et al. 2007; Gazo et al. 2008) that affects cetaceans and other marine species. Our results suggest that pingers do not have any potential mitigating application on the southeast Andalusian coast.

The invasive algae: Possible solutions

Small-scale fisheries from temperate areas are in danger due to tropicalization and the encroachment of alien species, among other factors (for example, Lloret et al. 2018). Many examples show that local and small-scale fisheries may be an effective management tool to eliminate or reduce invasive alien species (Aloo et al. 2017, Shaiek et al. 2021, Báez and Gutiérrez 2018), for which extractive fishing is the only option to control the invasion. Nevertheless, there are many invasive species that reduce biodiversity and for which there are no fisheries (Chinain et al. 2021).

However, despite these new opportunities for a selective control through fisheries, the European Union has limitations in EU Legislation to Address Marine Biological Invasions. Regarding the fight against the spread of the invasive species in Spain, it will be possible to evaluate and determine the conditions that favour it and carry out its valuation in sectors such as food, cosmetics or from the pharmaceutical point of view, at the same time as advancing in the possibility of using its biomass (Paton et al., 2022).

Moreover, fishermen due to their local and traditional ecological knowledge, could be an essential observer in the early detection of new expanding alien species. Thus, local fishers and scientists should improve the collaboration to share information, building mutual confidence through programs that include permanent communication channels, including surveys of local fishermen, the development of specific citizen science platforms, or on-board observers programs. This is particularly useful since it is expensive to maintain constant and thorough scientific monitoring of these changes over large areas (except perhaps in Marine Protected Areas, for example Aguzzi et al. 2020).

6. Conclusions

The results obtained in this study indicate that the interaction fishermen-cetaceans are a complex issue needing the collaboration of different stakeholders. The management of the problems faced by local artisanal fishing should be approached by managers with the collaboration of artisanal fishermen and the scientists who work with them, including experts on cetacean's biology. In the Mediterranean Sea, artisanal fishermen are an essential contributor to the human food chain and their activity represent an important part of the local economic activity. Moreover they have traditional local knowledge of the species distribution, presence in the fishing area, abundance, reproduction period, etc., and contribute with data and information about the used fishing gears, the fishing grounds and periods, the fishing season of the different species and the distribution of the target species. They also have experience with the species that negatively influence their daily activity such as dolphins and alien algae collaborating to improve the management of fisheries and exploited marine ecosystems and contribute to the scientific knowledge on bycatch and discarded species, improving the scientific knowledge about the ecosystem services and the level of degradation of the coastal ecosystems. After close collaboration with fishermen, Cofradias and administrations in the framework of the CETAFISHBE Action the main conclusions are as follows:

- The collaboration of the official fishers´ organization (Cofradias) and the group of fleets affected by depredation of captures by dolphins in the northern Alboran was progressively reduced as predation and the presence of an exotic alga, *R. okamurae* increased during the Action/Project.
- The low-cost mitigation devices used by our team (recycled glass bottles and CDs) do not show any clear results to reduce the interactions/depredation and more experiments are needed. The few

fishermen` collaborators and the reduced number of trials with every low cost device suggest that more experiments are needed to have statistical conclusions.

- The Pingers we used produced a dinner belt effect so it didn't have any mitigating effect
- Dolphins prey more in shallow than in deeper waters, perhaps due to lower energy costs and ease of encounter.
- Invasive algae (*R. okamurae*) and dolphin (*T. truncatus*) are two biological factors that severely affect local artisanal fishing activity, in addition to the recent war-dependent rising of the fuel costs.
- There is a clear local fishing strategy to adapt the fishing activity to both the presence of seaweed and dolphins.
- The losses produced by interactions represent an important percentage of the total revenue of artisanal fishermen. These group of artisanal fishermen request more attention from the administrations to maintain the activity.
- The economic situation of the fishermen is in a critical state due to the need to reinvest the few profits in repairing the nets and the time consumed to clean the nets after a fishing operation.

7. Deliverables performed under the MoU

A summary of the deliverables performed under the two Memorandums of Understanding (MoU) is showed in Table 14.

Table 14. Summary of the deliverables performed by the CETAFISHBE Action.

Activity	**Deliverables**
Meeting between AHE and IEO experts	A Plan to implement the activities
Summary for distribution to Cofradias	A ppt presented to Cofradias in Caleta
Meeting chairperson in Caleta de Velez	Authorization to work within the fish market
Meeting chairperson in Fuengirola	Authorization to work within the fish market
Selection of experts to the project	One labour contract under AHE in 2021 One labour contract under AHE in 2022
WS with Partner ANSE Nov. 2020	Agreement to collaborate
Meeting with fishermen in Caleta de Vélez	2 vessels collaborating
Meeting with fishermen in Fuengirola	2 vessels collaborating
Meeting with fishermen in Motril	1 vessel collaborating
Port questionnaires on interactions	Data base of the project
Weather data collection	Data base
Port questioning on daily depredation	Data base
Fishing vessel localisation	Data base

Activity	Deliverables
Selection of recording tools	6 Go-Pro cameras distributed to fishermen
Workshop in Sevilla (Regional and national Administrations)	JC Baez presented a ppt on CETAFISHBE JA Camiñas presented a ppt on fishers and scientist relationship to reduce bycatch and interactions.
ACCOBAMS project Partners meeting online November 2021	Presentation the communication “Progress in mitigation cetaceans depredation in artisanal fisheries in northern Alboran Sea”
Subregional Meeting GFCM-Western 2022	J Camiñas presented ppt on CETAFISHBE results
IUCN Med WS on monitoring dolphins depredation	Members of CETAFISHBE participating presenting partial results of the project.
ACCOBAMS project Partners meeting Sicily June 2022	Presentation of a communication with Results. Participation of two members of the team.
Progress Report	Sent to ACCOBAMS in October 2021
A complementary MoU in March 2022	Signed AHE-ACCOBAMS MoU document on additional budget and activities
Research paper submitted to the Journal *Reviews in Fish Biology and Fisheries*	Title: When nontarget wildlife species affect negatively to an artisanal fishery: the case of trammel net in the Alboran Sea
Paper published in a national journal for professionals of the sea.	J.A. CAMIÑAS, R. AGUILERA & J.C. BÁEZ (2021). Delfín mular y artes menores. Revista Mar, septiembre-octubre 2021: 54-57.

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10. Annexes

Annexe I

Table 1. Fishing effort

Fishing effort per sampling port						
Country Spain						
	Longliners		*Small-scale vessels*		*Purse-seiners*	
GSA 01	*Total number of vessel in the port*	*Fishing days*	*Total number of vessel in the port*	*Fishing days*	*Total number of vessel in the port*	*Fishing days*
Fuengirola			28			
Caleta de Vélez			42			

Table 2. Coverage by Ports x GSA

Total number of ports covered by the programme				
Country Spain				
	Number of fishing trips covered	***% Number of depredation events***	***Type of events***	***Main commercial species***
GSA 01				
Fuengirola	461	4%	Depredation on nets	Red stripped mullet, Sole, Common cuttlefish
Caleta de Vélez	744	22%	Depredation on nets	Red stripped mullet, Sole, Common cuttlefish

Table 3. Gear and catch composition

<table>
<tr><th colspan="4">Main fishing gear per vessel group</th></tr>
<tr><th colspan="4">Country Spain</th></tr>
<tr><th>Port</th><th>Main gear</th><th>Frequency (%) of gear used</th><th>Catch composition</th></tr>
<tr><td rowspan="3">Trawlers</td><td>bottom trawls</td><td></td><td></td></tr>
<tr><td>midwater trawls</td><td></td><td></td></tr>
<tr><td>......</td><td></td><td></td></tr>
<tr><td rowspan="3">Longliners</td><td>demersal bottom longline</td><td></td><td></td></tr>
<tr><td>pelagic longline</td><td></td><td></td></tr>
<tr><td>......</td><td></td><td></td></tr>
<tr><td rowspan="5">Small-scale vessels (with and without engine)</td><td>gillnets</td><td></td><td></td></tr>
<tr><td>trammel nets</td><td>100 %</td><td>Atlantic bonito Sarda sarda, European sardine, Sardina pilchardus, Frigate tuna Auxis spp, Cuttlefish Sepia officinalis, Red Mullet Mullus barbatus, Boops boops, Diplodus annularis.</td></tr>
<tr><td>combined gillnets-trammel nets</td><td></td><td></td></tr>
<tr><td>longliners</td><td></td><td></td></tr>
<tr><td>......</td><td></td><td></td></tr>
<tr><td rowspan="4">Polyvalents</td><td>gillnets</td><td></td><td></td></tr>
<tr><td>trammel nets</td><td></td><td></td></tr>
<tr><td>combined gillnets-trammel nets</td><td></td><td></td></tr>
<tr><td>......</td><td></td><td></td></tr>
<tr><td>Purse-seiners</td><td>purse seine</td><td></td><td></td></tr>
</table>

Annexe II

Table 3. Depredation data.

Depredation data	
Country Spain (GSA 01)	
Fleet segment: SSF	**Period: 2021-2022**
Total number of vessels	65
Main gear(s)	trammel net and gillnet
Total number of fishing trips (fishing days)	7150
Total catches	325000 (kg)
Medium weight of catch per day per vessel*	46 (kg)
Number of fishing trips (fishing days) with depredation events	145
Frequency of conflicts	2%
Daily income per single vessel	460 USD
Loss of catch in case of depredation event* (percentage)	3%
Main species affected by depredation event	Mullus barbatus (75%), Boops boops (15%), Diplodus annularis (10%)
Loss of money in case of depredation events (percentage)	45%

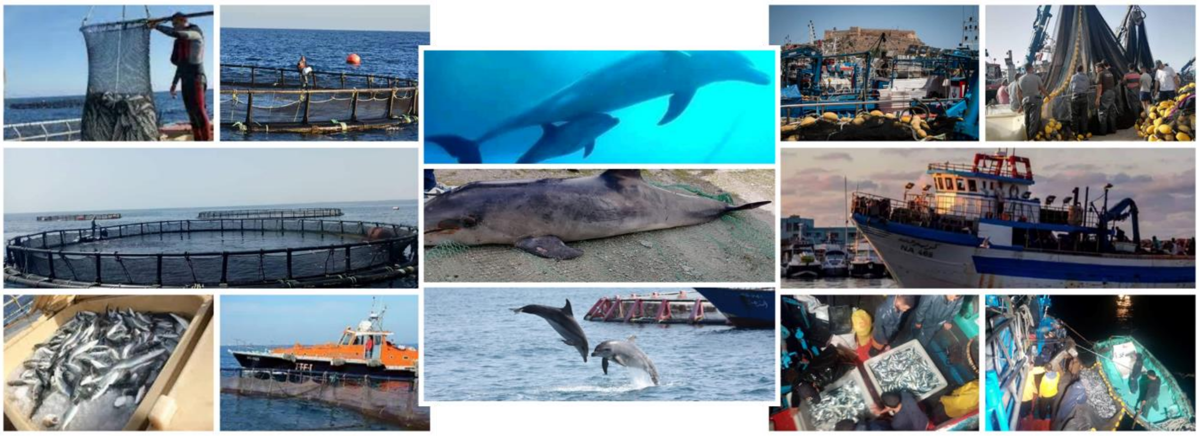
n. of fishing trip with depredation events/tot. number of fishing trips

Table 4. Mitigation measures.

Mitigation measure(s) in place											
Country	**GSA**	**Description Area**	**Group of vulnerable species concerned**	**Main species concerned**	**The vessel group interested**	**N. of commercial vessels involved in the trials**	**Fishing gear**	**Mitigation Measure**	**Period**	**Number of trials (fishing days)**	**Comments**
Spain	01	Caleta de Vélez, Nerja and Fuengirola	Cetaceans	Bottlenose dolphin (*Tursiops truncatus*)	Small scale vessels	3	Trammel net	Recycled glass bottles	from February to June 2022	19	Deterrent of finfish
Spain	01	Caleta de Vélez	Cetaceans	Bottlenose dolphin (*Tursiops truncatus*)	Small scale vessels	3	Trammel net	Compact Disks	from February to June 2022	34	Do not show any deterrent effect
Spain	01	XXXXXXXXXXXXX….	Cetaceans	Bottlenose dolphin (*Tursiops truncatus*)	Small scale vessles	1	Trammel net	Pingers	from February to June 2022	3	Dinner bell effect

MITIGATING DOLPHIN DEPREDATION IN MEDITERRANEAN FISHERIES
JOINING EFFORTS FOR STRENGTHENING CETACEAN CONSERVATION AND SUSTAINABLE FISHERIES

« Vers des solutions aux interactions entre communautés de pêcheurs et *Tursiops truncatus* dans les eaux tunisiennes »



BENMESSAOUD Rimel, CHERIF Mourad & KOCHED Wael,

Aout 2022

Vers des solutions aux interactions entre communautés de pêcheurs et cétacés dans les eaux tunisiennes

Study conducted in collaboration with:
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Study reference:
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With the participation of:

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- L'Arrondissement de la Pêche et l'aquaculture Kélibia, DGPA.
- Tunisie Teboulba Fish (Ferme aquacole)
- L'Arrondissement de la Pêche et l'aquaculture Ghar El Melh, DGPA.

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I. Contexte et objectifs de l'étude

Conscients des enjeux environnementaux, la Tunisie s'est engagée, dans le cadre des différents accords de coopération régionale à diminuer les impacts des interactions entre les activités de pêche et les espèces menacées concernées (captures accidentelles par les engins de pêche en activités ou abandonnés, surexploitation des ressources disponibles par la pêche). Certaines de ces espèces, en particulier les cétacés, entrent en compétition avec les pêcheurs en se nourrissant d'espèces marines d'importance commerciale, occasionnant parfois des dommages dans les filets de pêche pour y prélever des proies (déprédation). Cet impact crée une source de conflit avec les pêcheurs, souvent impuissants à préserver leur outil de travail. Cette situation entraîne une hostilité de la part des pêcheurs envers lesdites espèces ce qui est de nature à rendre plus difficile les efforts de conservation.

Dans ce contexte, le Secrétariat de l'Accord sur la Conservation des Cétacés de la Mer Noire, de la Méditerranée et de la zone Atlantique adjacente (ACCOBAMS) a reçu un appui financier, en 2015, de la Fondation MAVA pour la mise en œuvre du projet « Atténuation des interactions négatives entre les espèces marines menacées et les activités de pêche ». La Tunisie a beneficié de cet appui et une action pilote a été entretenue dans la région Nord-Est de la Tunisie intitulée « *Atténuation des interactions négatives entre les espèces marines menacées (Delphinidés et Oiseaux marins) et les activités de pêche des petits pélagiques dans la région de Kélibia* ». La coordination de cette action a été assurée par les secrétariats excecutifs de l'ACCOBAMS et de la Comission Genérale de la Pêche en Mediterranée (CGPM). Le Centre d'Activités Régionales des Aires Specialement Protegées (SPA/RAC) collabore dans cette coordination pour la mise en œuvre des activités en Tunisie qui seront mises en œuvre par les partenaires scientifiques nationaux respectivement l'Institut National Agronomique de Tunisie (INAT) et l'Institut National des Sciences et Technologies de la Mer (INSTM), en coordination avec la Direction Genérale de la Pêche et de l' Aquaculture (DGPA). Une deuxieme action « *Vers des solutions aux interactions entre communautés de pêcheurs et cétacés dans les eaux marocaines et tunisiennes* » (appelé ci-après « projet MAVA-Déprédation ») a été depuis 2019 et a été conçue pour assurer la poursuite des activités engagées dans le cadre de la premiere action pilote. Cette action complementaire vise à répondre à l'objectif stratégique de l'ACCOBAMS de réduire les intéractions entre les cétacés et les activités de pêche en adressant la déprédation par les grands dauphins dans les pêcheries à la senne aux petits pélagiques et à évaluer l'interaction avec les activités d'aquaculture.

II. Introduction

1. Généralités

Les interactions entre les cétacés, et spécifiquement les delphinidés, et les pêcheurs sont relativement anciennes, puisque des cas de pêcherie coopérative entre les dauphins et les populations locales sont décrits (Petrie, 1904). Les interactions ont souvent été rapportées comme une relation d'aide aux pêcheurs (Pryor *et al.,* 1990 ; Neil, 2002). Cependant en raison de la diminution des stocks de ichtyques, les interactions pêcheurs - dauphins sont considérées comme une compétition aux ressources (Trites *et al.,* 1997). En effet, les dauphins ont appris à exploiter les pêcheries comme de nouvelles sources de nourriture (Reeves, 2001). Le prélèvement des poissons dans les filets leur offre une alternative à la chasse puisqu'il est plus simple d'exploiter une ressource concentrée dans un filet (Díaz-López, 2006). L'association des dauphins aux filets de pêche permet d'augmenter leur taux d'alimentation, tout en diminuant la dépense d'énergie associée à la recherche et la consommation de nourriture (Fertl & Leatherwood, 1997).

Les interactions entre delphindiés et pêcheries peuvent être au détriment des deux parties concernées : les études ont le plus souvent porté sur les dommages créés aux mammifères marins, comme les blessures ou les captures accidentelles au contact des engins de pêche, et la réduction de la disponibilité en proies pour les cétacés. Mais une des conséquences les moins souvent mises en évidence sont les dommages causés aux pêcheurs, à savoir la destruction de leurs engins de pêche, la réduction de leurs captures et à la diminution de la disponibilité des espèces pêchées (Noke & Odell, 2002).

Les interactions peuvent être de deux types:

(i) Biologiques lorsqu'on s'intéresse à la compétition pour une même ressource (Northridge, 1991) où les dauphins prélèvent une partie importante des poissons ciblés par les pêcheurs (Reeves, 2001 ; Lavigne, 2003). Enfin, ces interactions induisent une opinion négative des cétacés par les pêcheurs (Fertl & Leatherwood, 1997);

(ii) Opérationnelles : lorsqu'on considère les captures accidentelles (By-catch) de cétacés et la déprédation.

2. Notion de déprédation

La déprédation est définie comme étant le prélèvement partiel ou total des poissons et/ou appâts des engins de pêche par des prédateurs comme les cétacés, les requins, les oiseaux ou autres. Elle s'oppose au terme prédation, qui est la capture des poissons évoluant librement et par conséquent elle est considérée comme un comportement de prédation non naturel (Donoghue et al., 2002).

3. Déprédation : transmission, adaptation et changement de comportement

Est-ce une culture ?

Selon Rendell & Whiteheadn (2001), la culture est un comportement ou une information partagée par une population ou une sous-population, et qui est transmise d'un individu à l'autre par le biais d'un apprentissage social, affectant par conséquent le comportement individuel chez les mammifères marins en général et les odontocètes en particulier. Les mêmes auteurs ont indiqué que dans le cas d'une culture qui n'est pas d'origine génétique, les individus peuvent en hériter d'autres individus, en plus de leurs parents. Ils peuvent choisir de l'adopter ou non, et leurs propres expériences et comportements peuvent influencer la culture qui est transmise à d'autres individus. Whitehead et al., (2004) ont mentionné que la culture peut affecter l'écologie comportementale d'une population.

Rabearisoa et al., (2012) ont montré qu'un élément de culture peut se transmettre de deux façons différentes: verticale et/ou horizontale. La culture horizontale se transmet entre les membres d'une même génération. Cette transmission peut être très efficace en modifiant rapidement le comportement d'une population dans une mesure adaptative. La culture verticale se transmet d'une génération à la suivante. Cette transmission peut être très conservative et peut contraindre la réponse adaptative aux changements environnementaux (Rabearisoa et al., 2012).

La transmission horizontale et verticale de la déprédation

Le phénomène de déprédation s'est rapidement transmis au sein des populations de cétacés. En effet et selon Whitehead et al., (2004), il s'est avéré que ce type d'apprentissage social est responsable de la conversion de certains individus de prédateurs en déprédateurs ou « voleurs de poissons ». A l'opposé, la transmission de culture verticale est conservative et peut inhiber les réponses adaptatives normalement imposées par situations auxquelles les individus y sont confrontés. Ce conservatisme est particulièrement efficace pour enraciner un comportement mal adapté dans une population (comme la déprédation) (Whitehead et al., 2004). Barrett-Lennard, (2006) et Carrillo et al., (2011), ont appuié le fait que la déprédation est un comportement qui peut se transmettre également de façon verticale. Whitehead et al., (2004) ont mentionné l'observation fréquente de juvéniles en situation d'apprentissage auprès de leur mère. Visser (2000) a photographié un orque juvénile impliqué dans des évènements de déprédation en compagnie d'adultes, et ceci pourrait être considéré comme un comportement d'apprentissage.

Les populations d'odontocètes sont structurées à la fois par des transmissions de culture horizontales (qui connaissent des changements fréquents) et verticales (qui sont stables). Chez les cétacés, l'apprentissage social détermine une large proportion du comportement, y compris des comportements d'une grande importance fonctionnelle comme le nourrissage. L'exploitation de nouvelles opportunités peut mener à des conséquences négatives, comme la déprédation. Ce comportement peut alors être considéré comme un élément de culture des populations d'odontocètes impliquées dans ce phénomène (Rabearisoa et al., 2012).

La déprédation : Un apprentissage social

Les facultés d'apprentissage accrues des mammifères marins contribuent également à la propagation des nouveaux comportements. Des études réalisées par Lennard (2006) ont montré que les espèces ne se rendent pas compte des nouvelles sources d'alimentation et n'en profitent pas. Par contre l'apprentissage social qui est défini comme l'acquisition de nouveaux comportements adoptés par d'autres membres de son groupe social, est largement développé. La combinaison de ce conservatisme et de ces capacités d'apprentissage social souligne leurs cultures complexes et stables.

Selon Lennard (2006), la prédominance de l'apprentissage des juvéniles par les adultes sur l'apprentissage par l'expérimentation reflète le fait que ces espèces adoptent préférentiellement une stratégie qui optimise leur survie et leur reproduction plutôt qu'une prise de risque pour acquérir des bénéfices à court terme. Cette nature opposée aux prises de risques peut les rendre relativement réticents à s'engager dans un comportement de déprédation. Mais une fois adopté par un membre du groupe, ce comportement peut s'étendre rapidement aux autres membres par le biais de l'apprentissage social. Cette technique "d'imitation" joue un rôle particulièrement important dans la transmission d'une culture. C'est alors le conservatisme qui rend la déprédation difficile à contenir et à freiner une fois qu'elle est établie dans une population. Il serait donc plus aisé d'empêcher l'initiation de la déprédation que d'essayer de la contrôler une fois qu'elle est adoptée par les individus d'une population ou d'un groupe. Par conséquent, il est indispensable de prévenir et d'atténuer la déprédation, même dans les zones où ce comportement est peu fréquent ou absent (Lennard, 2006).

La déprédation : Une adaptation comportementale

Gilman et al., (2006), ont affirmé que la déprédation peut conduire à un changement de comportement et de stratégies de pêche des prédateurs et ce en les incitant à privilégier la recherche active d'engins de pêche calés plutôt que la prédation directe de leurs proies usuelles. Ceci entraine la substitution des anciennes proies préférentielles par de nouvelles espèces facilement accessibles ce qui entraine la modification de leur bol et régime alimentaire. En s'engageant dans ce comportement, les cétacés encourent le risque de se faire prendre accidentellement ou de se blesser à cause des engins de pêche déployés. Zollett & Read, (2006) ont rajouté que les bénéfices, dus à l'accès facile à l'alimentation sans dépense énergétique, supplantent leur méfiance vis-à-vis de ces risques. La déprédation aura ainsi comme conséquence d'induire un phénomène d'accoutumance (Zollett & Read, 2006). Rabearisoa et al., (2012), ont précisé que la déprédation peut de ce fait être considérée comme un comportement adaptatif des odontocètes aux interactions avec les activités anthropiques.

4. Historique du phénomène de déprédation

L'interaction entre les cétacés et les engins de pêche est une préoccupation mondiale car elle affecte à la fois la survie des populations de dauphins et les moyens de subsistance des pêcheurs (Brotons et al., 2008 ; Northridge, 1984). D'après Sacchi (2018), il s'agit probablement d'une conséquence possible d'une dépendance à une activité de pêche pour diverses raisons (exp : réduction et épuisement des ressources ou facilité d'alimentation). Cette interaction est plus importante dans les aires de chevauchement des espèces ciblées par la pêche et les espèces-proies préférées des cétacés (Lauriano et al., 2004). D'après Reeves (2001), les cétacés et surtout les delphinidés ont appris à exploiter les pêcheries comme de nouvelles sources de nourriture. Le prélèvement des poissons dans les filets leur offre une alternative à la chasse puisqu'il est plus simple d'exploiter une ressource concentrée dans un filet (Díaz López, 2006). L'association des dauphins aux filets de pêche permet d'augmenter leur taux d'alimentation tout en diminuant la dépense d'énergie associée à la recherche et la consommation de nourriture (Fertl & Leatherwood, 1997).

En Tunisie, les interactions entre les delphinidés et les pêcheries sont fréquentes et ont été le sujet de plusieurs travaux de recherche scientifiques et ce depuis les années 70. D'après plusieurs travaux élaborés à l'échelle nationale, les interactions se produisent principalement entre les dauphins, les filets maillant et trémail en premier lieu (Gharbi, 2019). Néanmoins, des dommages considérables ont été également signalées suite à l'interaction de ces derniers avec les sennes tournantes (Ben Naceur et al., 2004 ; M'kacher, 2005 ; Benmessaoud, 2006, 2008 ; Benmessaoud et al., 2012 ; Ayadi, 2013 ; Benmessaoud et al., 2018, 2021).

Dans une étude d'évaluation des interactions entre les dauphins et les filets de pêche des sardiniers de la région de Mahdia, M'kacher, (2005) et Ben Naceur et al., (2007), ont démontré que les déchirures des filets causés par les dauphins dépassaient 53.1 %, et les autres sont causées par des épaves et des structures solides (clous, bois cassé et les fortes manœuvres) sont estimées à 46.9%. Le ramendage des filets déchirés par les dauphins est estimé à 58.74 % du coût du ramendage total contre 41.26 % pour les déchirures causées par les épaves et les autres structures solides. L'analyse des dégâts dus aux déchirures des filets selon les zones de pêche montre qu'ils sont plus importants dans les profondeurs inférieures à 50 m (46.47 %). Les déchirures causées par les dauphins nécessitent souvent l'ajout d'une pièce de filet pour remplacer la partie arrachée par les dents de ces mammifères marins et demandent plus de temps de travail pour le ramendage. Le coût total de réparation des filets de la senne tournante des sardiniers, représente environ 2% de la valeur totale brute des débarquements ; cette réparation correspond à des journées d'immobilisation qui représentent environ 9.9% du nombre total de journées de pêche effectuées.

