Killer Whale Attacks (2)

Deterring Orcas and Protecting Rudders
– Possible Solutions –

version 07/10/2023

Pierre Lang

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Introduction

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Who's who

I am Pierre Lang, born in Brussels (1951), Polytechnic School (Free University of Brussels), solo sailor, 40000 miles sailed in Europe between Greenland and Greece (2006-…)

I designed my sailboat Thoè with Gildas Plessis (French naval architect) in 1999-2000. I took a very active part in her construction. As a consultant, I surveyed the construction of one sister ship Tara (2004). Thoè won the first prize of the wooden boat challenge at the La Rochelle boat show (France, 2001).

I took part in humpbacks and blue whale research in Iceland from 2013 to 2018. It is the reason why I own a hydrophone that I used to record possible deterring sounds in this study.

Comments or questions can be sent to me: plang@irisoft.be – www.thoe.be

Analysing the problem

Since 2020, one or more groups of orcas have been attacking boats, mainly sailboats. They are called “interactions”. Humans often refer to them as “attacks” because they are perceived as aggressively by sailors. Yet, it doesn't appear that orcas act aggressively. But from the point of view of sailors, they are *attacks*, because rudders of many boats were destroyed and three boats sank.

I first wrote a first report about the **analysis** of the orca interactions because there is no good answers if the question is asked the wrong way, or not asked at all ! Download it from this page.

It was based on my good technology knowledge of material resistance, boat design and construction and a basic knowledge in whales. This previous document was reviewed by Alfredo Lòpez Fernandez (GT Orca Atlántica – GTOA, University of Aveiro).

Protecting the boat at low cost

This second report describes the techniques I decided to use to defend my sailboat (Thoè, www.thoe.be) in case of interaction with orcas.

The objective of this report is trying to define a low-cost way of protecting boats from orca attacks, if possible for less than 100 to 200 € depending on the number of rudders.

The techniques are sorted in 4 groups:

- **Preparing the boat.**