Une étude réalisée le long de la côte du Nord en coopération avec des pêcheurs, a mis en évidence de la déprédation infligée aux palangriers de la région (Ben Naceur, 1994). De même, des dommages importants provoqués par les Grands dauphins à des filets fixés à plus de 50 m de fond ont été signalés (Ben Naceur et al., 1997). Benmessaoud et al., (2012) ont montré que l'interaction entre les dauphins et les chalutiers et ainsi les lamparos est dû à l'attrait qux rejets de ces deux types de pêcheries ce qui a pu impacter négativement le comportement alimentaire de ces dauphins en les rendant de plus en plus opportunistes. Une étude plus actualisée datant de 2018 et 2021, ont montré que les interactions négatives entre dauphins et filets encerclant peuvent avoir lieu durant les différentes phases de l'opération de pêche à la senne. Le suivi a montré qu'il existe une variation mensuelle significative de la fréquence de déprédation en faveur d'une baisse lors de la période estivale. Les auteurs ont supposé que cette variation pourrait être liée à la disponibilité de proies, à la répartition spatio-temporelle des dauphins et à l'éthologie de ces derniers.

5. Espèce impliquée dans la déprédation

Dans le monde, au moins 15 espèces de cétacés ont été reconnues comme ayant des interactions de type alimentaire avec les engins de pêche (Fertl & Leatherwood, 1997), mais l'espèce la plus observée en interaction avec les pêcheries est *Tursiops truncatus* (Bearzi, 2002). À l'instar des autres régions méditerrannéennes, la Tunisie ne fait pas l'exception. En effet, Ben Naceur et al., (2004), Benmessaoud et al., (2012, 2018& 2021), Gharbi (2019) et Chakroun (2021) ont mentionné que le Grand Dauphin "*Tursiops truncatus*" est l'espèce la plus impliquée dans la déprédation.

C'est une espèce cosmopolite. Les groupes côtiers sont généralement sédentaires. L'espèce est présente de façon disjointe en Méditerranée, sur tout le littoral, depuis le détroit de Gibraltar jusqu'en Mer Noire. Considéré comme ayant un écotype côtier, *Tursiops truncatus* est communément rencontré en Méditerranée au niveau du plateau continental où la profondeur se situe entre 100 à 150 mètres. Les Grands dauphins se trouvent dans les eaux tempérées et tropicales du monde entier. Ils habitent une grande variété d'habitats, y compris les ports, les baies, les golfes et les estuaires ainsi que les eaux côtières proches du rivage, les eaux plus profondes sur le plateau continental et même loin au large en haute mer (Randall et al., 2009). Les limites de l'aire de répartition de l'espèce semblent être liées à la thermocline et à la distribution des proies (Randall et al., 2009).

Les Grands dauphins tirent leur nom de leur museau ou rostre court et épais (Montagu, 1821). Ils sont reconnaissables à leur aspect généralisé : un corps robuste de taille moyenne, une nageoire dorsale modérément falciforme de couleur foncée, avec une nette démarcation entre le melon et le court rostre. Ils sont généralement de couleur grise (**Fig.1**). Ils peuvent varier du gris clair au presque noir sur le dessus près de leur nageoire dorsale et du gris clair au presque blanc sur le ventre (Randall et al., 2009). Cette espèce est considérée comme une espèce de petite taille dont la longueur ne dépasse pas 4m. La longueur des adultes varie d'environ 2,5 m à environ 3,8 m, variant selon l'emplacement géographique (Mead & Potter, 1990). Dans de nombreuses régions du monde, La taille du corps varie selon la température de l'eau. En effet, Les Grands dauphins vivant dans les eaux côtières proches du rivage sont souvent plus petits et de couleur plus claire que ceux vivant au large (Read et al., 1993).

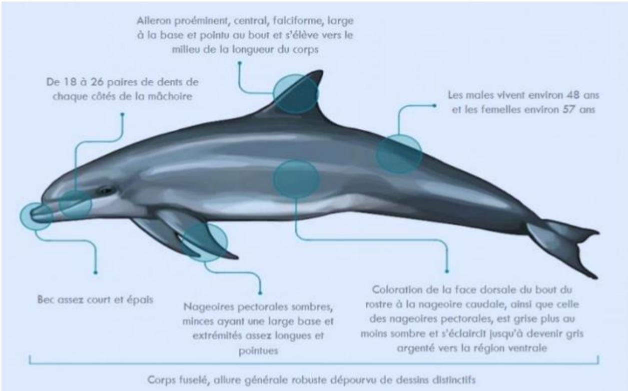


Figure 1: Caractères morphologiques de *Tursiops truncatus*

Les Grands dauphins se regroupent fréquemment en structures de groupes inférieures à 15 individus (Gonzalvo et al., 2001), mais peuvent occasionnellement former des rassemblements de plus d'une centaine d'individus (Diaz Lopez et al., 2001). *Tursiops truncatus* nagent souvent associés à d'autres cétacés. Les individus sont souvent observés en nage à l'étrave des bateaux ou d'autres cétacés.

Pour ce qui est de la sonde, ils plongent tous les 3 à 4 minutes et restent sous l'eau 12 minutes au maximum. *Tursiops truncatus* utilise des fréquences allant de 4 à 170 kHz. L'espèce émet des cliquetis au nombre de 30 à 800 par seconde (Mace, 2013). Deux types de signaux sont émis non simultanément des sifflements nécessaires à la communication et des « clics » servant à l'écholocation (Bortolotto et al., 2006). D'après Rossi (2011), les clics sont des signaux très brefs (50-200µs) et de grande intensité (jusqu'à 230 dB re 1 µPa à 1 m) répartis sur une large bande spectrale (une cinquantaine de kHz à 3 dB, mais pouvant aller de 20 kHz à plus de 100 kHz suivant la situation). Ils sont généralement émis par train d'impulsions et ils sont utilisés pour la navigation et la détection. Les sifflements sont de véritables signatures acoustiques. Ils sont bien localisés en fréquence et de faible intensité ; ils se situent plutôt dans les basses fréquences inférieures à 25 kHz (Rossi, 2011).

Les régimes alimentaires des Grands dauphins communs ont été décrits dans de nombreuses régions (Barros & Odell, 1990). Ces espèces se nourrissent d'une variété de proies comme les poissons, les calmars et les crustacés. Il s'agit d'une espèce éclectique opportuniste (Astruc, 2005). Ce delphinidé est classé comme euryphage (Corkeron et al., 1990). D'après Astruc (2005), le régime alimentaire de *Tursiops truncatus* est principalement composé de poissons benthiques démersaux (Merlucccidae) mais aussi de mésopélagiques (Clupeidae), de céphalopodes néritiques (Loliginidae et Octopodidae) et accessoirement de crustacés. D'après Boutiba (1992), *T. truncatus* des côtes Algériennes consomment essentiellement des poissons pélagiques. La ration alimentaire quotidienne de cette espèce est estimée entre 8 et 12% de sa masse corporelle (Fontaine 1998). Cependant, le régime alimentaire varie en fonction de la disponibilité des proies locales, les écotypes où ils vivent, du sexe et des stades de maturité (Wells & Scott, 1999). Les grands dauphins se nourrissent de plusieurs façons, principalement en tant qu'individus, mais il existe également un rassemblement coopératif de bancs de poissons contre des dunes de sable et des digues pour un repas facile. (Leatherwood, 1975). Les delphineaux apprennent les techniques de recherche de nourriture de leurs mères et ces comportements une fois acquis peuvent se propager à tous les individus de la population à partir de l'observation, comme une indication de la transmission culturelle des connaissances (Wells, 2003).

L'analyse sclérochronologique des pièces calcifiées comme les dents (Hohn et al., 1989) a montré que la longévité maximale des femelles des Grands dauphins peut atteindre 57 ans et les mâles 48 ans (Wells & Scott, 1999). Les femelles atteignent généralement la maturité sexuelle et physique avant les mâles et ce entre 5 et 13 ans. Tandis que chez les mâles, la maturité sexuelle est atteinte entre 9 et 14 ans (Wells, 2003).

Bien que des naissances aient été signalées à toutes les saisons, la mise bas a tendance à être saisonnière de façon diffuse, avec des pics pendant les mois du printemps et de l'été (Thayer et al., 2003). Le cycle reproductif chez les femelles des Grands dauphins est généralement long et prolongé. En effet, les femelles peuvent accoucher et élever des petits avec succès jusqu'à l'âge de 48 ans (Wells & Scott, 1999). Les delphinaux naissent après une période de gestation d'environ 1 an et mesurent entre 84 et 140 cm de long (Perrin & Reilly, 1984).

6. Caractérisation de la déprédation

Le phénomèe de déprédation peut avoir diverses consésquences. Outre les pertes économiques que la déprédation entraine, elle engendre des conséquences importantes sur l'écologie des espèces impliquées et des biais dans les statistiques de pêche (Rabearisoa et al., 2012).

Pertes économiques

La déprédation est à l'origine d'une perte économique considérable pour les filières impactées par ce phénomène et ce pour diverses raisons. D'une part, la déprédation au niveau des engins de pêche peut occasionner des dommages au niveau de ces derniers (déchirures des filets, emmêlement des avançons, rupture des lignes, pertes d'hameçons…) et leur réparation engendre des dépenses supplémentaires aux pêcheurs (Rabearisoa et al., 2007). Par ailleurs, lorsque des évènements de déprédation ont lieu, les pêcheurs qui en ont les moyens matériels vont quitter la zone de pêche afin de mettre de la distance entre leurs engins et les prédateurs. Ces déplacements occasionnent des dépenses supplémentaires en fuel qui est une composante majeure du coût d'exploitation d'une unité de pêche. Les avaries aux appâts induisent également un manque à gagner puisque l'engin de pêche est inefficace et ne capture probablement plus de poissons. Il ne faut pas aussi sous-estimer les pertes économiques liées aux dégâts au niveau des captures (Bach et al., 2011a). Par ailleurs, pour compenser les pertes économiques associées à la déprédation, les pêcheurs choisissent de prolonger la durée de la sortie en mer et d'établir plusieurs opérations de pêche, ce qui engendre un effort de pêche supplémentaire sur les stocks halieutiques (Gilman et al., 2006).

Impacts sur l'écologie des espèces déprédatrices

La déprédation est la source de multiples problèmes induisant des modifications de l'écologie comportementale des espèces impliquées. En effet, l'accoutumance des prédateurs supérieurs au comportement de déprédation conduit à une modification de leur régime alimentaire puisqu'ils vont prendre goût à des nouvelles proies et vont les privilégier lorsqu'ils sont en situation de prédation (Donoghue et al., 2002). Ce phénomène contribue aussi à modifier les techniques de prédation de ces prédateurs. Cette interaction avec les engins de pêche leur permet d'acquérir, sans une grande dépense énergétique, une nourriture à fort valeur calorique. Les individus ayant pris l'habitude de dépréder vont alors se mettre à la recherche de ces engins au lieu de chasser leurs proies naturellement. La déprédation peut aussi conduire à un changement dans la distribution géographique des prédateurs ayant adopté ce comportement : où les zones de pêche ne correspondent pas ni à leurs domaines vitaux ni à leurs aires d'alimentation habituelles (Gilman et al., 2006).

Impacts sur les stocks exploités

La déprédation conduit à une sous-estimation des débarquements et donc de la capture par unité d'effort (CPUE) utilisée comme indice d'abondance des ressources halieutiques (Bach et al., 2011a).

En effet, seuls les poissons débarqués sont déclarés et les poissons déprédés ne sont pas pris en considération lors des évaluations des stocks et de leurs états (Bach et al., 2011a).

D'après Benmessaoud et al., (2021), au Nord-Est de la Tunisie le phénomène de déprédation a tendance d'avoir lieu soit durant la phase de concentration des bancs de poissons sous les lumières, ce qui pourra induire la fuite totale du banc, ou bien lors de la phase d'encerclement et de boursage ce qui pourra entrainer la fuite partielle de la capture. Le suivi de la Capture Par Unités d'Efforts (CPUE) des embarcations échantillonnées pour cette étude a montré une variation en fonction de l'occurrence de déprédation. Effectivement, une réduction significative de la CPUE a été enregistrée lorsque les Grands dauphins interagissaient avec les sennes. En effet, la CPUE en présence de déprédation est égale à 149.968 kg/100m/jour (± 59,82 kg/100m/jour). Or, en absence de la déprédation la CPUE est égale à 198.892 kg/100m/jour (± 62,28 kg/100m/jour). En cas d'attaques des sennes lors de la phase d'encerclement ou de boursage, cette interférence se matérialise par de nombreuses perforations ayant des tailles et localisations différentes. L'inspection de l'état de sennes a montré qu'une senne peut présenter en moyenne 68,38 perforations (± 41,49 perforations) localisées au niveau de la poche et l'avant poche et dont la taille est comprise entre 20 et 60cm Benmessaoud et al., (2021). D'après les mêmes auteurs, ces perforations nécessitent des opérations de ramendage. L'évaluation des frais de ramendage totaux s'élèvent à 557Dt (± 461Dt). Les coûts moyens de ramendage des déchirures de dauphins sont d'une moyenne de 247Dt (± 140Dt) (Benmessaoud et al., 2021).

7. Zone d'étude

Le site choisi pour cette étude est le port de « Kélibia ». Il s'agit d'une ville côtière au Nord-Est de la Tunisie. Elle est située à la pointe de la péninsule du Cap Bon (36° 51′ N, 11° 05′ E) entre le canal siculo-Tunisien au Nord et le Golfe de Hammamet au Sud (**Fig.2**). Cette région constitue une zone de transition entre les bassins occidental et oriental de la Méditerranée (Benmessaoud et al., 2021).

La région de Kélibia regroupe certaines caractéristiques naturelles (océaniques, écologiques et climatiques) qui sont moins propices à l'exercice de pêche telle que l'aspect des côtes rocheuses, la raideur de la pente du plateau continental et la dominance des vents de type Nord-Ouest à courants violents. Cependant, les professionnels de la pêche se sont orientés vers les activités de pêche à caractères hauturiers et peuvent préserver l'exercice de pêche même à des conditions climatiques défavorables. En effet, le port de la région de Kélibia englobe la quasi–totalité de la flottille du Gouvernorat de Nabeul. Dans les paragraphes qui suivent nous allons traiter les données, que nous avons pu recueillir moyennant les relevés statistiques relatives au potentiel halieutique de la zone de Kélibia

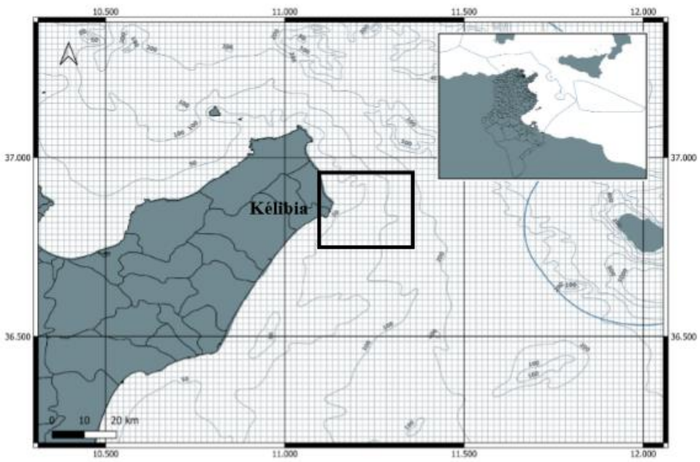


Figure 2 : Localisation géographique de la zone d'étude

Caractérisation de la flottille de pêche

Le port de Kélibia détient le maximum de flottille avec 48% de la flottille totale du Gouvernorat de Nabeul. Un total de 199 embarcations a été recensé au niveau du port de Kélibia en 2021 (DGPA, 2021). La flottille est répartie entre barques côtières motorisées et non motorisées, sardiniers et chalutiers **(Tab.1).**

Tableau 1 : Répartition de la flotte et le nombre de jours en mer par type d'activité
Nb Flott. : nombre total des embarcations, Nb J.M : Nombre de jours en mer

Effort de pêche								
	Pêche côtière		Sardiniers		Thoniers		Chalutiers	
GSA12	Nb Flott.	Nb J.M	Nb Flott.	Nb J.M	Nb Flott.	Nb J.M	Nb Flott.	Nb J.M
Kélibia	128		47		2		24	

Pour ce qui est de la répartition de la flottille par type de pêche, il s'avère que la pêche côtière détient le pourcentage le plus élevé avec 64% de la flotte totale. La majorité des embarcations côtières sont en bois vu qu'elles sont plus faciles à réparer sur place et qu'elles ont une durée de vie plus longue. En ce qui concerne la flottille hauturière, elle représente 36% de la flottille totale du port de Kélibia.

Nous séparons dans ce qui suit les chalutiers des unités de pêche des petits pélagiques :

- Les chalutiers représentent 12% de la flottille totale de la région d'étude. 79% de ces chalutiers ont une activité benthique et le reste sont pélagiques. 68% de cette flotte est munie de coque en bois tandis que le reste a une coque en acier. Ces unités ont une longueur comprise entre 15,59 et 32,96 mètres et sont propulsés par un moteur dont la puissance peut atteindre 850 Cv.

- Les sardiniers occupent le second rang avec 24% de la flottille du port de Kélibia. Elles ont une longueur comprise entre 13.5 et 25,03 mètres, une puissance motrice comprise entre 100 et 660 CV et une jauge brute allant de 11.77 à 93.65 tjb. Ces unités sont souvent associées à une ou deux embarcations annexes (**Photo.1**) : le groupât appeler aussi porte-groupe. Il est de puissance motrice comprise entre 10 et 60 CV et la stance (skiff) est d'une longueur moyenne égale à 10 m. Ces embarcations ciblent différentes espèces de petits pélagiques avec d'autre espèces accessoires partageant la même niche écologique. Nous citons : la Sardine (*Sardina pilchardus*), la Sardinelle (*Sardinella aurita*), l'Anchois (*Engraulis encrasicolus*), le Maquereau (*Scomber scombrus*), la Bogue (*Boops boops*) et le Chinchard (*Trachurus trachurus*). Le Thon rouge (*Thunnus thunnus*), le Calmar (*Loligo vulgaris*), la Bonite à dos rayé (*Sarda sarda*) peuvent être capturés comme espèces accessoires (**Fig.3**).

Photo 1 : Un sardinier trainant derrière lui la stance

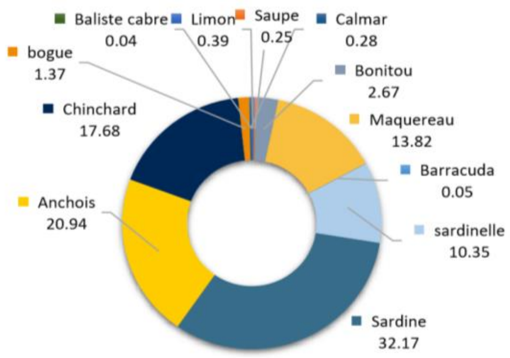


Figure 3 : Principales espèces de petits pélagiques débarquées dans le port de Kélibia (DGPA, 2020)

Aucune saisonnalité de l'effort de pêche n'a été soulevée. Les pêcheurs questionnés attestent qu'ils fréquentent les zones de pêche habituelles (**Fig.4**) tout au long de l'année à raison d'une moyenne mensuelle de 5 et 15 sorties respectivement en hiver et en été. Quand les conditions sont favorables à la pêche et hors la période de la pleine lune l'effort de pêche s'intensifie. Les grandes embarcations (LHT>18m) munies d'unité frigorifique peuvent entamer des sorties en mer de trois jours à des zones de pêche distantes du port d'attache soit jusqu' à plus que 20 miles nautique. Tandis que les petites embarcations (LHT<18m) ne passent qu'une seule nuitée en mer et retournent au port le lendemain à l'aube. Pour l'année 2021, Le capital investi estimé était aux alentours de 30164 milles dinars. Le volume de débarquement était de l'ordre de 3772 tonnes pour une valeur globale de 11589 milles dinars.

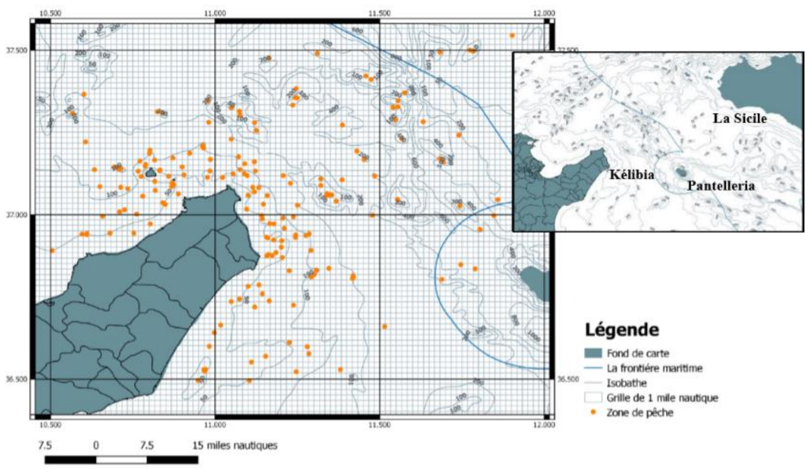


Figure 4 : Zones de pêche fréquentées par les sardiniers de la région de Kélibia

Caractérisation des engins de pêche

Les sardiniers de la région de Kélibia ont tendance a utilisé deux types de sennes : sennes tournantes coulissantes (STC) et des Diabolos. 82% des armateurs opèrent avec des STC et disposent de deux sennes : une à bord et une à quai. La loi nº 94-13 relative à l'exercice de la pêche en Tunisie interdise la pêche au feux par des profondeurs inférieures à 35 m;

Il est à noter qu'il n'existe pas un calendrier de pêche ou des campagnes de pêche des petits pélagiques. Le t**ableau 2** résume les mois de haut débarquement de chaque espèce ciblée par les sardiniers.

Tableau 2 : Calendrier de pêche des petits pélagiques dans la région de Kélibia

Espèces	**Mois**											
	Janvier	**Février**	**Mars**	**Avril**	**Mai**	**Juin**	**Juillet**	**Aout**	**Septembre**	**Octobre**	**Novembre**	**Décembre**
Maquereau	□	□	□	□	■	■	■	□	□	□	□	□
Sardine	□	□	□	■	■	□	□	□	□	■	■	□
Allache	□	□	□	□	□	□	■	■	■	□	□	□
Saurel	□	□	■	■	■	■	■	■	□	□	□	□
Bogue	□	□	□	□	□	□	□	□	□	□	□	□
Anchois	□	□	■	■	■	■	□	□	□	□	□	□

□ Débarquement moyen

■ Pic de débarquement

Caractérisation de la population maritime

Selon les données recueillis de l'annuaire statistique de la Direction Générale de la Pêche et de l'Aquaculture (DGPA, 2019) le Gouvernorat de Nabeul compte 3726 marins pêcheurs dont plus que 44% (n=1644) assurent l'activité de pêche dans la région de Kélibia. L'effectif des marins pêcheurs, au niveau du gouvernorat de Nabeul, suit une répartition non homogène. Nous avons remarqué que la majorité de la main d'œuvre est localisée dans la région de Kélibia vue le nombre important de la flottille qui y accoste.

La **figure 5** illustre la répartition de la main d'œuvre par type de pêche dans la région de Kélibia. La pêche au feu, appelée aussi pêche aux petits pélagiques, mobilise à elle seule 45.62% de la population maritime du port de Kélibia. Les marins opérant dans le secteur de la pêche côtière viennent en seconde position. Ils représentent 32% de la population maritime globale.

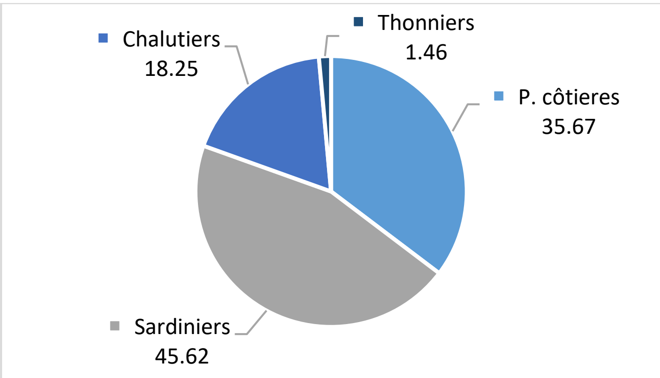


Figure 5 : Répartition de la population maritime par type de pêche dans la région de Kélibia (DGPA, 2020)

III. Méthodologie

Afin de faire un état sur la situation de déprédation, cette action complémentaire est menée dans le cadre d'une démarche participative, où les pêcheurs sont des acteurs à part entière.

L'étude comporte trois volets :

- Un volet écologique avec un inventaire des espèces de delphinidés interférant avec la pêche et un suivi de la démographie et l'éthologie de ces espèces.
- Un volet sociologique avec des enquêtes pour mieux comprendre la ressenti des pêcheurs par rapport aux phénomènes de déprédation et du by-catch. Le contexte socio-économique de la pêche professionnelle est également étudié.
- Un volet halieutique avec des embarquements à bord des sardiniers/ senneurs afin de mieux évaluer les risques de déprédation et la capture accidentelle et la corrélation avec le contexte environnemental.

1. Suivi de la population du Grand dauphin

Un suivi du Grand dauphin a été fait autour de la ferme aquacole « *Teboulba Tunisian Fish* » sise à l'Est de la Tunisie (**Photo.2**). C'est une société aquacole spécialisée dans l'élevage, le grossissement et la commercialisation de trois espèces de poissons : la Daurade royale *(Sparus aurata)*, le Loup *(Dicentrarchus labrax)* et le Maigre *(Argyrosomus regius)*.

Photo 2 : Site d’étude, la ferme TTF *(@MAVA-Déprédation – Tunisie)*

TTF pratique l’élevage des Daurades royales et Loups de la mer dans des cages flottantes en mer ouverte d'une profondeur de 35m au large de la mer de Teboulba. TTF est devenue parmi les Leader en Tunisie, d’une capacité de production annuelle de 2000 Tonnes de poissons de différents calibres avec une haute qualité. Durant la période d’observation, l’élevage s’effectue dans 61 cages, repartie sur quatre réticules A, B, C et E (**Fig.6**). Sur 61 cages, 28 cages sont utilisées pour élever la Daurade royale, 20 cages pour élever le loup et 13 cages pour élever le maigre (**Tab.3**).

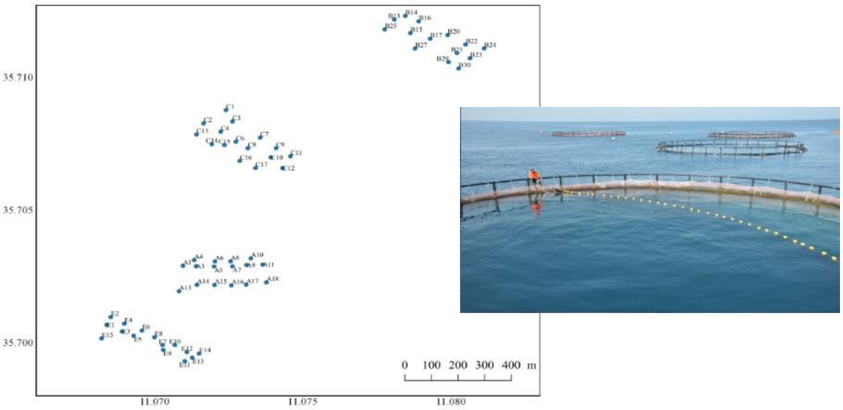


Figure 6 : répartition des cages au sein de la ferme aquacole

Tableau 3 : Espèces e poissons élevées par réticules

Réticules	Espèce élevée	Cages de cages	Total cage
A	Daurade	3	16
	Loup	8	
	Maigre	5	
B	Daurade	8	14
	Loup	1	
	Maigre	5	
C	Daurade	9	16
	Loup	4	
	Maigre	3	
E	Daurade	8	15
	Loup	7	
	Maigre	0	

Les observations directes

Durant le jour, la surveillance peut être réalisée à l'œil nu ou à l'aide de jumelles, par contre à l'obscurité, nous pouvons avoir recours à des jumelles de vision nocturne ou l'aide d'un hydrophone. Lors d'une observation, on peut observer un individu solitaire, ou en couple ou en groupe. Selon Shane (1990) un groupe est défini comme étant une agrégation d'animaux observés ensemble, dans la même zone, se déplaçant dans la même direction et engagés dans la même activité.

Conditions d'observation

En respectant la méthode d'Altmann (1974), des observations instantanées d'une durée de 20 minutes doivent être effectuées pour obtenir des informations sur l'absence ou la présence des dauphins. A la moindre détection de delphinidés, l'observateur s'immobilise pour identifier l'espèce, estimer la taille du groupe, relever l'activité qui mène le groupe à la surface de l'eau. De même, l'observateur notera les coordonnées géographiques de l'observation, la bathymétrie, l'heure de début et de fin ainsi que la durée du contact avec le groupe. Il est à noter qu'une observation n'est considérée comme achevée que si (i) la totalité des individus présents au sein du même groupe est photographiée, (ii) lorsqu'ils disparaissent de la vue (presque après 10 min de leur dernière émersion) ou bien si la formation du groupe ou son activité change (Benmessaoud *et al.,* 2018).

Il est primordial de prendre en considération, à chaque opération d'échantillonnage, un ensemble des variables environnementales (vitesse de vent, état de la mer, température de l'eau et visibilité, autres espèces…) et anthropiques (nombre et type des bateaux près de la ferme). Or la détection visuelle dépend de la durée d'émersion des Cétacés à la surface de l'eau et des facteurs météorologiques. D'après Gannier (1997 ; 1998b), les conditions favorables à la détection sont une mer calme et suffisamment d'ensoleillement. Les opérations de prospections et d'observations doivent s'établir que dans les conditions sus évoquées (mer calme avec niveau 3 à l'échelle de Douglas et une force de vent ne dépassant pas le niveau 3 à l'échelle de Beaufort). Ces paramètres doivent être relevés tous les 30 min.

Le choix des trajectoires n'est pas aléatoire mais orienté vers les cages et dépend du type de l'embarcation qui nous embarque (de patrouille ou d'alimentation). Mais dans tous les cas elle n'est pas être influencée par des détections antérieures des delphinidés. Une tentative de randomisation des routes empruntées par les différents types d'embarcations sera faite dans le but de couvrir tous les réticules.

Pour étudier les fluctuations saisonnières de présence des dauphins dans les fermes aquacoles, 4 saisons seront définies : hiver (janvier-mars), printemps (avril-juin), été (juillet-septembre) et automne (octobre-décembre). D'autre part, pour étudier les fluctuations circadiennes (+/-24h), nous pouvons diviser la journée en 3 périodes à durée égale (matin, après midi, crépuscule), et ceci en se basant sur la durée moyenne mensuelle de la journée (les heures comprises entre le coucher et le lever du soleil sont considérées comme « nuit »).

Formation des groupes

La taille du groupe sera estimée sur la base du nombre d'individus observés en surface et en une seule fois. L'estimation du nombre d'individus est souvent difficile à réaliser ; pour surmonter ce problème, il est important d'attribuer à chaque groupe un nombre maximal, un nombre minimal et un nombre moyen appelé « *best* » (Alessi, 2008). La composition du groupe est déterminée en comptant les adultes, les sub-adultes, juvéniles et les nouveau-nés présents. Dans cette étude, on va considérer que deux classes d'âges en se basant sur les travaux de Bearzi (2005) :

- **Les adultes** : tout individu dont la taille est supérieure à 2.5m.
- **Les immatures** : dont la taille ne dépasse pas le 2/3 de la longueur d'un adulte.

La détermination de sexe est très compliquée chez les dauphins en raison de la présence des organes génitaux sur la face ventrale. Le sexage sera établi en se basant sur les constats de Read *et al.,* (1993) et Tolley *et al.,* (1995) qui mentionnent que les individus supposés être des « mâles » sont de plus grande taille et présentent plus de cicatrices que les individus supposés être des « femelles ». Diaz López (2012), a affirmé que tout individu adulte accompagné dans la majorité du temps (une durée qui dépasse les 2 mois) par un jeune individu est supposée être une « femelle ».

Photo identification

La photo-identification est une technique qui permet de caractériser :

- Les paramètres démographiques de la population (taille et composition des groupes, taux de survie, taux de naissances…) ;
- L'utilisation de l'habitat (distribution spatio-temporelle, fidélité au site, modèle de déplacement) ;
- Les changements qui peuvent survenir dans la population (naissances, morts, maladies…) ;
- Les structures sociales reliant les différents individus observés dans le même groupe.

Cette méthode permet d'identifier les individus à partir de leurs marques permanentes servant comme caractères individuels reconnaissables. D'après Benmessaoud (2014), pour les delphinidés, les prises de photos ne concernent que la nageoire dorsale et sa base. Le bord de la nageoire dorsale, en particulier, est facilement endommagé d'où résulte un profil unique de cette nageoire. On doit tenir en compte de la grandeur, forme, pigmentation/ dépigmentation de la nageoire dorsale et de la présence d'encoches, des entailles et des mutilations sur cet aileron. Il ne faut pas se focaliser sur les traces de denture dans la reconnaissance des spécimens car ce type de cicatrice s'estompe au cours du temps ce qui peut fausser l'identification et amener à des doublons. Cependant tous les individus appartenant à un même groupe doivent avoir la même chance d'être pris en photos ; le degré de marquage de certains animaux ne doit pas influencer les prises de photos (Benmessaoud, 2014).

Selon Fortuna (2006), l'observateur devra prendre au moins trois à cinq photos de chaque spécimen, montrant aux mieux les deux côtés de la nageoire dorsale. Une fois le travail de terrain terminé, seules les photographies de bonne qualité et jugées exploitables pour la photo-identification seront conservées. D'après Benmessaoud (2014), les meilleures photos retenues seront alors analysées. L'analyse consistera à comparer les ailerons un à un. Il s'agit de vérifier les concordances entre les nouvelles images prises en mer et celles présentes au sein des bases de données existantes. La comparaison et la conformation des photographies du jour, de la semaine, du mois ou de la saison précédente, sont appelées « *Matching* ». Chaque individu nouvellement indexé aura un identifiant qui lui est propre.

Analyse comportementale

Le comportement est défini comme étant l'activité principale du groupe à laquelle la majorité des individus s'adonne initialement lors de leur détection. Plusieurs critères peuvent permettre d'affilier l'activité des animaux à un des comportements types. Ces critères sont notamment la taille et la structure de groupe, la durée du comportement, le temps de plongée, la présence d'activités ponctuelles à la surface (saut, frappe de la caudale ou la pectorale, exposition d'une partie du corps), la direction et la vitesse de nage (Ballance, 1992 ; Würsig *et al.,* 2003). Pour la description de la structure, de l'activité à la surface, de la direction et de la vitesse de nage des groupes focaux nous avons suivi ceux décrit par De Meglio (2013) et Benmessaoud et al., (2021).

Les catégories de comportement sont définies comme suit :

- La recherche de nourriture/ alimentation,
- La locomotion ou bien le déplacement,
- La socialisation,
- Le repos,
- La reproduction,
- Les interactions avec les engins de pêche.

L'un des principaux objectifs de cette étude est la détermination des budgets comportementaux des grands dauphins se trouvant dans la région d'étude. Il s'agit d'évaluer le pourcentage de temps alloué par les individus observés aux différents états comportementaux. Selon Weaver (1987) et Bearzi (2005), un état de comportement est défini comme une large catégorie d'activités qui intègre un certain nombre de modèles de comportement individuels dans un modèle reconnaissable. L'activité principale des groupes focaux a été enregistrée toutes les 10 minutes ce qui est considéré comme un temps suffisant permettant à la fois l'observation et l'enregistrement du comportement des dauphins (Díaz López, 2006a).

La taille des groupes observée sous l'eau n'est pas toujours cohérente avec la taille des groupes déterminée à la surface de l'eau. Le nombre de dauphins en association, observé lors de rencontres sous-marines, est défini comme un « sous-groupe » (Díaz López, 2006a). Chaque rencontre se poursuit jusqu'à la perte du sous-groupe (un sous-groupe sera considéré comme perdu après 3 min sans observation). Des prises de photos et de vidéos seront faites par un appareil *GoPro 5*. Lors d'une observation sous-marine, l'observateur notera sur un tableau deux critères : (i) la présence prolongée de dauphins entre les cages piscicole (> 30 min) et (ii) état de la mer <4 sur l'échelle de Douglas (Díaz López, 2006b). Les observations sous-marines seront recueillies par les plongeurs de la ferme aquacole. Un test du Khi-deux sera utilisé pour vérifier la variation de la taille des groupes en fonction du comportement suivi par le groupe.

Organisation sociale

Les animaux photographiés dans le même groupe et ayant la même catégorie d'alimentation ont été considérés comme associés. Le coefficient d'association (CoA) illustre l'intensité du lien social reliant deux individus observés ensemble. Les coefficients d'association (COA) varient de zéro à un (0 représente deux animaux jamais vus ensemble, 1 représentant deux animaux jamais vus séparément). Le *Half-Weight Index* (HWI) sera utilisé pour mesurer le CoA.

$$\mathbf{HWI} = \frac{\mathbf{2 * N}}{(\mathbf{Na + Nb})}$$

N est le nombre d'observations qui comprenait à la fois les dauphins a et b,
$\mathbf{N_a}$ est le nombre d'observations qui comprenait le dauphin a mais pas le dauphin b,
$\mathbf{N_b}$ est le nombre d'observations qui comprenait le dauphin b mais pas le dauphin a.

Le test de permutation sera utilisé pour tester les associations réelles (non aléatoires) pour toutes les données combinées par rapport aux hypothèses nulles que les dauphins s'associent au hasard les uns aux autres. Le même test sera utilisé pour tester les associations réelles (non aléatoires) pour chaque réticule. La matrice d'association observée sera randomisée 3000 fois avec 1000 essais par permutation pour chaque analyse. Les associations seront permutées dans les intervalles d'échantillonnage quotidiens pour éliminer les éventuels effets démographiques. Le sociogramme facilitera la présentation des données d'association individuelle de sorte qu'il sera possible d'évaluer la structure sociale des dauphins identifiés au cours de chaque année d'étude. Dans le sociogramme, les dauphins seront représentés par des nombres autour du périmètre du diagramme. L'épaisseur des lignes adjacentes dans le diagramme représentera la force des associations entre les individus.

2. Suivi de la déprédation

Etude quantitative des interactions entre les Grands dauphins et les STC

Enquêtes

Le suivi des interactions entre *Tursiops truncatus* avec et les STC s'est fait à l'aide de questionnaires (**Annexe-1**), spécifiquement élaborés pour cette action. Les fiches utilisées sont celles mentionnées par Benmessaoud et al., (2021). Ces questionnaires permettent de recueillir des données concernant la qualification et la quantification des interférences.

Une nouvelle fiche enquête (**Annexe-2)** a été élaborée par l'expert en économie de la pêche afin de collecter des données nécessaires à la bonne compréhension socio-économique de l'activité des sardiniers dans la zone d'étude. L'analyse de ces données via les différents variables collectées et les indicateurs estimés permettront l'évaluation de la perte économique du phénomène de la déprédation dans cette pêcherie.

Organisation des suivis de pêche

Au moins un observateur est présent à bord d'un des sardiniers suivis durant cette étude. L'embarquement s'effectue avant le coucher du soleil, vers 17 heures l'après-midi et pour une sortie de pêche de 8 heures en mer. Cette présence à bord permet à la fois (i) de mieux comprendre les aspects techniques de cette pêche, (ii) de mieux comprendre et documenter le phénomène de déprédation et (iii) de participer au déroulement de l'opération de pêche et au tri et mise en caisses de la capture.

Durant chaque sortie en mer, l'observateur embarqué est appelé à remplir les fiches questionnaires mentionnées ci-dessus. Il est important de rapporter des informations sur la présence-absence de spécimens de dauphins autour du navire. Pour cette partie, nous avons suivi les recommandations de Monaco et al., (2020) quant à la non-observation de dauphins à cause des conditions défavorables d'observation (les conditions météorologiques, les opérations de nuit, etc.) ou l'incapacité de l'observateur de prendre note de cette information. D'après ces auteurs, il s'agit de l'exigence minimale pour évaluer la répartition et les schémas spatiaux des dauphins, et pour comprendre si la déprédation se produit à un niveau notable et pour faire des observations. Monaco (2020) a rajouté qu'il est important de noter que la « présence de dauphins» ne fournit que des informations sur l'endroit où les spécimens ont été aperçus, et ne fournit guerre une idée exacte ni sur l'habitat préfrentiel ni sur la niche écologique de ces derniers. Le même auteur recommande de fournir une brève description de la formation du groupe et de son éthologie en cas où les conditions sont bonnes.

Sur ces fiches, une attention particulière est accordée à la variation du volume des prises ainsi que les captures endommagées. Il est important de remarquer que les captures totalement prélevées par les dauphins ne peuvent pas être comptabilisées lors de la prise de données. Une note est marquée sur le volume de capture observé et celui débarqué.

Durant l'opération de pêche, différents points ont pu être notés dans les fiches :

- *Identificateurs du relevé* : date, heure, embarcation, coordonnées GPS au début et à la fin de la calée du filet, profondeur.
- *Descripteurs de l'effort de pêche* : type d'embarcation (senneur/ sardinier), durée de l'opération de pêche.
- *Descripteurs d'interaction avec les dauphins* : observation éventuelle de dauphins dans la zone de pêche et/ ou à proximité du filet ; nombre, surface et position des perforations ; quantification des rejets de poissons endommagés par les puces, les dauphins et autres. Pour préciser qu'il s'agit d'une interaction négative entre delphinidés et sennes, on se limite seulement à la présence de perforations/ trous spécifiques au niveau des filets. Cet indice spécifique sera retenu vu qu'il est difficile de trouver des captures endommagées vu que ces dernières ne s'emmêlent pas au niveau des sennes.

Le choix de la zone de pêche et la route longée est imposé par le pêcheur. Nous avons eu l'opportunité d'embarquer à bord de plusieurs sardiniers/senneurs. Ces embarcations ont une vitesse de croisière et des puissances motrices variées qui nous ont permis de nous éloigner aisément de la côte. Ces dernières présentent aussi des tirants d'eau différents. Ces tirants d'eau offrent de multiples degrés de visibilité théorique ce qui nous permet de bénéficier d'une bonne détection visuelle des delphinidés. Les fiches questionnaires remplies à bord nous ont permis de relever toutes les 20 min les positions géographiques du navire. Une cartographie des routes suivies et des positions des observations de spécimens ou de groupes de dauphins a été faite à l'aide du logiciel *QGIS 2.14.3.*

Analyse des données

L'intensité du phénomène de déprédation est évaluée sur la base de la fréquence des sorties de pêches réalisées. Pour une échelle temporelle cette intensité est estimée par une fréquence moyenne mensuelle permettant de suivre l'évolution du phénomène d'attaque au cours de l'année.

Le calcul retenu pour l'évaluation des fréquences d'attaques est celui mentionné par Zahri *et al.,* (2004).

$$\textbf{Freq}_{p,i} = [(\textbf{SP att}_{p,i}) / \textbf{SP t}] * 100$$

SP att p, i: sortie de pêche attaquée dans le port (p) et le mois (i)
SP t : sortie de pêche totale

Pour évaluer le niveau de dommages des filets associés à la déprédation des dauphins, les observateurs ont comptés les perforations/trous dans le filet avant et après chaque opération de pêche. Les Observateurs ont classé les trous selon :

- Le nombre : ($N_1 < 50$; $50 \leq N_2 < 100$; $N_3 \geq 100$),
- La taille : (petite <20 cm ; moyenne 20-40 cm ; large> 40 cm). Il est à noter que les trous de petite taille peuvent être induites par la déprédation causée par *Octopus vulgaris* et *Muraena helena* (Brotons *et al.,* 2008).
- L'emplacement : ceintures (supérieure et inférieure), corps du filet et la poche. La location verticale a été enregistrée car la partie inférieure du filet peut être endommagée par le contact direct avec le fond de la mer, en particulier avec les rochers et les épaves. Quant à la partie supérieure, cette dernière peut également être endommagée par contact avec les flotteurs lors de la manœuvre du filet.

Afin d'évaluer les dégâts sur la capture, les dégâts morphologiques de chaque spécimen capturé ont été rapportés selon les cinq catégories mentionnées par Lauriano et al., (2004- **Photo.3**).

Photo 3: Reste de proies déprédées

De plus, le débarquement journalier par espèce de chaque embarcation faisant part de cette étude a été relevé et saisi dans une base de données. Le Débarquement par Unité d'effort (DPUE) est défini comme étant le total de débarquement (en grammes) divisé par la longueur d'une pièce de la senne (100 mètres) pour une journée de pêche (Ben Arfa, 2022). Une comparaison entre les différents DPUE en présence-absence de déprédation a été faite afin de dégager l'influence de cet événement sur le volume de débarquement et de dégager indirectement un attrait à une composition particulière de la capture.

Analyse socioéconomique

Cette partie a été établie par un expert en économie de pêche qui, à part les données par fournies par l'équipe MAVA-Déprédation Tunisie, a pu collecter des données des autorités compétentes soit directement de la profession de la région suite à des interviews directs. Les données colossales collectées ont permis de dégager différents indicateurs et variables. Ces derniers se présentent en groupe de variables à savoir : l'effort de pêche, l'emploi, la commercialisation, les coûts variables, les coûts fixes, les investissements, les dettes et les subventions, les revenus et la démographie. La méthode de leur estimation est celle mentionnée par FAO (2017).

D'aprés Ben Arfa (2022), la perte économique de la déprédation peut être divisée en deux parties (**Fig. 7**). La premiere partie englobe la perte économique directe totale (PEDt) présentée sous forme de charges financières subies par l'armateur durant l'excercice de pêche. Ces charges sont comme suit :

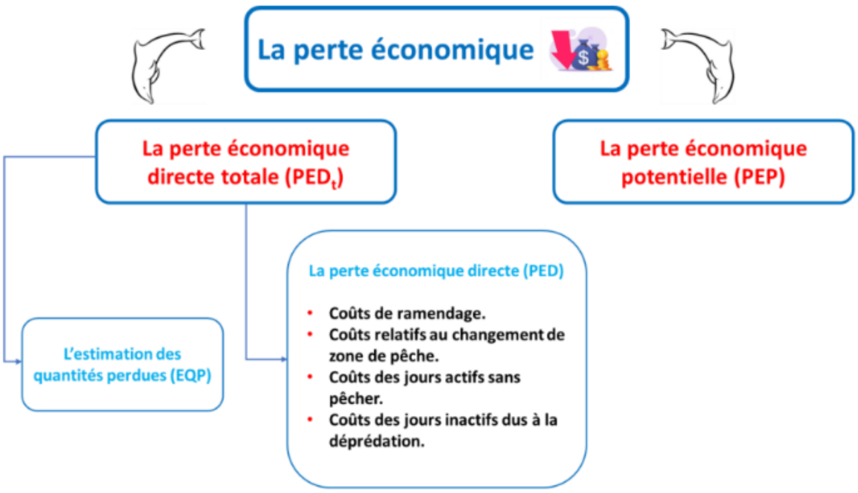


Figure 7: Caractérisation de la perte économique de la déprédation causée par le dauphin

- *Les coûts de ramendage* : cette variable concerne principalement les coûts de ramendage liés aux dommages perpétués par le dauphin (**Photo. 4**). Les coûts de ramendage perpétués par d'autres prédateurs ou ceux dus aux épaves ou aux fausses manœuvres sont exclus de cette estimation économique.

Photo. 4: Exemple de déchirure causée par le dauphin

- *Les coûts de sorties actives sans pêcher* : cette variable s'intéresse essentiellement à identifier le nombre de sorties annuelles actives sans débarquement à cause de la présence du dauphin. L'estimation de cette variable nécessite l'estimation du coût moyen annuel de la sortie par navire.
- *Les coûts de jours inactifs* : cette variable se focalise principalement sur le nombre de jours inactifs sans activité dont la raison est le ramendage des sennes endommagées par le dauphin. Au port de Kélibia, les sardiniers disposent de deux sennes tournantes coulissantes ce qui minimise l'ampleur de ces coûts.
- *Le coût de l'énergie additionnel* : Il s'agit essentiellement du coût de carburant consommé lors du changement de la zone de pêche à cause de la présence excessive du dauphin et handicapante au travail. Cette variable a été calculée sur la base de la distance additionnelle parcourue ou bien sur la base de temps écoulé pour arriver à la nouvelle zone de pêche. Une moyenne de consommation de gasoil par navire par unité de temps ou de distance a été identifiée.
- *La quantité de poissons perdus lors de l'opération de pêche* : cette variable décrit une estimation potentielle des quantités de poissons escampés ou perdus (EQP) par les différentes déchirures faites par le dauphin dans la senne. Les attaques peuvent être localisées principalement au niveau de la poche de l'engin, l'avant poche ou bien au niveau du corps de la senne. L'estimation de cette variable reste tributaire de l'observation et de l'estimation personnelle faite par le patron de pêche.

La deuxième partie traite la perte économique potentielle (PEP) qui est définit comme étant un manque à gagner potentiel. Cette partie s'intéresse principalement à la dispersion du poisson suite à la présence du dauphin. Cette variable, fortement réclamée par les pêcheurs, consiste à quantifier la masse de poissons perdue suite à la dispersion du banc par le dauphin durant l'opération de pêche. L'estimation économique de cette variable reste complexe pour plusieurs raisons dont nous pouvons citer quelques-unes :

- L'estimation de la quantité de poissons dispersée par le capitaine reste approximative et incertaine.
- Il y a une certaine ambiguïté et confusion dans la détermination de la composition en espèces du banc détecté par le sonar ou le sondeur. Suite à ces deux déductions, l'estimation de cette variable parait alambiquée. Sa réalisation requiert un suivi rigoureux à bord du navire et une assistance des capitaines.

3. Essai d'atténuation de la déprédation

Mesure d'atténuation acoustique

Il est prévu dans cette partie d'établir des expérimentations de différents types de répulsifs acoustiques à savoir :

- *Dolphin Deterrent Device* (DDD-03-H);
- *Dolphin Interactive Deterrent* (DiD-01);
- Le système LICADO.

Les caracteristique techniques de ces différents répulsifs sont résumés dans le **tableau 4**. Les répulsifs seront testés à la fois au niveau de la ferme aquacole de Teboulba (conditions bassin d'essai) et en condition de pêche pour les sennes de la région de Kélibia. Seule l'expérimentation, couplée à un hydrophone, en condition bassin n'a pas été faite.

Tableau 4: Caractéristiques techniques des trois modèles de répulsifs acoustiques utilisées dans l'étude

Caractéristiques/Répulsifs	DDD-03-H	DiD-01	Licado
Fréquence (kHz)	5-500		27-120
Intensité (dB (1 µPa @ 1m))	165		180
Profondeur (m)	10-200m		Jusqu'à 150m
Pression	3 Mpa (30 Bar)		
Dimension (diamètre*long)	62mm * 215mm		85mm* 220mm
Poids	940g		2.2 Kg
Caractéristique – **Durée de chrge de la batterie** (heures)	40 heures	Dépend des fréquences émises par les dauphins	
Caractéristique – **Distance horizontale entre deux appareils**	300 et 500 m		
Caractéristique – **Distance verticale entre deux appareils**	60 à 80 m		
Photos			

Positionnement des pingers

Pour cette partie nous avons suivi la même approche avancée par Benmessaoud et al., (2021). En effet, un seul répulsif acoustique est déployé par senne (**Fig. 8**). Ce répulsif doit attacher à une ligne de mouillage et suspendu le plus verticalement possible à l'arrière de la barque porte-groupe du début de l'opération de pêche jusqu'à sa fin

.

Comme indiqué par Benmessaoud et al., (2021), le but de cette partie est comparé l'efficacité respectives des répulsifs acoustiques choisis dans le cadre de cette étude et ce par la production d'une série statistique. En effet, 14 embarcations ont bénéficié de répulsifs (06 DDD-03-H, 06 DDD-01, 02 Licado) tandis que six autres embarcations dépourvues de répulsifs serviront de témoin. Chaque embarcation munie d'un répulsif assurera une alternance entre chaque opération de pêche « avec répulsif » puis « sans répulsif ». Il est très important de respecter l'ordre de la séquence « avec répulsif » / « sans répulsif » dans la série des opérations de pêche à réaliser dans les mêmes conditions (Benmessaoud et al., 2021). Ces auteurs insistent aussi sur le fait de respecter l'alternance entre la séquence « avec /sans répulsif » durant la même sortie comme indiqué dans le **tableau 5**.

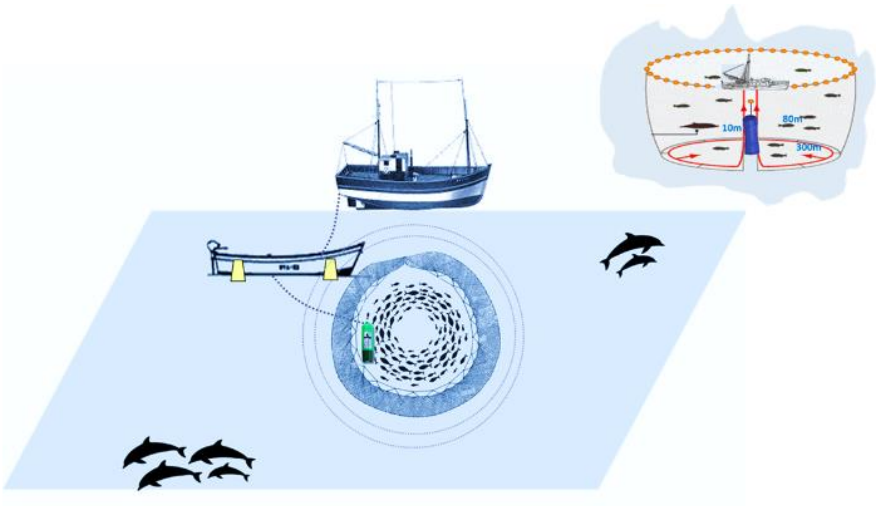


Figure 8 : Dispositif de déploiement d'un répulsif acoustique depuis la barque annexe porte-groupe

Tableau 5 : Schéma théorique de l'alternance des opérations de pêche avec /sans répulsif

Mois/Operations de pêche	Opération 1	Opération 2
Jour$_1$	Avec répulsif	Sans répulsif
Jour$_2$	Sans répulsif	Avec répulsif
Jour$_3$	Avec répulsif	Sans répulsif
	Sans répulsif	Avec répulsif
Jour$_n$	Avec répulsif	Sans répulsif

Chaque jour, avant le départ des navires, une vérification de l'état de fonctionnement des répulsifs sera effectuée par un observateur afin de garantir les résultats. Durant la période de l'étude, aucun remaniement des répulsifs n'aura lieu sauf en cas de perte ou disfonctionnement. Les autres navires de la flottille, non équipés de pinger, devront également renseigner les fiches de déprédation.

Méthodologie d'analyse

L'analyse utilisée pour tester l'efficacité des répulsifs acoustiques choisis pour cette étude est celle décrite par Benmessaoud et al., (2021). Cette analyse consiste à estimer :

- La répétitivité des évènements de déprédation lors d'une opération de pêche tout en tenant compte de la durée de cette dernière,
- Le nombre et la taille des perforations, en cas de déprédation, donc d'estimer l'intensité de l'évènement,
- La position des perforations dans le filet permet de mieux situer à quel moment de la calée ont lieu les attaques et de spécifier la vulnérabilité des phases de pêche.

Pour ce faire, les observateurs à bord et les patrons de pêche déja formés inspectent les conséquences de l'utilisation des répulsifs tout en surveillant le taux de présence de dauphins à proximité des sennes, le comportement suivi (nage en direction des filets, rode près de la senne, s'éloigne de la senne), la fréquence de déprédation, la typologie des perforations (nombre, taille et position des déchirures) et l'efficacité des répulsifs.

Pour le taux de présence des dauphins autour des filets de pêche, il s'agit d'un rapport entre le nombre de sorties où les pingers sont utilisés et que nous avons observés les dauphins sur le nombre totale de sorties.

La fréquence de déprédation avec ou sans l'usage des répulsifs est calculé selon la formule de Zahri *et al.,* (2004). L'efficacité d'un répulsif est calculé comme suit :

Eff $_i$ = Fréquence de déprédation avec répulsif / fréquence de déprédation sans répulsif

Mesure d'atténuation technique

Une des recommandations avancée par Benmessaoud et al., (2018; 2021) est de chercher d'autres alternatives pour remédier au problème de déprédation pérpétué par le Grand dauphin comme le développement d'activités compensatrices (pescatourisme, whale watching) des pertes et attribuant une valeur ajoutée en même temps à cette interaction. Cependant, ceci est difficile a être mis en place avec l'absence de texte législatif qui réglemente cette activité.

Nous nous sommes orientés, en concertation avec les patrons de pêche et les ramendeurs de la région d'étude, vers le changement des pratiques de pêche. Nous avons songé à renforcer les sennes sujettes de déprédation et ce dans ses parties les plus fragiles et les plus vulnérables soit au niveau de l'avant poche et la poche. A cet effet, une enquête a été élaborée pour réactualiser les caractéristiques techniques des sennes utilisées par l'échantillon de flottille suivi dans le cadre de l'étude et proposer des changements.

4. Etude du régime alimentaire

Une autre manière d'étudier la population du Grand dauphin consiste à intervenir dès qu'ils s'échouent sur un site côtier. Chaque échouage est une source précieuse d'informations scientifiques. L'échouage peut nous renseigner sur la répartition géographique, l'identification d'espèces rares, la biologie et l'éthologie alimentaire (Larbi Doukara et al., 2013). Un échouage doit être suivie par une nécropsie et des analyses complémentaires afin de déceler à la fois la cause de mortalité et les principales menaces qui pèsent sur eux (Jauniaux et al., 1999).

Une fois récupeéé, le cétacé échoué est photographié en allant du gros plan aux détails (denture, cicatrices sur la nageoire dorsale, région génito-anale). Les photographies peuvent faciliter l'identification subséquente d'espèce, sexe et âge relatif.

A la suite, des mensurations seront faites. La technique de la mensuration appliquée dans ce travail est celle adoptée par Boutiba (1992). Les mesures corporelles seront prises en plaçant un mètre-ruban parallèlement à l'axe longitudinal du corps et non pas selon les courbes du corps. Le relevé le plus important est la longueur totale. Une fiche signalétique est remplie pour chaque observation de cétacé échoué ou capturé accidentellement dans les eaux territoriales. Les informations relatives aux commémoratifs de l'échouage (date, lieu, circonstance de l'observation, observateur) et les informations concernant l'animal (espèce, sexe, biométrie, blessure, état de décomposition, etc.) sont relevées minutieusement (**Annexe-3**). Toutes ces données sont stockées dans une base de données de référence.

Le contenu stomacal, à savoir les restes non-digérés retrouvés dans les estomacs, et les fèces sont recupérés pour l'étude de l'écologie alimentaire des echoués. Cette méthode repose sur l'identification des restes stomacaux non-digérés présents dans le tractus digestif à la mort de l'animal, soit sur la base de critères taxonomiques classiques lorsque les restes sont peu digérés, soit de pièces diagnostiques dures telles que les otolithes et les os chez les poissons ou les mandibules, communément appelées becs, chez les céphalopodes. D'autres techniques ne cessent d'émerger et qui présentent des alternatives à l'analyse traditionnelle des contenus stomacaux. Il s'agit de l'identification génétique des restes non-digérés et l'utilisation de traceurs écologiques. Ces traceurs sont de différentes natures : acides gras, métaux, isotopes stables du carbone et de l'azote (Marçalo et al., 2018).

Dans le cadre de cette étude nous allons nous contenter des analyses classiques afin de fournir une description du bol alimentaire de neuf spécimens (n=09) de *Tursiops truncatus* échoués le long des côtes tunisiennes (**Tab.6**). Afin d'avoir une idée sur le régime alimentaire de l'espèce de delphinidés qui interaggissent le plus avec les pêcheries tunisiennes et spécifiquement avec les sardiniers, nous avons tenu à calculer l'indice de vacuité, la méthode d'occurrence, la méthode numérique, la méthode pondérale et l'indice d'importance relative.

Selon Astruc (2005), l'index de vacuité correspond à la proportion d'estomacs vides (E0) par rapport au nombre total d'estomacs étudiés (E).

VI= (E0/E)*100

La méthode d'occurrence comptabilise le nombre d'estomacs contenant au moins un individu de chaque catégorie de proie (Astruc, 2005). Cette méthode est utilisée comme indicateur de la compétition interspécifique en supposant que, quand l'occurrence d'une espèce proie est supérieure à 25% pour deux prédateurs ou plus, la concurrence est probable (Johnson, 1980). La méthode a été aussi utilisée pour illustrer des changements saisonniers de régime alimentaire (Frost 1977 in Hyslop, 1980). Cette méthode n'a qu'un intérêt qualitatif, puisqu'elle ne prend pas en compte le nombre d'individus pour une catégorie de proie. Elle évalue une disponibilité dans le milieu de chacune des espèces proies, et renseigne sur le degré de sélectivité du prédateur (Astruc, 2005).

Fi = (Ei/E)*100

Avec :
- Fi la fréquence d'occurrence d'une proie i,
- Ei le nombre d'estomacs contenant la proie i, et
- E le nombre total d'estomacs pleins.

Pour la méthode numérique, elle est fondée sur le nombre d'individus de chaque catégorie de proie, exprimé en pourcentage du nombre total de proies. Elle exprime la contribution en nombre d'une catégorie dans le régime alimentaire. Le nombre moyen d'individus par estomac de chaque catégorie de proies peut également être calculé (Astruc, 2005). Cette méthode prend uniquement en compte l'aspect quantitatif. Elle sera dans certaines situations la méthode la plus appropriée, lorsque par exemple les espèces proies sont toutes comprises dans la même classe de taille. Elle est la plupart du temps liée à l'organisation sociale de l'espèce proie, et on trouvera ainsi dans un même estomac beaucoup de proies d'espèces vivant en banc (Astruc, 2005).

Ni= (ni/N)*100

Avec:
- ni le nombre d'individus de la proie i,
- N le nombre total de proies.

Pour la méthode pondérale, elle est fonction du poids de chaque espèce proie par rapport au poids total des proies, exprimé en pourcentage. Elle exprime la contribution en poids d'une proie dans le régime alimentaire (Astruc, 2005).

P= (pi/Pt)*100

Où
- pi est le poids de la proie i,
- P le poids total des proies ingérées.

Cette méthode renseigne sur les quantités ingérées, mais a tendance à surestimer la contribution des éléments lourds du régime alimentaire (Astruc, 2005). D'après Astruc (2005), les poids respectifs des proies n'étant pas toujours indiqués par les auteurs, l'analyse pondérale peut être effectuée à partir de plusieurs sources.

Selon Pate (2008), l'indice d'importance relative (IRI) est déterminé par l'abondance numérique (N%) et la fréquence d'occurrence (% F). L'Abondance numérique a été définie comme le nombre total d'une proie se trouvant dans un estomac par rapport à toutes les proies trouvées dans l'estomac, et qui s'exprime en proportion de tous ces éléments (Pate, 2008). La Fréquence de l'événement a été définie comme le nombre de fois une proie particulière a été récupérée à partir d'estomacs examinés et exprimée en pourcentage de tous les estomacs contenant des produits alimentaires (Pate, 2008). En raison de la distribution non-normale des données, des tests non paramétriques ont été utilisés dans cette étude. Par ailleurs, cet index combine les différents paramètres, il prend ainsi en compte la fréquence, le nombre et le poids (calculé ou estimé) de chaque catégorie de proies et établit pour chacun un index d'importance relative, qui évalue le rôle de chaque espèce proie dans le régime alimentaire (Astruc, 2005).

IRI = (N%+W%)*F%

- N% est le nombre d'une proie par rapport au nombre total de proies exprimé en pourcentage.
- W% est le poids d'une proie divisé par le poids total des proies ingérées, exprimé en pourcentage.
- F% est le nombre d'estomacs dans lesquels la proie est présente, exprimé en pourcentage.

Cette méthode, basée sur la superposition des différentes sources de données en combinant plusieurs indices, donne une vision plus synthétique et réaliste, et donc plus représentative, de l'importance de chaque espèce dans un régime alimentaire. L'Indice de l'importance relative en pourcentage est proposé comme mesure normalisée pour les analyses alimentaires (Cortès, 1997). Le débat qui a suivi cette proposition conclut sur l'intérêt de cet indice pour une représentation globalisée et normalisée des régimes étudiés (Astruc, 2005).

IV. Résultats et discussions

A. Zone d'étude- Teboulba

Le travail de terrain a commencé du mois de Mars jusqu'au mois l'Aout. Au total **35** enquêtes ont été réalisées auprès des pêcheurs de la région de Teboulba pour mettre la thématique et ce pour actualiser les données collectées au sein de l'action MAVA-Déprédation de 2021.

Au total, **11** sorties en mer à bord des navires d'alimentation et de contrôle ont été réalisées. L'effort de prospection commence dès la sortie du port jusqu'à l'arrivée aux cages. Nous avons essayé, à chaque fois de collecter les données portant sur l'occurrence de dauphins et/ ou d'autres prédateurs, la taille et la composition des groupes, le comportement, le numéro du réticule, les coordonnées de la cage, les activités autour de la cage, le poisson élevé dans cette dernière et l'activité de l'embarcation qui nous débarque. En cas d'observation de dauphins nous avons essayé d'appliquer le protocole de photo-ID et/ ou de prendre des photos sous-marines par GoPro.

Sur les **11** sorties réalisées, un total de **39** visites a été effectué au niveau des différents réticules (n=04). Au cours de ces sorties, nous avons veillez à ce que chaque réticule aille la même probabilité d'être visité et prospecté, ce qui explique le faible écart entre le nombre maximal et minimal de visite par réticule. En effet le réticule A et C sont les réticules les moins visités avec 7 et 9 visites respectivement. Alors que le réticule B et E sont les plus visités avec 12 et 11 visites respectivement. Nous avons rencontré le même probleme de 2021, où malgré toute l'attention accordée pour assurer un effort de prospection équitable entre les quatre réticules, la nature des activités menées à bien influencée la durée de prospection entre les réticules. Un total de **47h** de prospection a été établi avec une durée totale d'observation égale à **01h32min**. La plus longue durée de prospection est réalisée au niveau de réticule **B** (**n=21h18)** et **E (n=10h19)**. Seulement **06h55** ont été écoulé au niveau de réticule **A** (**Tab.7**).

Tableau 7 : effort de prospection et d'observation par réticule

Réticule	A	B	C	E	Total
Nombre des visites	7	12	09	11	39
Durée de prospection	6h55min	21h18min	8h29min	10h19min	47h01min
Nbr d'observation des dauphins	7	11	8	11	37
Durée d'observation	22min	21min	16min	33min	1h32min
Nombre des groupes	11	11	9	12	43

1.Effort de prospection et d'observation

Tursiops truncatus étaient présents lors de la majorité des sorties. Un total de **37** observations a été enregistré. L'effort d'observation des delphinidés était trop faible par rapport à l'effort de prospection. Le contact avec les delphinidés n'a duré que **01h32min** ce qui est relativement faible par rapport à l'effort de prospection. La durée d'une observation variait de **01** à **07**min avec une moyenne de **2min29s** ± **1min20s** par observation.

La comparaison du nombre de visites par rapport au nombre d'observation et/ou des groupes, ne montre pas une corrélation étroite. Par contre, la comparaison des moyennes « test de Student » montre qu'il existe une relation entre la fréquence d'observation et les activités menées à bord de la plate-forme d'observation**.** D'autre part, la plus longue durée d'une observation est enregistrée durant les opérations de changement des filets ou l'installation des cages. Au cours de ces opérations les dauphins se rapprochent beaucoup de la cage en présentant plusieurs types de comportement : socialisation, inspection et prédation. Par contre, à bord des navires d'alimentation les dauphins ne s'approchaient pas de l'embarcation et ils restaient lointains.

2. Formation des groupes

La taille des groupes varie d'un **singleton** à **5** dauphins (χ =**01.72±0.74** ; médiane=**01.50**). Le nombre maximal de groupes observés simultanément est de **trois** sous-groupes. Durant cette étude, il nous a été extrêmement ardu d'enregistrer les détails des sous-groupes en raison de leurs structures fluides et la distance qui les séparent de la plate-forme d'observation.

Nous avons constaté une tendance en faveur des petits groupes. En termes d'individus, le nombre maximal d'individus observés simultanément dans le même groupe est **5** (**11.12%**). La taille des groupes la plus fréquemment observée est celle constituée d'individus solitaires. Ils représentent **35.55**% des groupes détectés. Les dyades constituent **20%** des groupes observés.

Nous avons aussi suivi la variation de la taille des groupes en fonction des réticules, la plate-forme d'observation et de l'activité au sein de la cage prospectée. D'après les observations *in situ*, la plupart des groupes (**n=12**) sont observés autour du réticule **E** et dont la taille de groupe la plus largement observée est comprise entre un singleton et un triplet (**Tab.9**).

Tableau 9 : Variation de la taille des groupes par réticule

Variable	Minimum	Maximum	Moyenne	Ecart-type
A	1.00	3.00	1.54	0.61
B	1.00	3.00	1.77	0.75
C	1.00	3.00	1.78	0.94
E	1.00	3.00	1.79	0.75

Nous avons constaté que l'agrégation de *Tursiops* était influencée par l'activité autour de la cage. Nous avons énuméré quatre activités principales et qui sont comme suit :

- Contrôle + Alimentation;
- Maintenance + Alimentation;
- Contrôle + Maintenance + Alimentation.

Le suivi de la taille des groupes autour des cages n'a pas montré une variation significative en fonction de l'activité y est (*p>0.05*) (**Tab.10** & **Fig.9**).

Tableau 10 : Variation de la taille des groupes en fonction de l'activité entretenue dans les cages

Variable	Minimum	Maximum	Moyenne	Ecart-type
Contrôle + Alimentation	1.00	3.00	1.72	0.748
Maintenance + Alimentation	1.00	2.50	1.67	0.76
Maintenance + Contrôle + Alimentation	1.00	3.00	1.73	0.81

La concentration des dauphins autour de certains réticules peut s'expliquer par les activités intenses autour de certaines cages (**Fig.10**) et le fait que les dauphins profitent des courants marins qui poussent la nourriture en dehors des cages ce qui attirent également les ressources halieutiques sauvages et d'autres prédateurs. Les activités d'entretien, de rejet de la mortalité ainsi que le replacement de filet attirent d'avantage les dauphins et favorisent l'apparition d'une dépendance directe avec une visite régulière de ces derniers à proximité des installations. L'écosystème de proximité est alors complètement modifié engendrant l'attrait des dauphins, ayant un régime alimentaire varié et qualifiés comme opportunistes, autour de ces cages. Cet ajustement aux nouvelles conditions environnementales chez le *Tursiops truncatus* ne fait qu'appuyer les réflexions de Díaz López *et al*., (2005) et Benmessaoud et *al.,* (2017) quant à la plasticité écologique et trophique de cette espèce.

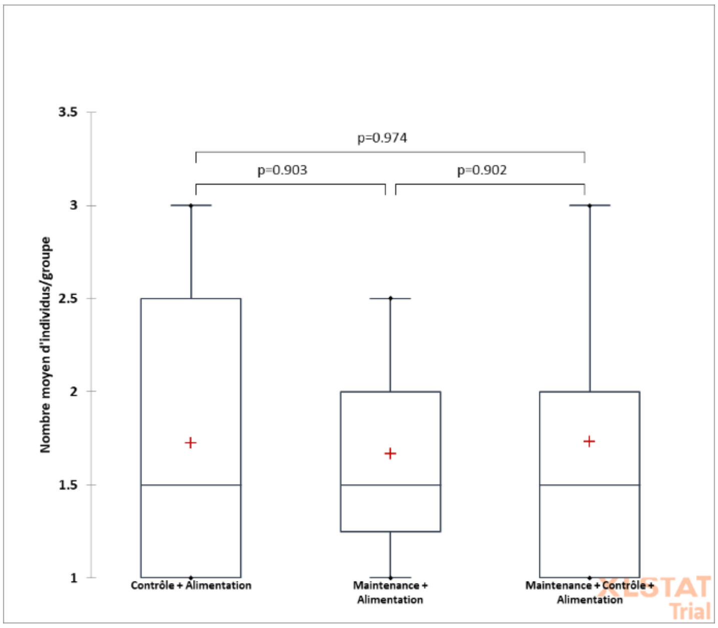


Figure 9 : Variation de la taille des groupes de *Tursiops* en fonction de l'activité autour de la cage

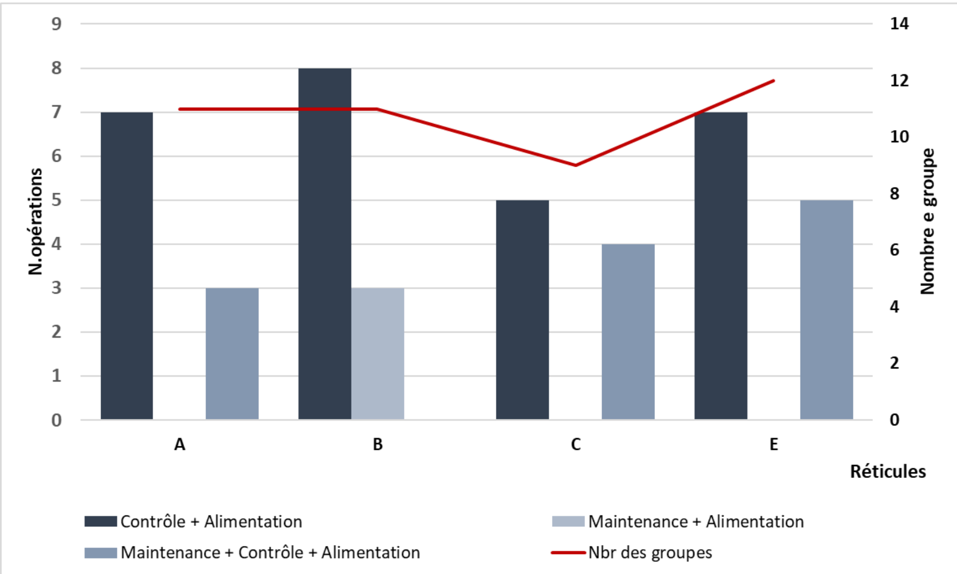


Figure 10 : Répartition de nombre des groupes et des activités par réticules.

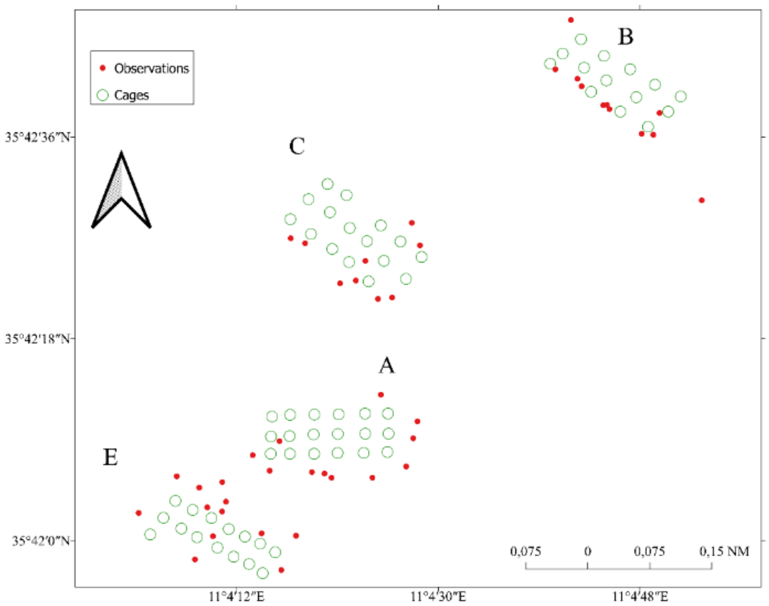
Pour ce qui est de l'attrait d'autres prédateurs aux installations aquacoles, à part la présence d'une avifaune si variée (Goéland leucophée *Larus michahellis,* Grand cormoran *Phalacrocorax carbo,* Aigrette garzette *Egretta garzetta,* Sterne voyageuse *Thalasseus bengalensis,* Sterne pierregarin *Sterna hirundo*), nous avons observé la présence accrue de thonidés (**Photo.5**) et d'élasmobranches**.**

▪

Photo 5 : Thon rouge nageant près des cages

3. Distribution de *Tursiops* autour de la ferme

Après le géoréférencement des positions d'observation, la répartition spatiale des dauphins montre qu'ils sont détectés sur les **4** réticules de la ferme avec plus de concentration au niveau du réticule **B** et **E (Fig.11).**



Figures 11 : Répartition spatiale des observations de *Tursiops truncatus*

Comme nous l'avons cité auparavant, cette forte association enregistrée au niveau du réticule **B** et **E** est le résultat de la nature des activités menées dans ces réticules et qui sont dans la plupart des cas des travaux de changement et installation des filets. Ces activités influencent non seulement la durée de prospection et de détection des dauphins mais aussi elles influencent leur éthologie. En effet les dauphins sont devenus de plus en plus curieux et s'approchent davantage de la cage, de l'embarcation et même du plongeur. Le schéma de répartition des Grands dauphins n'a pas changé de 2021 à 2022 (**Fig.12**)

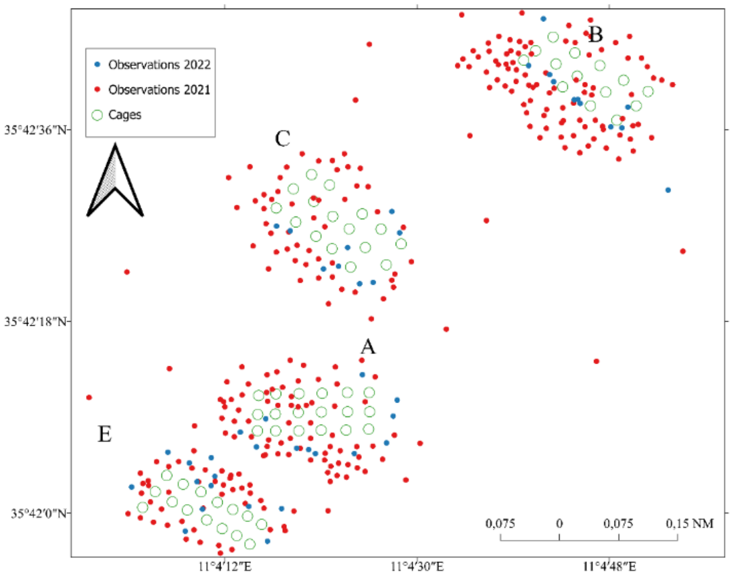


Figure 12 : Variation spatiale des observations durant les actions MAVA-Déprédation de 2021 et 2022

4. Photo Identification

Au total **135** photographies des Grands dauphins ont été prises dont seulement **62** sont à la fois de bonnes qualités et exploitables. Nous avons pu identifier trois spécimens à partir des photographies prises. En croisant et comparant les photos de ces trois spécimens avec celles des autres spécimens inclus dans le catalogue de photo-identification de 2021, nous avons pu recapturer 3 spécimens ($Tteb_1$, $Tteb_2$ et $Tteb_3$). Les trois spécimens recapturés présentent différentés typologies de marques (**Fig. 13**).

$Tteb_1$	$Tteb_2$	$Tteb_3$

Figure 13 : Nageoires dorsales des trois différents individus recapturés.

Comme nous l'avons déjà mentionné, les trois individus recapturés se distribuent autour des différents réticules sans schéma de préférence défini (**Tab.11**).

Tableau 11 : Répartition des individus par groupe et par réticule durant les sorties realisées (n=11)

Sortie		Individu(s) identifié(s)	Groupe	Réticule
1	31/03/2022	Tteb3	G1	C
	31/03/2022	Tteb3	G2	B
2	23/04/2022	Tteb1	G1	B
	23/04/2022	Tteb1 Tteb2	G2	B
	23/04/2022	Tteb3	G3	E
3	14/05/2022	Tteb3	G1	E
	14/05/2022	Tteb1	G2	B
4	27/05/2022	Tteb1	G1	B
5	28/05/2022	Tteb1	G1	B
	28/05/2022	Tteb3	G2	E
6	11/06/2022	Tteb3	G1	E
	11/06/2022	Tteb3	G2	E
	11/06/2022	Tteb1	G3	B
7	01/07/2022	Tteb3	G1	E
	01/07/2022	Tteb1 Tteb2	G2	B
	01/07/2022	Tteb1 Tteb2	G2	B
8	24/07/2022	Tteb1 Tteb2	G1	B
	24/07/2022	Tteb3	G2	C
	24/07/2022	Tteb3	G3	C
	24/07/2022	Tteb3	G4	C
9	30/07/2022	Tteb1	G1	B
	30/07/2022	Tteb1 Tteb2	G2	B
	30/07/2022	Tteb1	G3	B
10	06/08/2022	Tteb3	G1	E
	06/08/2022	Tteb3	G2	E
11	19/08/2022	Tteb1 Tteb2	G1	B
	19/08/2022	Tteb3	G2	E
	19/08/2022	Tteb1	G3	B
	19/08/2022	Tteb1 Tteb2	G4	B

Dans la présente étude, la fréquence d'observation et le taux d'occurrence mensuel (TOM) ont été utilisés pour évaluer le degré de résidence et la fidélité aux « domaines vitaux » des dauphins identifiés tel qu'évoqué par Moller *et al.,* (2002). Nous avons remarqué que les taux d'observation et la d'occurrence mensuel variaient d'un individu à l'autre. En effet, le taux d'occurrence mensuel calculé a une valeur qui varie entre 0.0.9 et 1 (**Tab.12**). En se basant sur la valeur du TOM, nous pouvons classer les 3 individus observés en 2 catégories de fidélité à la ferme : les visiteurs sporadiques (TOM 0.25), les fréquents (0.25<TOM≤0.5) et les résidents (TOM>0.5).

Tableau 12 : Fréquence d'observation, taux d'occurrence mensuel (TOM) et modèle de résidence des individus marqués durant 2020-2022

Individus	Frequence d'observation	T. O.M	Modèle de Résidence
Tteb1	29	1.00	Résident
Tteb2	21	0.82	Résident
Tteb3	22	1.00	Résident
Tteb4	1	0.09	Sporadique
Tteb5	2	0.18	Sporadique
Tteb6	11	0.55	Résident
Tteb7	5	0.45	Fréquent
Tteb8	7	0.36	Fréquent
Tteb9	6	0.36	Fréquent
Tteb10	5	0.45	Fréquent
Tteb11	5	0.45	Fréquent
Tteb12	5	0.45	Fréquent

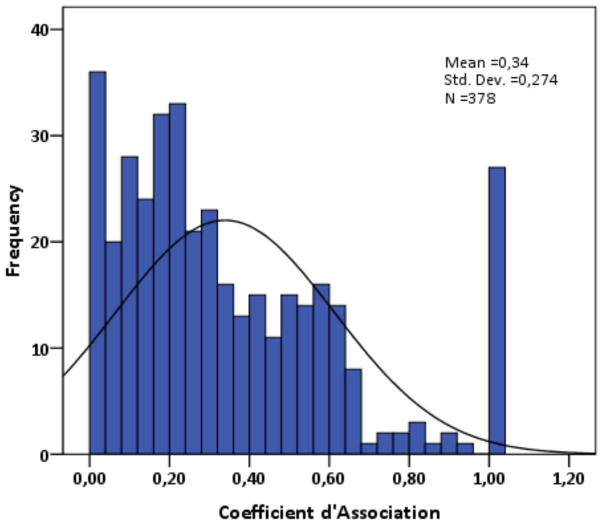
5. Structure sociale

Un seuil de 5 observations a été fixé comme notre limite permise. Ce chiffre est jugé approprié pour le jeu de données vu qu'il nous permet d'inclure suffisamment d'individus dans l'analyse et nous permettra de comparer nos résultats avec ceux d'autres études (Chilvers & Corkeron, 2002). Nous avons épargné de ce calcul le dyade femelle-delphineau vu que leur COA est égale à 1. A cet effet, nous avons examiné le coefficient d'association de **378** identifications établies lors d'une période d'échantillonnage (*Te*) égale à **39** jours en mer. Lors de cette période d'échantillonnage, Seuls les adultes observés plus cinq fois qui ont été pris (**n=10**).

La moyenne d'identifications par période d'échantillonnage est de l'ordre de **2.95** identifications/*Te,* soit une moyenne de **2.54** individus identifiés/*Te.* La proportion d'individus identifiés au cours de cette période d'échantillonnage étant égale à **0,25**.

Coefficients d'association **(CoA)**

Le (CoA) calculé varie de **0** à **1** (**Fig.14**). La majorité des *Tursiops* ont un faible niveau d'association (**39%, n=149**). Cependant, certains individus identifiés semblaient former des groupes relativement stables au cours de la période d'étude. Peu de dyades ont un niveau d'association de type « modéré à élevé » et de type « élevé ». Pour les **378** identifications, seulement **7%** (**n = 25**) ont une association « modérée à élevé » et **8%** (**n = 32**) ont des associations de haut niveau. La répartition des (CoA) pour tous les affiliés montre une variation significative (Kw-H : df=4 ; H=344.14 ; p<0,01*). Tous les spécimens qui ont été associés ont une moyenne de coefficient d'association égale à **0,34** (±**0,27**).



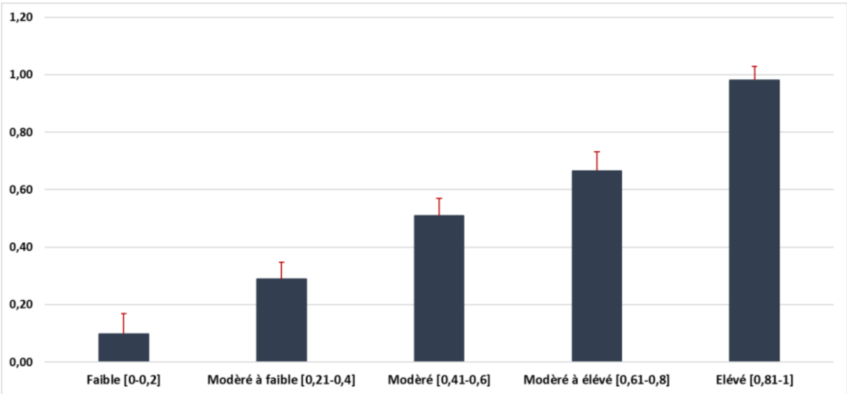


Figure 14 : (a) histogramme de la distribution des (CoA) de dix individus retenus pour cette étude. (b) pourcentage de chaque classe de (CoA)

Résultats des tests de permutations

L'ensemble des données des associations a été permuté aléatoirement 10000 fois avec 1000 essais par permutation. En utilisant la méthodologie de Whitehead (1999), nous avons constaté que le comportement d'association des grands dauphins autour de la ferme est loin d'être le fruit du hasard.

Les résultats du test de permutation « *permuter les groupes au sein de l'échantillon* » ont montré que le coefficient de variation des associations réelles était supérieur à celui des associations aléatoires (**Tab.13**). D'où la conclusion que les *Tursiops* observés à maintes reprises dans la zone d'étude, lors de la même période d'échantillonnage, ne sont pas susceptibles d'adhérer au même groupe par hasard, mais suite à un choix d'association privilégié ou évité.

Les associations de ces spécimens n'étaient pas des associations à court-terme. Ceci a été établi depuis les moyennes des deux types d'association (**Tab.13**). Les SD des moyennes des indices d'association appuyaient cette dernière conclusion. Les SD des associations réelles étaient significativement plus grands que ceux des associations permutées aléatoirement ($p < 0{,}01$), indiquaient que les dauphins de la région d'étude ne s'alliaient pas d'une façon arbitraire mais ayant des associations préférées à long-terme.

Tableau 13: Résultat du test de permutation par type d'associations

	Coefficient de variation (CV)	Moyenne	Écart type (SD)
Associations réelles	1.45	0,20	0,29
Associations permutées	0,00145	0,0002	0,0003
Valeur de *p*	0.000	0,000	0,000

***Analyse de partitionnement de données* (CAH) et (ACP)**

La **figure 15** illustre le sociogramme des associations globales des dix individus observés autour de la ferme aquacole. Il en ressort que les liens entre les individus ne font que s'intensifier et devenir plus étroits au fils des années du suivi. Nous pouvons remarquer l'asymétrie des liens à travers les axes du sociogramme. Ce qui permet de conclure que certains individus passent plus de temps en compagnie d'autres individus et/ ou évitent d'autres compagnons.

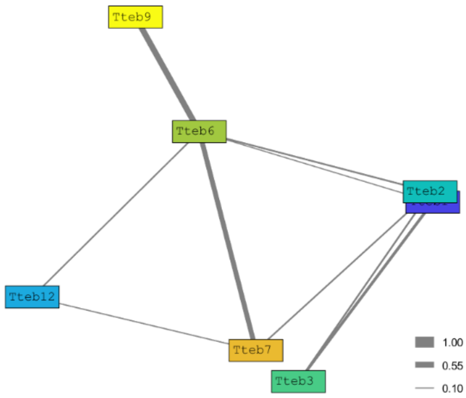


Figure 15 : Sociogramme des individus observés dans la zone d'étude de 2022 (n=10).

6. Budget comportemental

Notre étude a montré que les activités à la surface de *Tursiops truncatus* sont classées en cinq catégories : «chasse», «interaction avec les cages», «déplacement» et «socialisation ».

Le comportement « chasse » était marqué par un mouvement directionnel à la surface. *T. truncatus* remontent à la surface et plongent d'une façon synchrone selon un grand cercle, plongeant ensuite en convergeant vers le centre de ce cercle. Les proies sont parfois visibles dans la tranche d'eau contournées par les dauphins. Deux stratégies alimentaires ont été observés: alimentation/chasse sous les cages et alimentation/chasse loin de cages. L'« interférence avec les engins de pêche » est la résultant d'une alimentation sous les cages. Le grand dauphin, attiré par la faune sous les cages, vient s'y alimenter. Sa présence est accompagnée par un changement du comportement du poisson élevé. Deux comportements de poissons ont été distingués : la plongée des poissons vers le fond de la cage ou bien le regroupement plus intense des poissons au centre de la cage. Ceci a été décrit, par Misund (1994) et Benmessaoud et al., (2012), pour les poissons grégaires vivant en banc et qui optent pour une structure plus compacte et témoignent d'un effet de groupe (coaction homotypique).

Le comportement « déplacement » a été observé généralement dans des groupes compacts de *Tursiops*. Ce comportement est caractérisé par un mouvement monodirectionnel de tout le groupe. *Tursiops* se déplacent en unité, sondant et faisant surface de manière synchrone à une vitesse de nage moyenne comprise entre 3 et 6 nœuds. Ils sondent de 2,5 à 3 minutes et refont surface pour respirer à des intervalles de temps d'environ 30 sec.

La « socialisation » a été caractérisée par un niveau d'activité agitée à la surface. Les grands dauphins en socialisation remontent ensemble à la surface avec un regroupement très compact et restent souvent à la surface pendant plusieurs minutes. Pendant ce temps, les dauphins présentent des contacts corporels prolongés traduits par des coups et des claques de la nageoire pectorale d'un animal contre le corps d'un second (**Photo.6**).

Photo 6 : Comportement de socialisation

Les groupes de *Tursiops* recensés lors de la période d'étude passaient **35%** de leur temps respectivement entre « chasse » et « interaction avec les cages ». Ces groupes de *Tursiops* entamaient des activités de « socialisation » et suivaient un mouvement de « déplacement » omnidirectionnel avec une vitesse de nage rapide et ne manifestaient aucune activité soutenue à la surface respectivement durant **19%** et **46%** de leur temps (**Fig.16**). la dominance du comportement de déplacement peut être expliquée par l'évitement des cages suite à la présence d'autre prédateurs comme les requins.

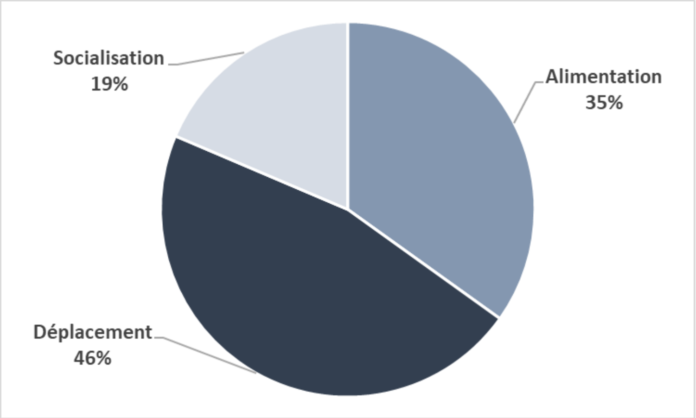


Figure 16: Budget comportemental pour les années de suivi confondues

7. Expérimentation des répulsifs acoustiques

Au cours de cette étude, deux types de répulsifs acoustiques ont été expérimentés : le DDD-03- H et le DiD-01 **(Photo.7)**. Le nombre total des pingers utilisés est quatre (02 DDD-03-H, 02 DiD-01). Le déploiement a été fait selon le protocole conçu pour cette action et ce un seul répulsif par réticule par jour. Nous avons tenu à placer les répulsifs assez distants afin d'éviter tous chevauchements et interférences entre eux et pour mieux couvrir la totalité de la ferme **(Fig.17).**

Les observations, après la mise en œuvre des pingers, montrent que les dauphins sont encore bien détectés dans la ferme. Cependant nous signalons un changement de la distribution par rapport aux cages et aux réticules. En effet, nous avons remarqué que le déplacement est devenu le comportement principal observé près des réticules. Une absence totale du comportement « alimentation » et une raréfaction du comportement « Socialisation » ont été enregistrées. Nous avons aussi constaté que les interactions avec les cages ont bien diminué.

Photo 7 : Répulsif déployé autour de la ferme aquacole

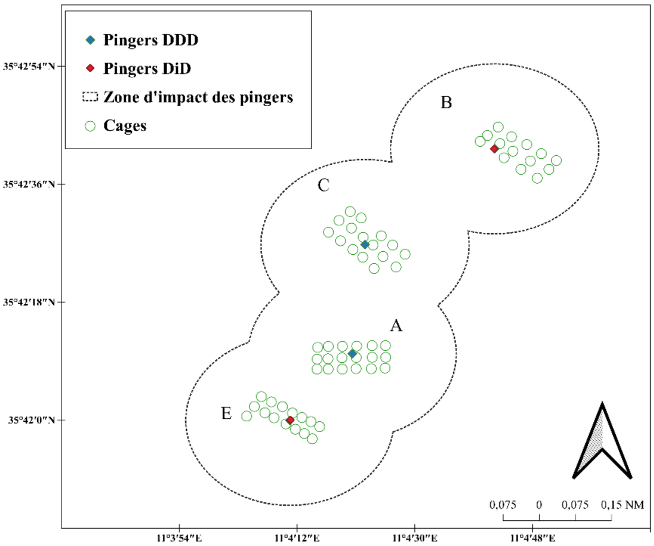


Figure 17 : L’emplacement des répulsifs acoustiques et leur zone d’impact

Nous avons aussi constaté que les interactions avec les cages ont bien diminué et surtout les cages situées près des répulsifs. En effet, la fréquence d’interaction avec les cages a passé de 75% à 9.9% après la mise en œuvre des répulsifs. Ces résultats doivent être entretenus à long-terme pour déterminer la période d’adaptation des Grands dauphins aux ondes émises par les répulsifs acoustiques. De même, il est conseillé de faire le suivi couplé avec un hydrophone pour des résultats plus raffinés.

8. Conclusion & Recommandations

Une seule espèce de delphinidés a été observée qui est le grand dauphin *(Tursiops truncatus).* L'étude de la répartition spatiale, montre que les dauphins sont plus concentrés au niveau du réticule « **E** », mais ceci peut être influencé par le nombre et/ou le temps d'observation écoulé autour de ce réticule. En effet c'est au niveau de réticule « **E** » où le plus grand nombre de visite et la plus longue durée de prospection ont été réalisés. Il est à noter qu'aucun attrait à une cage ou à une espèce de poisson élevé particulière n'a été decelé. Généralement, les groupes de *Tursiops* observés dans le site d'étude, sont souvent observés entre et/ou à côté des réticules. Ceci ne nie pas le fait que certains individus s'approchent des bateaux annexés à la ferme ou des cages pour les inspecter. Les interactions sont surtout observées au cours des opérations de pêche, de maintenance et de contrôle (changement du filet, installation de cage, …).

Les groupes observés sont de trés petites tailles. Juste trois individus ont été recaptués (n=12). En se basant sur le calcul du modèele de résidence, il semble que les individus observés depuis 2022, utilisent différemment la ferme. Il y en a ceux qui y sont endémiques et d'autres qui sont des simples visiteurs. L'analyse de la structure sociale entre les individus observés autour de la ferme, montre qu'elle est de loin d'etre hasardeuse mais en faveur de compagnon préféré/évité à long-terme.

Nos observations après la mise en œuvre des répulsifs acoustiques, montrent un certain changement au niveau des comportements des dauphins près des réticules. En effet le déplacement devient presque le seul comportement observé par rapport aux autres types de comportements qui sont plus observés sur les côtés des réticules. Ce changement de budget doit être surveillé surtout que nous avons noté la présence de requins dans la ferme. D'autre part, nous signalons qu'aucune interaction avec les cages n'a été enregistrée depuis l'application des pingers. Un tel constat doit être suivie par d'autres observations appuyées par un hydrophone pour confirmer ou infirmer l'efficacité des répulsifs acoustiques.

Comme nous l'avons signalé dans la première partie du projet MAVA-déprédation Tunisie, la prise des bonnes photos proches et nettes reste un souci majeurs. En effet, les plateformes d'observation sont en réalité des embarcations d'alimentation et de contrôle qui ne sont pas désignées pour faire les tâches d'observation. En effet, les observations étaient conditionnées par les activités de la plate-forme et non pas par l'occurrence des delphinidés. Également le comportement d'évitement observé chez les dauphins a compliqué d'avantage la situation surtout face à l'impossibilité de se rapprocher. Ce qui laisse la majorité des photos sont prises de loin et par conséquent non exploitables. Nous avons proposé précédemment la possibilité d'être independant des bateaux de la ferme. Cependant, ceci doit être discuté avec les propriétaires de la ferme qui essayent de minimiser les sources de bruit autour des cages.

B. Zone d'étude – Kélibia

1. Suivi de la déprédation

Pour analyser les interactions entre les Grands dauphins et les sennes, au total **154** enquêtes ont été réalisées entre Mars et Aout 2022. Au total **09** sorties ont été effectuées pour mieux comprendre et documenter le phénomène de déprédation. Dans ce qui suit, nous exposons les résultats des données recueillies durant l'année 2022 (Aout 2021 – Aout 2022).

Fréquence de déprédation

Les résultats ont montré que la fréquence moyenne des sorties de pêche déprédées est de l'ordre de **36%**. La **figure 18** illustre la variation mensuelle de la fréquence de déprédation. Nous remarquons qu'un pic a été enregistré au mois d'Aout avec une fréquence égale à **50.1%**. Tandis que la fréquence la plus faible est de l'ordre de **19.3%** et a été enregistrée au mois de Janvier. L'analyse statistique montre que la fréquence de déprédation varie significativement en fonction des mois (p <0.05).

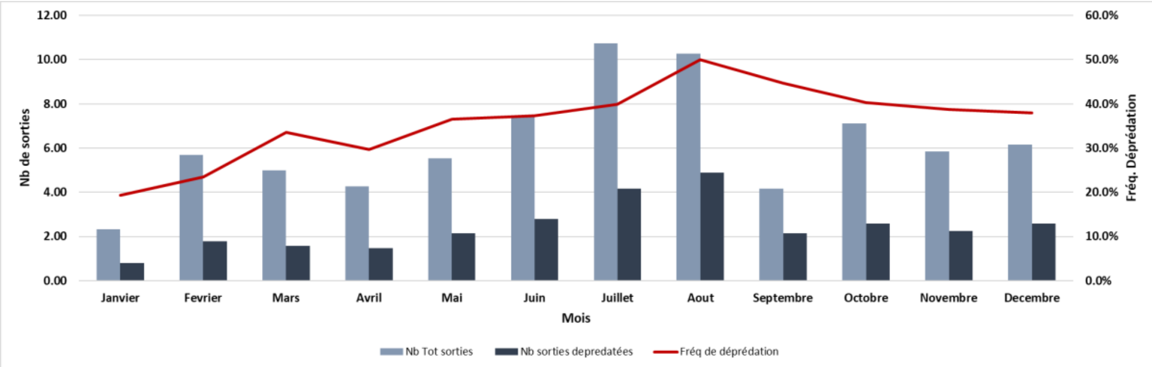


Figure 18 : Variation mensuelle de la fréquence de déprédation

Typologie des perforations

La déprédation au niveau des sennes se manifeste par des perforations généralement de forme rondes ou ovales avec des bords irréguliers et se trouvant réparties tout le long de la senne avec une concentration autour de la poche **(Fig.19)**. Le suivi mensuel des causes de déchirures montre que les déchirures observées sur les filets de pêche sont dans la majorité des cas causées par *Tursiops* à raison de **79%,** alors que les autres déchirures causées par les épaves et les fausses manoeuvres sont estimées à **21%**.

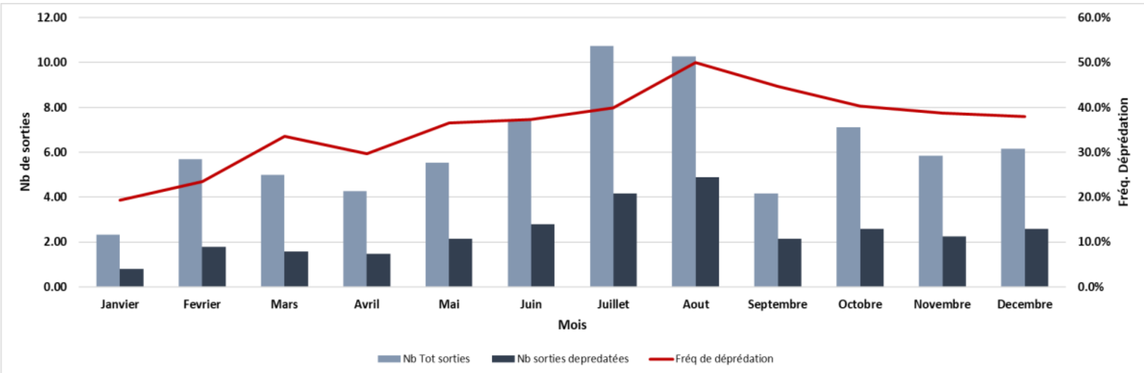


Figure 19 : Différents types de déchirures observées dans la zone d'étude

Les interférences entre *Tursiops* et les sennes se traduisent par de nombreuses perforations ayant une taille et localisation diverses. **715** perforations ont été recensées. Le nombre de perforations le plus important a été enregistré au niveau de l'avant poche (X=**89.13** ± **96.54** ; n=**357**) et le moindre est localisé au niveau des ceintures (X=**5.48** ± **9.06**; n=**40**). La taille des perforations varie de quelques centimètres à un mètre (**Fig.20**). La classe de taille la plus observée est celle des perforations dont la taille comprise entre **20 et 40cm** (n=**345**) et celle inferieure à **20cm** (n=**324**).

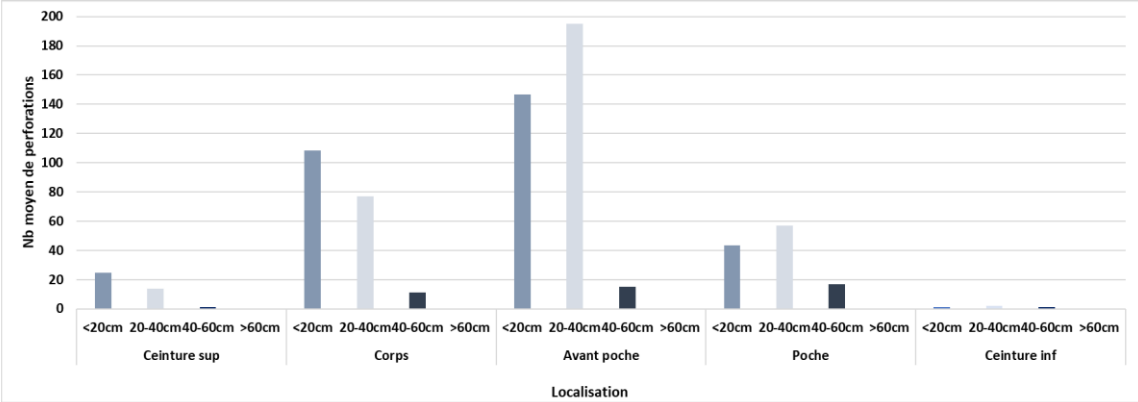


Figure 20 : Typologie des perforations induites par les dauphins

Les conséquences de la déprédation

Outre les conséquences importantes sur l'écologie des espèces impliquées et les stocks exploités, la déprédation engendre des pertes financières considérables

Impact sur l'effort de pêche

L'analyse du mouvement des embarcations montre la même tendance que lors de la phase de la première phase de cette action avec une limitation du nombre de sorties de pêche. Durant la période de suivi, l'analyse des facteurs responsables de cette inactivité montre que le mauvais temps est la cause principale de la réduction de l'effort de pêche (**62%**) suivi par les périodes de pleine lune qui présentent **22%** des parts des jours d'immobilisation. Le carénage (**6%**), L'annulation des opérations de pêche à cause des dauphins (**6%**) et le ramendage des filets (**4%**) viennent en dernière position.

Pertes économiques

La déprédation est à l'origine d'une perte financière considérable pour les filières impactées par ce phénomène, et ce pour diverses raisons. D'une part, les interactions entre les *Tursiops* et les sennes peuvent occasionner des déchirures au niveau du filet et leurs réparations engendrent des dépenses supplémentaires aux pêcheurs. D'autre part, lorsque des évènements de déprédation ont lieu, les pêcheurs qui ont les moyens matériels vont changer la zone de pêche afin de mettre de la distance entre leur bateau et les prédateurs, et parfois, ils annulent complétement l'opération de pêche après avoir quitté les ports d'attache. Ces déplacements occasionnent des dépenses supplémentaires en fuel, qui est une composante majeure du coût d'exploitation d'une unité de pêche.

Le suivi de l'évolution mensuelle des coûts de ramendage des déchirures perpétuées par les Grands dauphins montre que les valeurs moyennes de ramendage les plus élevées ont été enregistrées au mois d'Aout avec **1286.05Dt** par embarcation (**Fig.21**). Une chute de ces moyennes a été notée, en hiver, pour atteindre une moyenne minimale de **260.53Dt** par unité de pêche au mois de Décembre. Le coût de ramendage moyen est égal à **660.22Dt** (± **272.32Dt**). Cette variation mensuelle est peut-être expliquée par (i) l'effort de pêche accentué durant cette période estivale, (ii) l'abondance de proies préférentielles de *Tursiops* et surtout (iii) la présence accrue de *Tursiops*, avec des groupes plus larges, durant ces périodes, vu qu'il s'agit d'une aire d'importance pour *Tursiops* (Benmessaoud & Cherif, 2021), avec un chevauchement de leurs aires de répartition avec les aires d'exploitées par la profession.

Il est à noter que l'occurrence des événement de déprédation suit la même cadence que celle de 2021. Les interférences ont lieu lors de la phase de la concentration des poissons sous les feux (**43**%), la phase de l'encerclement des bancs de poissons (**38%**) et la phase de salabardage (**19%**).

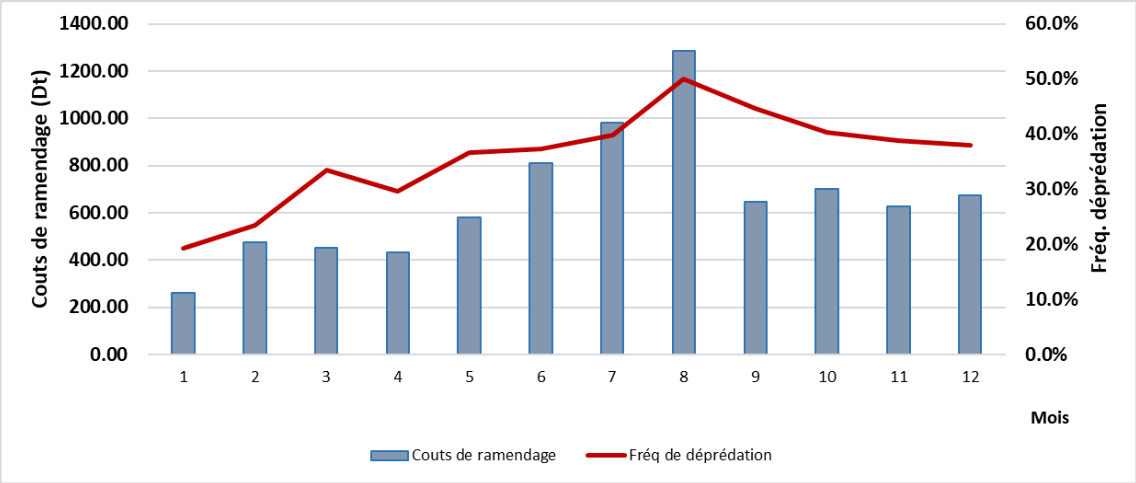


Figure 21 : Evolution mensuelle des coûts de ramendage de dauphin

Impact sur les débarquements

En inspectant les filets de pêche lors de l'opération de ramendage, nous avons trouvé des restes de poissons endommagés par les dauphins au niveau de perforations **(Photo.8).** Ce résultat est similaire à celui trouvé par Goetz et al., (2013) à la Galice. Les auteurs ont mentionné que les dauphins en déchirant la chair et le corps du poisson laissent des marques de morsures et souvent juste la tête du poisson piégé dans les mailles du filet.

Ce résultat est similaire à celui trouvé par Lauriano et al., (2004) en Sardaigne où la composition de la capture et la CPUE ont été réduit en présence de dauphins. Bien que la plupart des interactions ont été jugées négativement affecter l'activité de pêche, Rocklin *et al.,* (2009) ont souligné que la déprédation par les dauphins étaient significativement associées à des valeurs de CPUE élevées. De même, Silva et al., (2002) ont également remarqué que les captures dans les pêcheries thonières étaient plus élevées lorsque les cétacés étaient présents dans la zone de pêche. Ces mêmes auteurs ont essayé d'expliquer ce phénomène en émettant les hypothèses suivantes : soit les cétacés ne s'approchent pas des filets que lorsque les captures sont de quantités appréciables soit ils rabattent les poissons contre les filets tout en augmentant la CPUE.

Photo 8 : Poissons endommagés par les dauphins

Le suivi de l'évolution de la composition du débarquement montre que la composition varie significativement en fonction de la déprédation ($p<0.05$). Le même constat que celui de 2021 a été fait concernant l'augmentation de la richesse spécifique durant certains mois en présence du phénomène de déprédation et un enrichissement du DPUE en calmars et en clupéiformes.

L'analyse économique faite par Ben Arfa (2022) dans le port de Kélibia a permis de dégager une corrélation entre les débarquements de 2021, en quantité et en valeur, avec les sorties déprédées et non déprédées. Le même auteur a mentionné que pour l'année 2021, la fréquence de déprédation est de l'ordre de 39% avec un pic en mois de Septembre (**Fig. 22**). Ben Arfa (2022) a indiqué que la déprédation peut impacter différemment le volume de débarquement et ce en fonction de la severité de cet événement. En effet, l'auteur explique que le débarquement des sorties déprédés n'est pas forcément en faveur d'une baisse sauf si la fréquence de déprédation est élevée et les dégâts sont importants. Dans le cas contraire où la fréquence de la déprédation diminue et le volume des débarquements des sorties déprédées augmente, les dégâts causés par le dauphin sont jugés comme modérés à faibles.

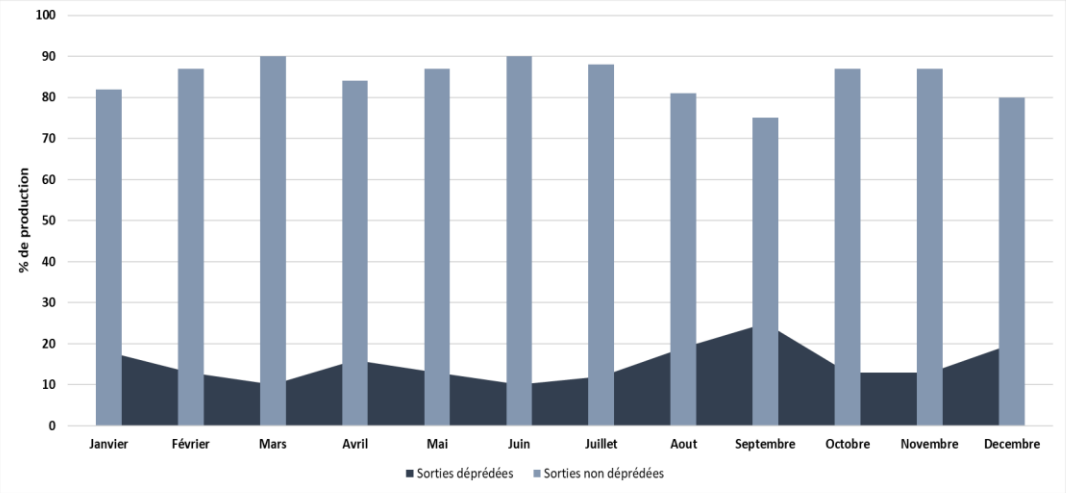


Figure 22: Evolution mensuelle des débarquements par type de sortie

Le suivi du DPUE montre une difference nette en fonction de la déprédation. Pour les sorties déprédées, le DPUE est évalué à **284.8 T.** Tandis qu'il est de **6 fois** pour les sorties non déprédées (**Q=1619.84T**).

En termes de composition par type de sortie, le même agencement a été observé. La Sardine a occupé la première place avec **36,2%** suivie de la Saurel (**18,5%**) et l'Allache (**16,1%**) (**Tab.14** & **Fig. 23**). Par contre, une nette différence dans les quantités débarquées en Calmar a été observée. La quantité du Calmar est plus abondante dans les sorties déprédées que les sorties non déprédées. Ceci nous pousse à supposer que peut- être il s'agit d'une proie préférentielle pour le Grand dauphin des côtes Nord de la Tunisie.

Tableau 14 : Répartition du débarquement annuel en espèces par type de sortie

Quantité (Tonne)	**Maquereau**	**Sardine**	**Allache**	**Saurel**	**Bogue**	**Calmar**	**Anchois**	**Divers**
Sorties déprédées	18.66	96.49	46.48	55.21	16.25	6.83	35.90	9.04
Sorties non déprédées	56.32	592.79	260.70	297.26	33.89	5.93	332.59	40.35

D'aprés Ben Arfa (2022), le suivi de l'évolution mensuel des revenus a indiqué que le mois d'Aout et le mois le plus productif. Cette productivité assez élevée s'explique par le volume de la production débarquée et le faible nombre de jours inactifs. Le mois le moins productif est le mois de janvier où le nombre de sorties moyen a avoisiné 1,2 sorties par navire actif.

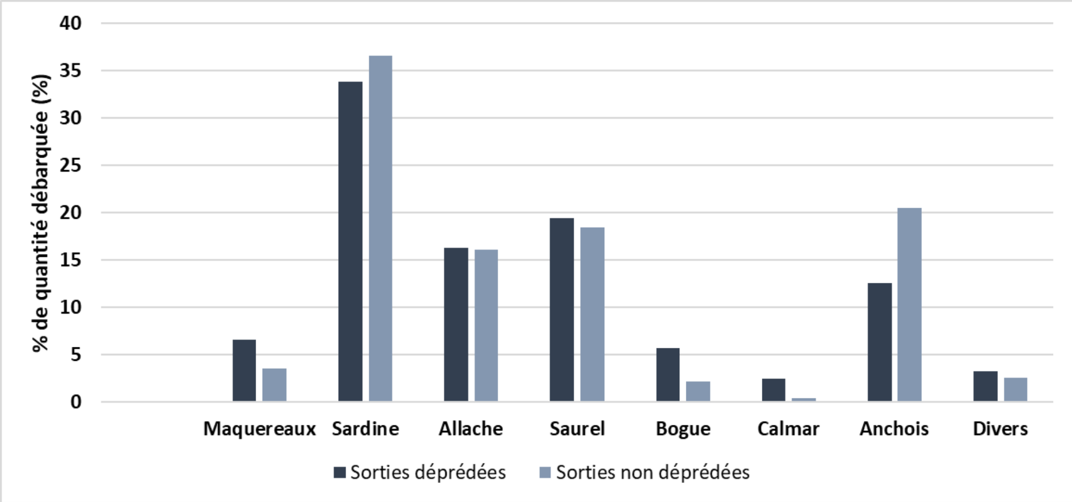


Figure 23: Répartition du débarquement annuel en espèces par type de sortie

Quant au chiffre d'affaires moyen par navire par sortie, il a été estimé à 1843 dinars (± 830 dinars) pour les sorties déprédées et 5324 dinars (± 2771 dinars) pour les sorties non déprédées (**Fig.24**).

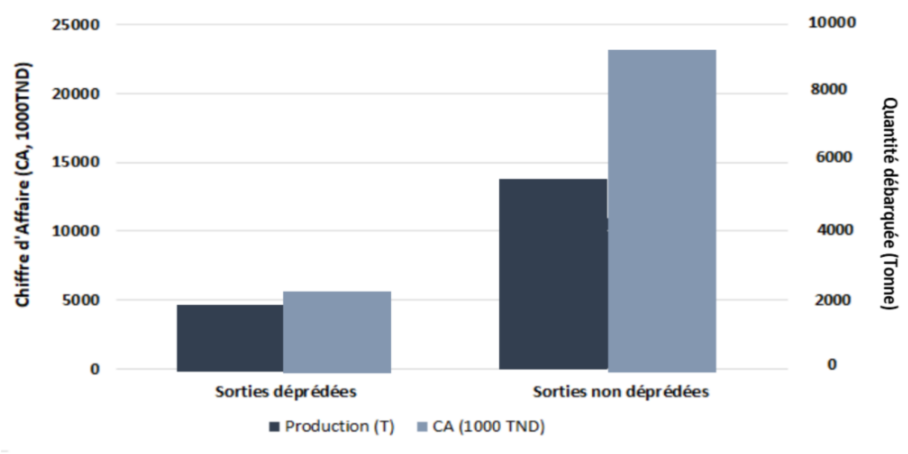


Figure 24: Chiffre d'affaires moyen par navire et par type de sortie

2. Atténuation acoustique de la déprédation

Face au phénoméne de déprédation, la majorité des bateaux suivis utilisent des pratiques, des procédures ou des technologies qui visent à réduire et à minimiser les impacts associés à la déprédation.

La **figure 26** récapitule les mesures d'atténuations utilisées dans le port de Kélibia. Nous citons:

- L'usage de feu d'artifice (**Photo.9**): il s'agit d'une pratique qui sert à disperser le dauphin suite aux sons dégagés. Plus que 50% des sardiniers suivis utilisent cette alternative. Le reste des sardiniers n'utilisent pas cette mesure vu l'élévation du prix et l'accès difficile à ce produit.
- Le lavage des filets : l'utilisation répétitive et fréquente de la senne laisse une certaine odeur jugée attractive pour le dauphin. De ce fait, les pêcheurs les imprègnent avec du détergent afin de diminuer l'intensité de cette odeur. Cette conduite a été préférée par 33% de la flotte suivie.
- Le versement du fioul : cette mesure consiste à verser une quantité du fioul autour des filets. Malgré son effet polluant, cette solution est pratiquée par 6% des sardiniers suivis.

- Le jet d'une quantité de poisson. Cette pratique présente un coût faible et révèle des résultats assez encourageants selon les pêcheurs.
- L'usage des répulsifs acoustiques : cette alternative a été adaptée par 11% de la flotte. Son efficacité a été bien identifiée lors de l'enquête. La majorité des utilisateurs la juge moyennement efficace et approuve sa contribution à améliorer leurs revenus.

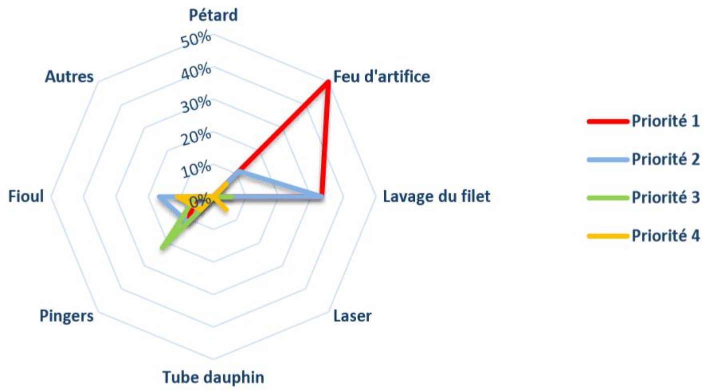


Figure 26: Répartition des mesures d'atténuation utilisées dans le port de Kélibia (Ben Arfa, 2022)

Photo 9: Feux d'artifices utilisés par les sardiniers

L'échantillon de sardiniers choisi pour cette étude a bénéficié de trois types de répulsifs acoustiques. Au total **165** opérations ont fait l'objet d'expérimentation le long de l'année 2022 (**39** avec DDD- 03-H, **40** avec DiD-01, **10** avec Licado et **76** sans répulsifs). La différence du taux d'utilisation est strictement liée à l'activité du sardinier utilisant le répulsif et aux conditions de déroulement de l'opération de pêche.

Fréquence de déprédation

La fréquence de déprédation varie d'une embarcation à une autre en fonction de l'utilisation des répulsifs acoustiques. En effet, la moyenne de déprédation pour les embarcations témoins (*X*=**30.36% ± 17.78%**, n=83) est supérieure à celles équipées de répulsifs (X=**18,0.4%** ± **21.19%,** n=82) (**Fig.27**). Ces résultats coïncident avec ceux trouvés par Bruno *et al.,* (2021). Ces auteurs ont mentionné que l'utilisation des pingers « *FishTek banana* » a diminué considérablement la fréquence de déprédation.

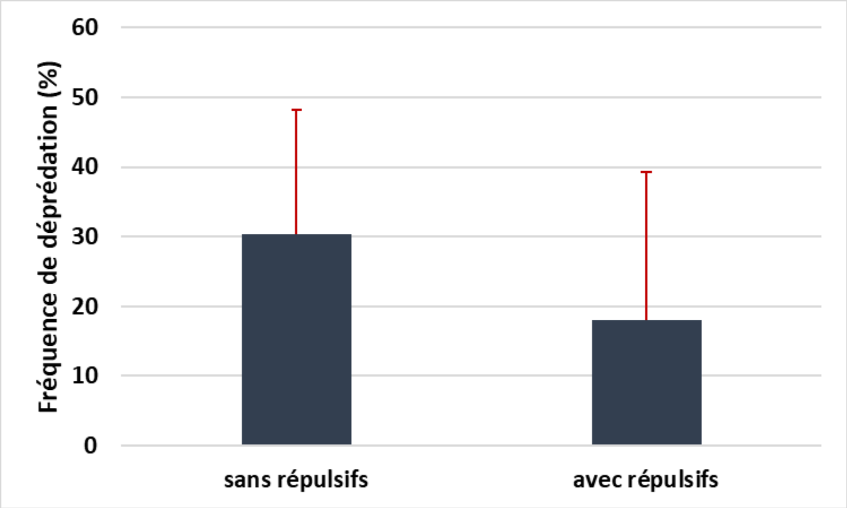


Figure 27 : Variation mensuelle de la fréquence de déprédation en fonction de l'utilisation des répulsifs

Les embarcations dépourvues de répulsifs ont la fréquence d'interférence la plus élevée (*X*=**29.76% ± 17.51%**) suivie par celle des embarcations utilisant les répulsifs du type DDD-03-H (X=**30.15% ± 23.99%**). La fréquence de déprédation enregistrée chez les embarcations munies du répulsif de type DiD-01 est de l'ordre de **14.02%** (± **15.98%**). Cependant, cette fréquence est nulle chez les embarcations ayant testé le système Licado (**Fig. 28**). Le test ANOVA montre une variation significative de la fréquence de déprédation en fonction du type de répulsif testé (ANOVA : df = 3, F= 13.43, *p<0.01*).

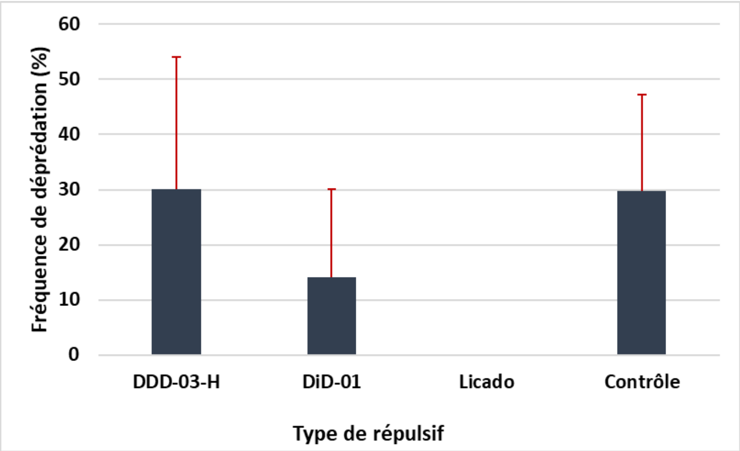


Figure 28 : Variation de la fréquence de déprédation en fonction du type de répulsif déployé

Typologie des perforations

En absence de répulsifs, une concentration de perforations a été détectée au niveau de l'avant poche. La classe de taille des perforations la plus observée est comprise entre **20** et **60** cm (**Fig.29**).

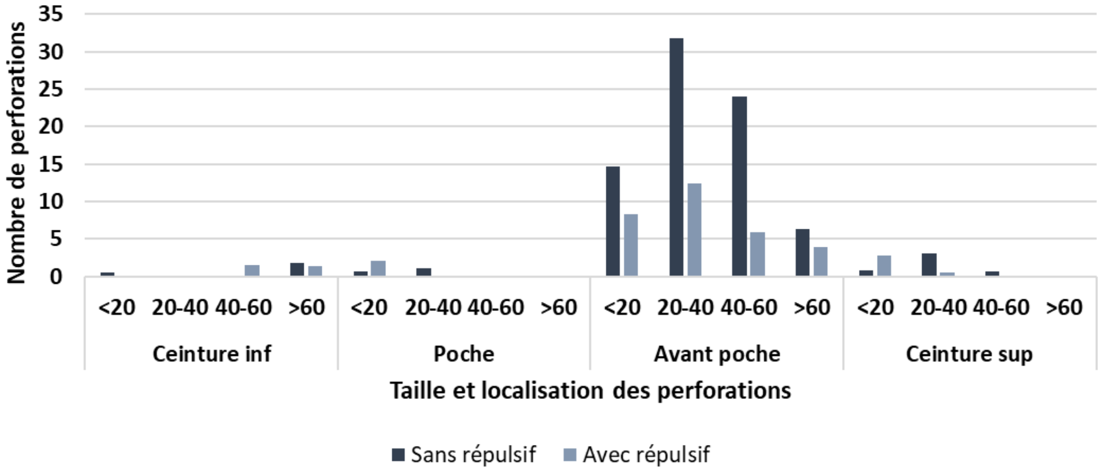


Figure 29 : Typologie des perforations en présence et en absence de répulsifs

La **figure 30** montre la variation du nombre moyen des perforations en fonction du type du répulsif testé. En effet, le nombre moyen de perforations le plus élevé a été enregistré chez les embarcations témoins ($X_{Contrôle}$= **29.89** ± **24.96** trous) suivi par les unités munies d'un répulsif de type DDD-03-H ($X_{DDD--03-H}$=**26.17** ± **20.04** trous) et de type DiD-01 (X_{DiD-01}=**17.06** ± **20,03** trous). Alors que chez les sardiniers bénéficiant du système Licado, le nombre de perforations ne dépasse pas cinq trous (X_{Licado}= **4.33** ± **2.75** trous).

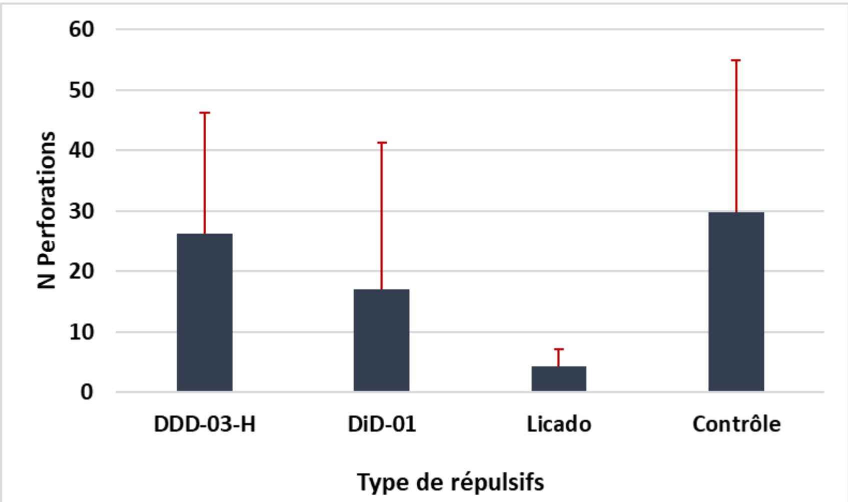


Figure 30 : Nombre moyen de perforations en fonction du type de répulsif testé

Nos résultats ont la même tendance que ceux de la première phase du projet MAVA-déprédation. Benmessaoud et al., (2021) a cité que suite à l'experimentation des trois répulsifs (DDD-03-H, DiD-01 et Licado), une baisse du nombre et de la taille des perforations. À une échelle régionale, nos résultats coïncident avec les résultats de Brotons *et al.,* (2008b). Ils ont rapporté que l'utilisation de pingers a découragé les Grands dauphins à s'approcher des filets maillants ce qui a entrainé la diminution du nombre de déchirures. De même, Buscaino *et al.,* (2009) ont montré que les filets maillants de fond équipés de « *DDD-02* » étaient moins endommagés de 31 % par rapport aux filets de contrôle. En revanche, Cox *et al.,* (2003) ont observé des réponses comportementales limitées des Grands dauphins par rapport aux filets maillants équipés de « *Dukan netmark 1000* ». Ces mêmes auteurs ont également noté que les pingers utilisés n'ont pas empêché les dauphins d'endommager les filets de pêche. Des résultats similaires ont été observés par Burke (2004) où les pingers « *Save wave* » n'étaient pas efficaces pour dissuader les grands dauphins de s'approcher des filets maillants et de se livrer à la déprédation des filets ciblant le maquereau. Récemment, Bruno *et al.,* (2021) ont montré que l'utilisation des répulsifs de type « *FishTek banana* » a diminué complétement les dommages causés au niveau des filets maillant et 86% des dommages causés au Lamparo. Une augmentation du volume de capture en poids et en valeur a été notée (Bruno *et al.,* 2021).

Il est judicieux de rappeler qu'à part l'expéerimentation des répulsifs acoustiques, les patrons des sardiniers ont attribué certains changements dans l'épaisseur du fils où ils sont orientés vers des fils plus épais pour les zones les plus fragiles de la senne (avant poche et poche). Ce changement peut aussi être la cause de la baisse du nombre de perforations.

Coûts de ramendage

Dans cette partie, nous avons évalué l'avantage économique de l'utilisation des répulsifs. Nous avons trouvé que les frais de ramendage chez les embarcations munies de répulsifs (X= **182.38Dt** ± **207.35Dt**/embarcation) ont diminué d'un tiers par rapport aux embarcations de contrôle (X= **313.43Dt** ± **202.05Dt**/embarcation) suite à la baisse du nombre de perforations.

En effet, les coûts moyens de ramendage sont plus élevés chez les embarcations de contrôle (X= **282.76Dt** ± **175.48Dt**/embarcation). Par contre pour les embarcations munies de DiD-01 et DDD- 03-H, la valeur moyenne des coûts est respectivement égale **202.25Dt** (± **246.50Dt**) et **286.28Dt** (± **233.56Dt**). Les frais de ramendage lors de l'utilisation des Licado sont les moindres (**Tab. 15**). Le test de Kruskall Wallis montre une variation significative des coûts de ramendage en fonction du type du répulsif testé (p<0,05).

Tableau 15 : Variation mensuelle du coût moyen de ramendage en fonction de type des répulsifs

Type répulsifs	Mean	N	Std. Deviation
DDD-03-H	286.28	39	233.56
DiD-01	202.25	40	246.50
Licado	22.50	10	71.15
Contrôle	282.76	76	175.48

Variation du débarquement

Le suivi du DPUE avec et sans répulsifs acoustiques ne montre aucune variation mensuelle significative ($p > 0.05$). Le DPUE moyen en utilisant les répulsifs est légèrement plus élevé que celui des unités sans répulsifs (DPUE $_{\text{avec répulsifs}}$= **9279.1** ± **5485.36 Kg** ; DPUE $_{\text{sans répulsifs}}$= **9057.3** ± **4057.54 Kg**). Le suivi du DPUE en fonction du type de répulsif déployé montre une variation significative ($p < 0.05$). Le **tableau 16** montre la variation du DPUE des unités suivies. En analysant de près le DPUE en fonction du type de répulsifs déployé, nous trouvons une nette élévation chez les embarcations munies de système Licado, succédé par les embarcations dotées de DiD-01. Celles munies de DDD-03-H présentent un DPUE inferieur à celui des sardiniers témoins dépourvus de répulsifs.

Tableau 16 : Variation du DPUE des embarcations suivies

Embarcations	Moyenne DPUE	Ecart type
Témoins	9039.70	5172.18 Kg
DDD-03-H	7373.80	5172.18 Kg
DiD-01	10014.00	4704.36 Kg
Licado	13749.00	5120.32 Kg

L'évaluation de la perte en capture suite à la déprédation a montré que les embarcations déployant les répulsifs présentent une capture par unité d'effort supérieure à celle des embarcations témoins. Buscaino *et al.,* (2009) ont rapporté que les filets maillants équipés de « DDD-02 » contenaient 28 % plus de poissons que les filets témoins. En Turquie, Gönener et Özdemir (2012) ont montré que les filets maillants ciblant le Rouget munis de répulsifs acoustiques de type « *Savewave* » présentait une capture par unité d'effort (0,96 ± 0,10 kg/km/h) supérieure à celle des embarcations de contrôle (0,50 ± 0,06 kg/km/h). En 2014, une étude menée par Maccarrone *et al.* a montré une augmentation de la production suite à l'utilisation de répulsif de type DDD-02. Ce résultat a été rapporté dans d'autres études (Dawson *et al.,* 1988 ; Lauriano *et al.,* 2004 ; Brotons *et al.,* 2008a ; Broton *et al.,* 2008b ; Gazo *et al.,* 2008). Les ondes émises par les dispositifs acoustiques peuvent dissuader l'approche des dauphins des engins de pêche ce qui réduit les prises accessoires, les dommages aux matériels de pêche et la perte de capture (Dawsons *et al.,* 1998).

Efficacité technique

L'efficacité des répulsifs faisant l'objet de cette analyse montre une variation mensuelle significative (p<0.01). En vérifiant l'efficacité par type de répulsif, le système Licado montre, jusqu'à maintenant, l'efficacité la plus élevée avec une moyenne de **90%**. Le répulsif interactif DiD-01 vient en deuxième position avec une efficacité technique moyenne légèrement inférieure à celle du système Licado (X=**74.78%** ± **33.59%**). Pour ce qui est du répulsif DDD-03-H ce dernier a une efficacité moyenne de **55%** (± **41.52%)** (**Fig.31**).

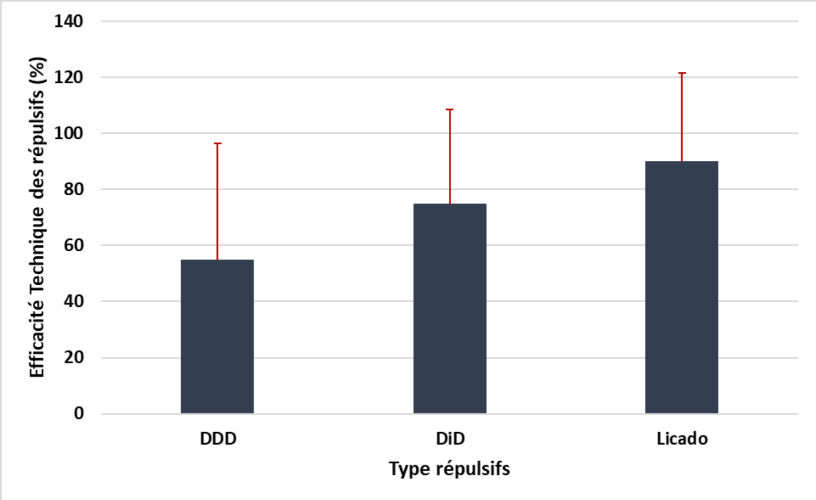


Figure 31 : Efficacité technique des répulsifs acoustiques

Au début de l'expérimentation, un comportement d'évasion des dauphins a été décrit avec un changement rapide de direction ou une augmentation de la vitesse de nage. En effet, des dauphins ont été observés par les pêcheurs en train de s'éloigner de la proue du navire immédiatement après le déploiement des trois types de répulsifs.

L'efficacité technique de DDD-03-H a chuté jusqu'à 38% à partir de mois d'Avril. Ainsi que celle de DiD-01 qui a baissé pour avoir une efficacité de 68% au mois de Mai. Cependant, seul le Licado a montré une efficacité technique stable. Cette baisse d'efficacité s'est accompagnée par la présence de dauphins aux alentours des sennes (**Fig.32**). Nous avons remarqué que seuls les systèmes Licado et les DiD-01 qui continuent à effaroucher et disperser les Grands dauphin. Par contre les DDD-03-H semblent attirer davantage les dauphins. Nos résultats supportent l'hypothèse de Kraus (1999), sur la possibilité d'évitement des répulsifs par les delphinidés et l'accoutumance de ces derniers. Ces deux facteurs doivent être pris en considération vu que le Grand dauphin est considéré comme étant l'espèce qui s'adapte le plus à l'impact extrinsèque (Whitehead *et al.,* 2000).

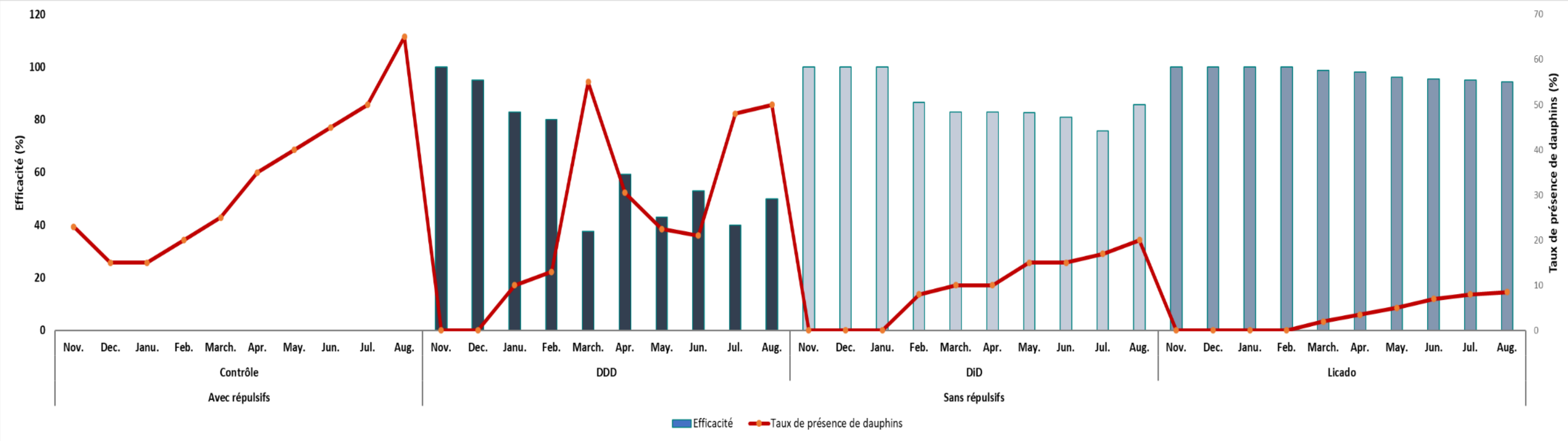


Figure 32: Evolution mensuel de l'efficacité technique des répulsifs testés et du taux de présence des dauphins

En effet, l'efficacité à long terme des pingers est encore controversée car les Grands dauphins, en particulier, peuvent s'habituer aux sons émis par les répulsifs et par conséquent ces répulsifs deviennent une source d'attraction pour eux (Cox *et al.,* 2003 ; Northridge *et al.,* 2003). Il s'avère que la probabilité d'accoutumance peut être minimisée en utilisant des pingers réactifs qui ne s'activent que lors de la réception de clics de cétacés (Leeney *et al.,* 2007) ou en modifiant périodiquement les fréquences d'émission des pingers (Gazo *et al.,* 2008). Ce qui explique notre choix pour les répulsifs interactifs (DiD-01 et Licado).

L'un des principaux problèmes liés à l'utilisation de moyens de dissuasion acoustique est le risque d'accoutumance. Richardson *et al.* (1995) ont défini l'accoutumance comportementale comme « une diminution progressive des réponses lorsqu'un stimulus répété ou en continu n'a aucune conséquence significative pour l'animal ». Plusieurs chercheurs ont détecté des signes d'accoutumance au cours de l'essai des dispositifs dissuasifs (Barlow & Cameron, (2003) ; Dawson *et al.,* (1998) ; Gordon & Northridge, (2002) ; Laake & coll, (1998) ; Reeves & coll, (2001) ; Richardson & coll, (1995) ; Trippel *et al.,* (1999). Carlström *et al.,* (2009), ont couplé des enregistreurs avec des pingers du type « *Netmark 1000* » au niveau des filets maillants. D'après ces auteurs la fréquence d'écholocalisation était faiblement enregistrée pendant la première période d'essai. Avec le temps, l'occurrence du marsouin autour des filets a augmenté et les signes d'écholocalisation ont été fréquemment détectés. Carlström *et al.,* (2009), ont confirmé qu'il s'agit d'une preuve d'accoutumance. Il semble que cette accoutumance compromette l'efficacité des répulsifs acoustiques utilisés. Franse (2005) a définit l'accoutumance comme une sorte d'ignorance des cétacés des ondes émises par les répulsifs. Dans ce cas, la présence de répulsif n'a aucune valeur. Il faut savoir que les recherches associées à l'effet d'accoutumance sont réalisées sur des courtes durées. Cependant, des études à long-terme sont nécessaires pour déterminer à quel moment le cétacé s'acclimate avec le répulsif. Cependant, une utilisation non responsable de ces dispositifs peut avoir des effets négatifs sur les cétacés (Marton *et al.,* 2002). En effet, selon Gordon & Northridge (2002), des lésions auditives peuvent survenir lorsque le dauphin s'approche du répulsif de moins de 3m. En revanche, Taylor *et al.,* (1997) ont déclaré que des troubles auditifs peuvent se produire à 30m du répulsif. Reeves *et al.,* (2001) ont indiqué que les dauphins exposés aux impulsions générées par les répulsifs acoustiques peuvent également engendrer des incapacités auditives.

D'autres problèmes peuvent être mentionnés suite à l'utilisation non responsable de ces mesures d'atténuation. D'après Franse (2005) et Gordon & Northridge (2002), l'exposition prolongée des cétacés, à des sources sonores intenses, peut provoquer l'échec de l'écholocalisation ce qui fera survenir de graves problèmes vitaux. Dawson *et al.,* (2013) ont indiqué aussi que l'utilisation permanente de répulsifs peut amener à la désertion des dauphins de leurs domaines vitaux.

Un autre méfait qui doit être pris en considération est le « *Dinner bell effect* » où le delphinidé lie la disponibilité et la facilité d'accès à la ressource à l'emplacement de la source sonore. Dans ce cas, les répulsifs fonctionnent d'une façon inverse (Gönener & Özsandıkçı, 2017). En effet, d'après une étude réalisée par Diaz Lopez & Marino (2011), ces auteurs ont mentionné que la chance de rencontrer les Grands dauphins dans une zone de pisciculture peut être augmentée suite à l'utilisation des répulsifs acoustiques car les dauphins pourraient se rendre compte qu'il y a de la nourriture à proximité de la source sonore.

3. Mesure d'atténuation technique

Comme nous l'avons mentionné dans la partie méthodologie, afin d'attenuer la severité des evenements de déprédation nous nous sommes orientés vers le changement de certaines caractéristiques techniques des STC utilisées au port de Kélibia.

Pour ce faire nous avons établi une enquete auprés de 25 armateurs utilisant les STC. Cette enquête nous a permis de distinguer deux types de STC ayant des dimensions distinctes:

- La plus grande est utilisée, à bord d'embarcations dépassant les 20m, dans les zones profondes et ce pour la capture de l'Anchois. La grande STC n'est lestée que du côté de l'aile, la poche et l'avant poche. Les patrons évitent le plombage de la grande senne de peur qu'elle s'accroche au fond ou dans les épaves. Ils peuvent rajouter du béton armé pour alourdir la senne en cas de besoin (**Photo.10**) ;

- La plus petite est utilisée, dans les zones côtières peu profondes, à bord des embarcations dont la longueur hors tout ne dépasse pas 20m [14-18m] et ce pour la pêche de la Sardine, le Maquereau et la Bogue.

La productivité de ces engins est étroitement liée à la superficie couverte par la senne. Les grandes sennes sont les plus productives par contre les petites sennes le sont moins.

La longueur des STC utilisées varie de 320 à 650m pour une chute allant de 80 à 170m. Sur chaque mètre de la ralingue supérieure se fixe entre 5 et 6 flotteurs. Le lestage de la ralingue inferieure dépend de la profondeur de la zone et du savoir-faire du patron. Le maillage varie entre 9 et 12mm pour le filet et entre 8 et 11mm pour la poche. Le nombre de coulisses varie entre 35 et 52 (**Fig.33**).

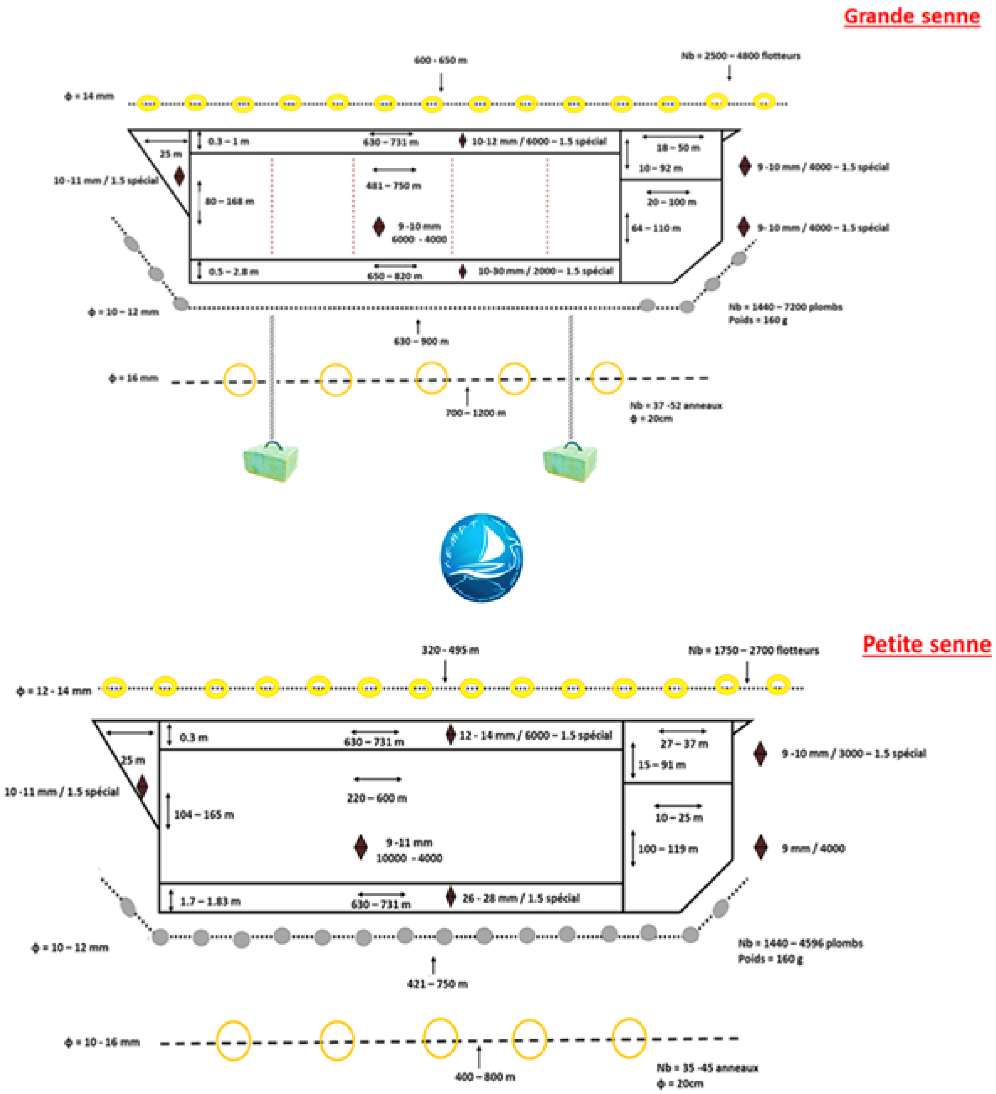


Figure 33 : Plan de senne les plus utilisées dans le port de Kélibia

Pour ce qui est de la finesse du fils utilisé, les petites sennes sont celles qui subissent le plus de dégâts perpétrés par le grand dauphin. En effet, les petites sennes sont formées de fils allant de 10000 à 4000m/Kg respectivement du corps de la senne vers la poche. Par contre, les grandes sennes utilisent generalement des fils plus epais, 6000 m/kg à -1.5 special respectivement du corps de la senne vers la poche, plus resistant aux morsures de dauphins.

Photo 10 : Béton armé utilisé pour alourdir les grandes STC

Pour ce qui est de la senne renforcée, comme nous avons un budget limité, nous avons proposé aux armateurs la substitution des alèzes les plus vulnérables à savoir la poche et l'avant poche par d'autres renforcées. Après concertation, les patrons ont préféré remplacer l'avant et l'arrière poche. La poche ne sera pas remplacée vue que la majorité des armateurs ont déjà suivi nos recommandations et ont remplacé les fils 4000 et 6000m/kg utilisées dans ces parties du filet par le 3000m/kg et même le fils spécial 1.5 (**photo.11**).

Photo 11 : Fils spécial 1.5 utilisé pour renforcer la poche de la STC

A cet effet 15 morceaux de filets ont été commandés et seront montés à la charge d'un patron volontier. Ces morceaux seront repartis comme indiqué dans le **tableau 17**. Une fois montés, la fréquence de déprédation, la typologie des perforations, les coûts de ramendage, le volume et la composition du DPUE seront suivis et comparés avec ceux d'une senne ayant la même longueur et chute et œuvrant dans la même aire d'exploitation.

Tableau 17 : Caractéristiques techniques des morceaux de filets renforcés

	Arrière poche	Avant poche
Nombre	8	7
Longueur (brasse)	27	27
Hauteur (brasse)	40	30
Maillage (mm)	10	10
Epaisseur du fils (m/kg)	3000	3000

4. Régime alimentaire du Grand dauphin

Dans l'objectif de comprendre l'ethologie alimentaire du Grand dauphin et pour mieux comprendre le phénoméne de déprédation, nous avons tenu) étudier le régime alimentaire. Il est à noter qu'il s'agit de résultats préliminaires.

Les estomacs récupérés proviennent d'animaux échoués trouvés le long du littoral tunisien de 2019 à 2022 et qui ont servi de base à cette étude. A partir des cadavres de delphinidés échoués durant cette période, nous avons examiné 09 contenus stomacaux de Grand dauphin ayant un indice de vacuité égale à 11.11 % (**Tab. 18**).

Tableau 18 : Principales informations concernant les individus échoués

Spécimen	Date d'échouage	Taille (cm)	Sexe	Contenus stomacaux
1	01/03/2021	295	F	Plein
2	11/06/2022	200	M	Vide
3	09/09/2019	300	F	Plein
4	24/07/2021	385	F	Plein
5	06/02/2019	210	M	Plein
+	27/05/2019	205	F	Plein
7	15/03/2020	265	M	Plein
8	13/09/2021	315	F	Plein
9	13/04/2022	320	F	Plein

Les longueurs totales des individus dont les estomacs ont été analysés sont en dessous de la taille moyenne des individus adultes. Selon Sergeant et al., (1973), en Mediterranée un *Tursiops* adulte a une taille moyenne à la maturité sexuelle de l'ordre de **315cm**. Par contre la taille moyenne des individus retrouvés échoués le long des côtes Tunisiennes est égale à **266.11** cm avec un écart-type égal à **61.13cm**.

Sur **09** estomacs examinés, **88.89%** (**N=08**) contenaient des restes de proies. Le **tableau 19** présente les valeurs absolues et relatives des abondances, poids (estimé) et fréquences d'occurrence, ainsi que l'indice d'importance relative de chaque espèce proie identifiée dans les contenus stomacaux de *Tursiops truncatus*.

Un total de **315** spécimens de poissons (à partir des otolithes) et **20** spécimens de céphalopodes (à partir de becs) ont été retrouvés dans les estomacs analysés. Nous avons dénombré **15** espèces de poissons appartenant à **huites** familles. Pour les céphalopodes, nous avons recensé une **seule** famille représentée par une **seule** espèces. Il est à noter que certains spécimens de poissons et de céphalopodes n'ont pas été identifiés vu la qualité médiocre des pièces trouvées dans les CS (**Tab.19**). Les Poissons sont le type de proies le plus important, tant au niveau de la fréquence de présence (dans toutes les estomacs pleins), que d'un point de vue numérique (comptabilisant **94.03%** du nombre total de proies) ou pondéral (**91.23%** du poids total). **Trois** proies (*Engraulis encrasicolus, Merlucius merlucius, Pagellus erythrinus*) regroupent plus de **88%** du poids total estimé (**Photo.12**).

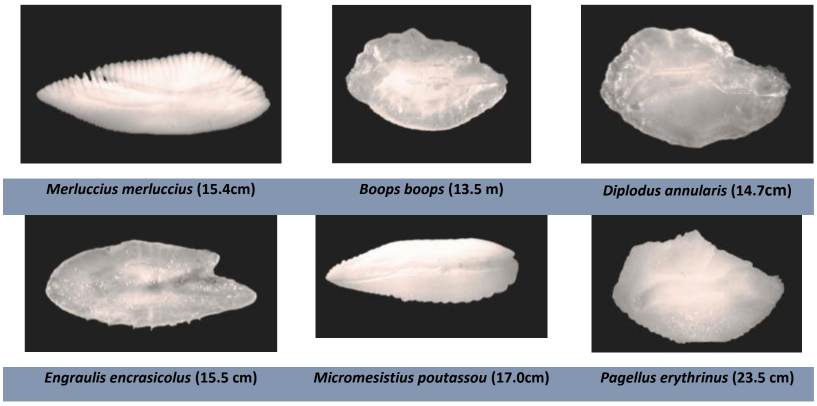


Photo 12: Exemple d'otolithes d'especes présentes dans les contenus stomacaux récupérés

Les Céphalopode sont présents dans **trois** contenus stomacaux sur les **08** analysés (pleins) et représentent **4,78%** du nombre de proies ingérées. *Loligo vulgaris* est la seule espèce identifiée. Cependant, les Crustacés étaient absents dans la totalité des CS inspectés.

L'IRI, en classant les proies par ordre d'importance dans le régime alimentaire, renseigne sur la place occupée par chaque proie dans l'alimentation. Les poissons dominent le bol alimentaire (100% IRI) de *Tursiops* (**Tab.19**). *Merlucius merlucius* apparaît comme l'espèce la plus dominante dans l'alimentation, se retrouvant dans **62.5%** des estomacs et représentant **31.34%** du nombre total de proies et ayant un IRI égal à **42,26%**. Les familles des Engraulidae et des Sparidae sont également des proies importantes dans l'alimentation, avec un IRI atteignant respectivement **17.01%** et **34.89%**.

Tableau 19: Nombre (N), poids (W) et fréquence d'occurrence (F) des proies identifiées dans les CS des spécimens de *Tursiops truncatus* échoués le long des côtes tunisiennes

Familles	Espèces	N	N%	W	W%	F	F%	IRI	IRI%
Poissons									
Carangidae	*Trachurus trachurus*	15	4.48	130	0.26	2	6.06	7.88	0.17
Engraulidae	*Engraulis encrasicolus*	65	19.40	8725.3	17.13	3	9.09	793.23	17.01
Gadidae	*Micromesistius poutassou*	5	1.49	350.5	0.69	1	3.03	10.62	0.23
Merlucciidae	*Merlucius merlucius*	105	31.34	12697	24.93	5	15.15	1923.84	41.2%
Mullidae	*Mullus barbatus*	5	1.49	150	0.29	1	3.03	4.55	0.10
	Mullus surmulutus	7	2.09	150	0.29	1	3.03	4.55	0.10
Mugilidae	*Liza aurata*	6	1.79	150	0.29	1	3.03	4.55	0.10
	Liza saliens	5	1.49	150	0.29	1	3.03	4.55	0.10
	Chelon labrosus	3	0.90	100	0.20	1	3.03	3.03	0.06
Moronidae	*Dicentrarchus labrax*	15	4.48	4260	8.36	2	6.06	258.18	5.54
Sparidae	*Boops boops*	20	5.97	2016	3.96	2	6.06	122.19	2.62
	Diplodus annularis	10	2.99	1430	2.81	2	6.06	86.67	1.86
	Oblada melanura	5	1.49	150	0.29	1	3.03	4.55	0.10
	Pagellus erythrinus	34	10.15	15500	30.44	3	9.09	1409.10	30.22
	Spondyliosoma cantharus	5	1.49	150	0.29	1	3.03	4.55	0.10
Indeterminées		10	2.99	350	0.69	2	6.06	21.21	0.45
Total Poissons		**315**	**94.03**	**46458.8**	**91.23**	**29**	**87.88**	**4663.22**	**100.00**
Céphalopodes									
Loliginidae	*Loligo vulgaris*	16	4.78	4218.66	8.28	3	9.09	0.01	0.00
Indeterminées		4	1.19	250	0.49	1	3.03	0.00	0.00
Total Céphalopodes		**20**	**5.97**	**4468.66**	**0.09**	**4**	**12.12**	**0.01**	**0.00**
Total Proies		**335**	**1**	**50927.46**	**1**	**33**	**1**	**4663.24**	**100%**

Nos résultats concordent avec ceux de Sekiguchi et al., (1992) ; Boutiba et Abdelghani (1995) ; Astruc (2005) ; Spitz (2010) et Larbi Doukara et al., (2014) qui ont mentionné que Tursiops truncatus ne cible pas une espece donnée mais quil est plutot opportuniste et que son régime alimentaire se compose principalement de poissons et secondairement de céphalopodes étant faiblement représentés dans la composition des espèces proies identifiées.

4. Conclusion & Recommandations

Ce travail a pour objectifs de tester trois types de répulsifs acoustiques dans le but d'atténuer le phénomène de déprédation induit par *Tursiops truncatus* au niveau de la pêcherie sardinière de la région de Kélibia. Pour atteindre cet objectif, nous avons quantifié, en premier temps, le phénomène de déprédation et évaluer ses répercussions économiques sur la rentabilité des unités de pêche sardinière.

La déprédation était très répandue dans la zone de Kélibia. Elle était observée chez **36%** des opérations suivies. Les Grands dauphins ont été fréquemment impliqués dans ces événements de déprédation et ce durant les différentes phases de pêche. Le suivi a montré qu'il existe une variation mensuelle de la fréquence de déprédation. Nous supposons que cette variation pourrait être liée à la disponibilité de proies, à la répartition spatio-temporelle de *Tursiops* et à l'éthologie de ces derniers qui est conditionnée par l'environnement qui l'entoure.

Cette interférence entre *Tursiops* et senne se matérialise par de nombreuses perforations ayant des tailles et localisations différentes. L'inspection de l'état de sennes a montré une concentration des perforations au niveau de la poche et l'avant poche. Le suivi de la DPUE des embarcations échantillonnées pour cette étude a montré une variation en fonction de l'occurrence de déprédation. Effectivement, une réduction significative de la DPUE a été enregistrée lorsque les Grands dauphins interagissaient avec les sennes.

Afin d'amortir le phénomène de déprédations, trois types de répulsifs ont été testés. L'objectif de cet essai était de voir si l'utilisation de ces répulsifs influence ou non la redondance et l'intensité du phénomène de déprédation. Sauf qu'il est à rappeler qu'une mesure d'atténuation est considérée comme optimale si seulement elle est (i) fonctionnelle, (ii) simple à mettre en œuvre et dont le prix est abordable, (iii) sans danger pour les pêcheurs et les prédateurs, (iv) n'affecte pas négativement l'environnement marin, (v) réduit effectivement les taux de déprédation, (vi) n'affecte pas le volume de capture et (vii) efficace à long-terme.

L'expérimentation des trois répulsifs a montré une baisse significative de la fréquence de déprédation où les embarcations munies de répulsifs présentent la fréquence moindre. En comparant les moyennes de la fréquence de déprédation en fonction du type de répulsif, il s'avère que les sennes équipées de répulsifs acoustiques interactifs (DiD-01 et Licado) ont enregistré les taux de déprédation les plus faibles. Lors de l'utilisation des répulsifs, nous avons remarqué une baisse du nombre de perforations occasionnées au niveau des sennes. Ces déchirures sont majoritairement localisées au niveau de l'avant poche avec une classe de taille de 20-40 cm. Chez les embarcations dépourvues de répulsifs, les perforations étaient localisées au niveau de l'avant poche et ayant une taille comprise entre 20 et 60 cm. Nous avons déduit, de cet essai, que les répulsifs interactifs réduisent plus le nombre de perforations que les DDD-03-H. La diminution du nombre de perforations s'est répercutée sur les frais de ramendage qui ont chuté.

Nos résultats ont montré aussi que le filet muni de répulsif est plus rentable en termes de production que le filet témoin. Ce résultat prend un sens supplémentaire si l'on considère que les coûts supportés par le bateau au cours de chaque journée de pêche ont été réduits (ex : carburant, lubrifiants, le ramendage…etc.) ce qui améliorerait encore une fois la rentabilité économique et les aspects de durabilité environnementale de l'activité de pêche.

Parmi les trois répulsifs testés, seul le DDD-03-H qui a donné des résultats décourageants. Une baisse nette de l'efficacité a été observée. Ceci peut être liée au taux d'utilisation et probablement à l'accoutumance de *Tursiops* vu que ce type de répulsif s'active immédiatement en contact de l'eau. Il peut avoir aussi développé un effet « *Dinner Bell* » chez cette espèce ce qui explique probablement l'attrait des Grands dauphins au senne lorsqu'ils sont déployé.

Cette étude doit être entretenue afin de déterminer la période d'accoutumance aux répulsifs choisis. Nous recommandons aussi que ce travail doit être complété par une étude de faisabilité de :

- Renforcement de la senne dans ses parties les plus fragiles comme a été fait avec l'équipe de l'INRH du Maroc.
- Utilisation d'un hydrophone lors des opérations de pêche pour détecter la présence du Grand Dauphin et déterminer la phase de l'opération de pêche la plus vulnérable.
- Expérimentation d'autres répulsifs acoustiques : les professionnels de région de Kélibia sont convaincus que les DiD-01 et le système Licado sont les moyens les plus efficaces pour atténuer la déprédation même si c'est à court-terme. Ils souhaitent que tous les sardiniers accostés au port de Kélibia les testent.
- Introduction du phénomène de déprédation dans le Plan Régional de Conservation du Grand dauphin.

D'autres recommandations ont été formulées et qui émanent directement de la profession et qui sont comme suit :

- Subvention de l'acquisition des répulsifs : Étant donné que les répulsifs acoustiques sont relativement chers (600 euros/la pièce) et peuvent ne pas être abordables surtout pour les petits métiers. Les professionnels de la pêche de la région d'étude souhaitent bien que l'Etat considère ces équipements acoustiques comme équipements de base à bord et qu'il leurs accorde une subvention pour les acquérir.
- Suggestion du repos biologique en concertation avec les autorités compétentes des deux rives de la Méditerranée afin de résoudre le problème de la surexploitation des stocks partagés.

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Annexe -1

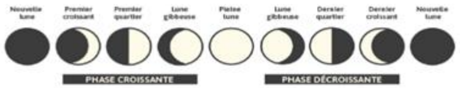
Fiche 1 : Observation autour de la ferme TTF

Date de la sortie : .... Type d'embarcation.. Opération à bord prévue............................

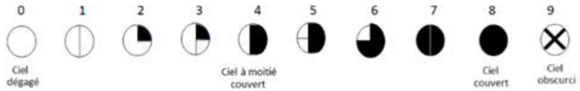
Réticule visité.. Cage(s) visitée(s).. Présence de plongeurs................................

Conditions environnementales :

Cycle lunaire



Etat du ciel : Nébulosité (Octa)



Etat de la mer	Calme	Belle	Peu- agitée	Agitée
Direction du courant	....			
Visibilité	Très bonne	Bonne	Moyenne	Médiocre
Vent en nœuds	0	1-3	3-5	>5
Direction du vent	....			

Opérations de la ferme							Observation									
Heure	Réticule	Cage	Position	Prof.	Activité		Espèce	N min	N max	Composition		Comportement du groupe		Comportement des poissons élevés		Rque (Obs. sous-marines, Présence d'autres espèces marines ; bateaux etc...)
					Alimentation					Adulte		Déplacement		Stable -inchangé		
					Changement du filet							Socialisation		Compact et concentration au milieu		
					Maintenance							A opportuniste				
					Pêche					Immature		A non-opportuniste		Plonge		
					Surveillance							Déprédation		Remonte à la surface		
					Passage							Repos				
					Autre							Indéterminé		Indéterminé		
					Alimentation					Adulte		Déplacement		Stable -inchangé		
					Changement du filet							Socialisation		Compact et concentration au milieu		
					Maintenance							A opportuniste				
					Pêche					Immature		A non-opportuniste		Plonge		
					Surveillance							Déprédation		Remonte à la surface		
					Passage							Repos				
					Autre							Indéterminé		Indéterminé		

Fiche : Suivi Pinger autour des cages

Réticule : ....

Cage : ....

Type de répulsif : ....

Numéro de série : ....

Date	**Vérification du niveau de la batterie du répulsif** (oui/ non)	Répulsif déployé (Oui / Non)	Position (Longitude/ latitude)	Heure et minutes		Occurrence de delphinidés (Oui / Non)	**Formation du groupe**		**Ethologie du groupe**
				Mise à l'eau	Remontée		**Taille**	**Composition**	

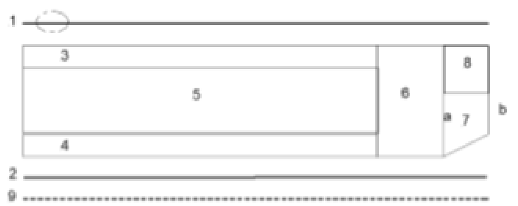
Fiche enquête 1 : Caractéristiques techniques de la flottille & des sennes

Date : .... Port : ....
Nom de l'enquêteur : .... Nom de l'enquêté ....

Embarcation : .... Matricule : ....
Pingers : .... Type : ....
Reference pingers : .... Reference chargeur : ....

Caractéristiques techniques de l'embarcation								
L.H.T :					Largeur :			
J. B :					C.V :			
Equipage :	Patron				Mécanicien :			
	Marins				Ramendeurs :			
	Système de rémunération :							
Equipements :	G. P. S		V. M. S		P. auto		Radio	
	Sonar		Sondeur		Boussole		Téléphonie	
	P. Block		Grue + P. Block		Salabarde			
	Treuil pour virer la capture				Treuil pour virer le filet et le cordage			
B. annexes :	Nombre		N porte-feu		Intensité lumineuse			
	Type				Puissance lampe			
	Nb				Type de lumière			
	Puissance groupe électrogène				N porte filet			
Power Block :	Marque				Charge (Kg)			
	Puissance				Largeur			
	Écartement entre la gorge de la poulie et arceau de support (cm)							
Treuil :	Marque				Puissance			
	Longueur coulisse (m)							

Caractéristiques techniques de la sennes



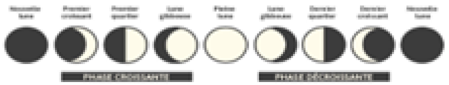
1. Ralingue Supérieure		2. Ralingue Inférieure	
Longueur		Longueur	
Diamètre		Diamètre	
Nb. Flotteurs		Nb. Lests	
Diamètre flotteur		Poids unitaire de plomb	
3. Bande de Renfort Supérieure		**4. Bande de Renfort Inférieure**	
Longueur (maille)		Longueur (maille)	
Chute (maille)		Chute (maille)	
Maillage		Maillage	
Force du fil		Force du fil	
5. Corps de la senne		**6. Avant poche**	
Longueur (maille)		Longueur (maille)	
Chute (maille)		Chute (maille)	
Maillage		Maillage	
Force du fil		Force du fil	
7. Complément poche		**8. Poche**	
Longueur (maille)		Longueur (maille)	
Chute (maille)	a | | b |	Chute (maille)	
Maillage		Maillage	
Force du fil		Force du fil	
9. Coulisse/câble		**10. Anneaux**	
Longueur		Nb anneaux	
Diamètre		Diamètre	

Fiche : Sortie en mer

Numéro de l'embarcation : .... **Matricule :** .... **Date de la sortie :** ....

Conditions environnementales :

Cycle lunaire



Etat du ciel : Nébulosité (Octa)

Etat de la mer	**Calme**	**Belle**	**Peu- agitée**	**Agitée**
Direction du courant	....			
Visibilité	**Très bonne**	**bonne**	**moyenne**	**médiocre**
Vent en nœuds	**0**	**1-3**	**3-5**	**>5**
Direction du vent	....			

Opérations de pêche					Observation										
Heure	**Activité**	**Long.**	**Lat.**	**Prof.**	**Espèce**	**N min**	**N max**	**Composition**		**Comportement**		**Réaction au bateau**		**Rque** (Présence d'autres espèces marines ; bateaux etc…)
								Adulte		Déplacement		Fuite		
										Socialisation		Evitement		
										Chasse		Indifférence		
								Immature		Déprédation		Approche		
										Repos		Étrave		
										Indéterminé		Indéterminé		
								Adulte		Déplacement		Fuite		
										Socialisation		Evitement		
										Chasse		Indifférence		
								Immature		Déprédation		Approche		
										Repos		Étrave		
										Indéterminé		Indéterminé		
								Adulte		Déplacement		Fuite		
										Socialisation		Evitement		
										Chasse		Indifférence		
								Immature		Déprédation		Approche		
										Repos		Étrave		
										Indéterminé		Indéterminé		
								Adulte		Déplacement		Fuite		
										Socialisation		Evitement		
										Chasse		Indifférence		
								Immature		Déprédation		Approche		
										Repos		Étrave		
										Indéterminé		Indéterminé		

Fiche _ : Suivi Pinger

Nom de l'embarcation : ....   **Matricule :** ....

Type de répulsif : ....   **Numéro de série :** ....

Date	Niveau de la batterie du répulsif vérifié (Oui / Non)	Opération de pêche													
		Calée N° 1						Calée N° 2							
		Répulsif déployé (Oui / Non)	Position Longitude/ latitude	Heure et minutes		Déprédation (Oui / Non)	Conséquence	Répulsif déployé (Oui / Non)	Position Longitude/ latitude	Heure et minutes		Déprédation (Oui / Non)	Conséquence
				Mise à l'eau	Remontée					Mise à l'eau	Remontée		

Fiche _ : Suivi de relai

Nom de l'embarcation : ....   **Matricule :** ....

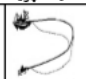
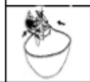
Type de répulsif : ....   **Numéro :** ....

Date	Vérification du niveau de la batterie du répulsif (Oui / Non)	Semaine 1		Semaine 2	
		Op 1 Avec répulsif	Op 2 Sans répulsif	Op 1 Avec répulsif	Op 2 Sans répulsif
J1					
J2					
J3					
J4					
J5					
J6					
J7					

ميناء الصيد البحري بقليبية

اسم المركب .... المعرف ....

خاصية الشباك .... جهاز صد الدلافين ....

تاريخ الخرجة		عملية الصيد	بداية عملية الصيد	نهاية عملية الصيد	استعمال جهاز الصد				ظهور الدلافين				فترة الظهور			سلوك الدلفين (الهروب)				تفاعل الدلافين مع الشباك				الكمية المنزلة				حالة معدات الصيد (التقطيع)			
																															
	1				نعم		لا		نعم		لا					نعم		لا		نعم		لا		↖		↘		نعم		لا	
	2				نعم		لا		نعم		لا					نعم		لا		نعم		لا		↖		↘		نعم		لا	
	1				نعم		لا		نعم		لا					نعم		لا		نعم		لا		↖		↘		نعم		لا	
	2				نعم		لا		نعم		لا					نعم		لا		نعم		لا		↖		↘		نعم		لا	
	1				نعم		لا		نعم		لا					نعم		لا		نعم		لا		↖		↘		نعم		لا	
	2				نعم		لا		نعم		لا					نعم		لا		نعم		لا		↖		↘		نعم		لا	
	1				نعم		لا		نعم		لا					نعم		لا		نعم		لا		↖		↘		نعم		لا	
	2				نعم		لا		نعم		لا					نعم		لا		نعم		لا		↖		↘		نعم		لا	
	1				نعم		لا		نعم		لا					نعم		لا		نعم		لا		↖		↘		نعم		لا	
	2				نعم		لا		نعم		لا					نعم		لا		نعم		لا		↖		↘		نعم		لا	
	1				نعم		لا		نعم		لا					نعم		لا		نعم		لا		↖		↘		نعم		لا	
	2				نعم		لا		نعم		لا					نعم		لا		نعم		لا		↖		↘		نعم		لا	
	1				نعم		لا		نعم		لا					نعم		لا		نعم		لا		↖		↘		نعم		لا	
	2				نعم		لا		نعم		لا					نعم		لا		نعم		لا		↖		↘		نعم		لا	

Annexe -2 (Ben Arfa, 2022)

Confidentiel - Information collectée pour des besoins statistiques uniquement

Questionnaire sur la déprédation de l'activité des sardiniers du port de pêche de Kélibia (TUNISIE)

Code du navire		**Période de référence**	**2021**
Date de l'entretien		**N° de tél. de la personne interviewée (facultatif)**	

01 Source des informations	
Propriétaire / Armateur	☐
Partenaire	☐
Capitaine	☐

Propriété du navire	
02 Propriétaire/armateur impliqué dans les activités du navire en mer	OUI ☐ NON ☐
03 Propriétaire/armateur impliqué dans les activités du navire à terre	OUI ☐ NON ☐
03 bis Propriétaire/armateur impliqué dans les activités d'autres navires ?	OUI ☐ NON ☐
04 L'unique activité du propriétaire est dans la pêche	OUI ☐ NON ☐
05 Si non à (04), est-ce que la pêche est la principale source de revenu ?	OUI ☐ NON ☐
Si non à (05), quelle principale source de revenu pour le propriétaire (secteur d'emploi)	Nbre

Codes des secteurs économiques

1 = Aquaculture
2 = Agriculture
3 = Forestrie
4 = Hotels, restaurants, tourisme
5 = Manufacturier, construction
6 = Commerce de gros et de détail
7 = Fonction publique
8 = Autre

GROUPE DE VARIABLES	**VARIABLE**	**UNITE**
	06 Activité du navire	
	a) Nombre de mois pendant lesquels le navire a travaillé durant l'année 2021	Nbre
	b) Nombre de sorties en mer (moyenne mensuelle)	Nbre
	07 Durée moyenne d'une sortie en mer (En heures) Nbre (ou) (En jours)	Nbre
Effort	08 % des sorties en mer d'une durée supérieure à 24 h (Par mois)	%
Code des engins de pêche	09 Nombre moyen d'heures de pêche effective par sortie (base journalière moyenne de 24 h)	Nbre
Ref. Annexe D - DCRF	10 Nombre d'opération de pêche par sortie	Nbre
	11 Durée de l'opération de pêche (En heures)	Nbre
	12 Nombre d'opération déprédatées (moyenne mensuelle)	Nbre
	13 Fréquence de déprédation	%
	14 Nombre de jours inactifs (sans navigation) du à la déprédation (moyenne mensuelle)	Nbre
	15 Nombre de sorties actives (avec navigation) mais sans pêcher à cause de la présence du dauphin Par an (2021)	Nbre
	16 Engins de pêche utilisés pendant une sortie	
	a) Specifier l'engin Code — Nombre de pièces à bord Nbre — (En heures)	Nbre
	b) Specifier l'engin Code — Nombre de pièces à bord Nbre — (En heures)	Nbre
	17 En cas de déprédation, quelle est la partie de l'engin la plus attaquée	
	(a) la poche: % — (b) l'avant poche % — (c) le corps % — (d) Autre (spécifier):...........................	%

GROUPE DE VARIABLE	**VARIABLE**	**UNITE**
	18 Equipage engagé par navire (y compris propriétaire/armateur, si embarqué)	Nbre
	19 Nombre total de personnes différentes ayant travaillé sur le navire dans l'année (y compris propriétaire/armateur si embarqué)	Nbre
	20 Heures de travail à bord des navires (base journalière moyenne de 24 h)	Nbre
Emploi	21 Nombre de personnes impliquées dans les activités à terre (en lien avec la pêche) sur la base d'une moyenne journalière	Nbre
	22 Système de partage: Attribuer le nombre de part tota et par chaque poste à bord et/ou à terre, dans le cas d'un salaire (mensuelle) spécifier le entre (.......)	

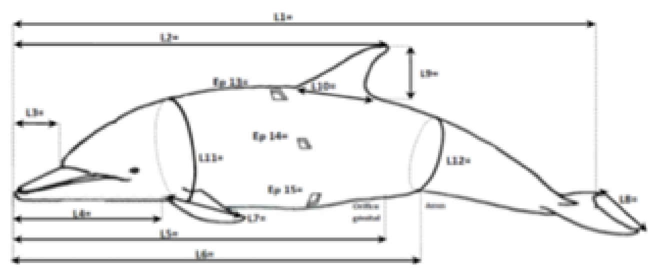
Total parts	Nbre		d-Groupiste	Parts	Nbre	h-Comptable	Nbre
a-Capitaine	Parts	Nbre	e-Marin spécialisé	Parts	Nbre	i-Transporteur	Nbre
b-Aide-capitaine	Parts	Nbre	f-Marin	Parts	Nbre	j-Gardien	Nbre
c-Mécanicien	Parts	Nbre	g-Ramendeur	Parts	Nbre	k-................................	Nbre

Annexe-3

Fiche d'information d'échouage – cétacés

Données générales					
Nom du référent :		Tel :			
Date d'échouage :					
Lieu d'échouage :		Coordonnées Géographiques	Lat :		
			Long :		
Circonstance de l'observation :	1.Par hasard	2.Par informateur	3.Autre		
Photos prises :	Oui	Autres animaux observés à proximité :	Oui		
	Non		Non		
Espèce :		Sexe :			
Age[1] :	1.Adulte	2.Sub-adulte	3.Juvenile	4. Nv-née	
Critère de détermination :		Détermination	1.Probable		
			2.Certaine		
Animal vivant					
Date échouage :		Date de renflouage :			
	Animal remis à l'eau avec succès		Animal mort avant intervention		
			Animal mort pendant l'intervention		
Commentaires :	Cas isolé ou échouage multiple, circonstances, soins apportés, tentatives de renflouage, intervenants, etc.				
Animal mort					
Date de la découverte :		Date de la mort :			
Code de décomposition :	1-Très frais (<48h)		3-Décomposition légère		
	2-Décomposition avancée		4-Reste		
Protocole de prélèvement réalisé :			1.Solo		2.Équipe
Compte rendu nécropsie :	Oui	Référence de l'échouage :			
	Non				
Capture :	1.Probable	Indice(s) de capture :			
	2.Certaine				
Commentaires :					

Examen externe			
Oui :		Non :	
Si oui cocher les observations, réaliser des photos avec échelle, indiquer les localisation sur le schéma et en commentaire			
	1.Aucune lésion		8.Abrasion
	2.Hématome		9.Coupe nette
	3.Perforation		10.Morsure
	4.Malformation		11.Grosseur/Tumeur
	5.Lésion pathologique		12.Fracture
	6.Corps étranger		13.Parasite externe
	7.Lésion indéterminée		14.Autre
Commentaires :			
Avis sur la cause de mortalité :	1.Probable	2.Certaine	
1.Capture		4.Collision	
2.Pathologique		5.Prédation/compétition	
3.By-catch		6.Indéterminée	
Commentaires :			
Mensurations			



Dents :	Sup G	Sup D	
	Inf G	Inf D	
Poids :	Réel :		
	Estimé :		
Commentaires :			
Examen interne			
Oui		Non	
1.Dents		6.Œsophage	
2.Poumons		7.Cœur	
3.Intestins		8.Estomac	
4.Reins		9.Foie	
5.Appareil génital		10.Appareil urinaire	
11. Chair		12. Graisse sous-cutanée	
13.Muscle dorsale		14. Autre	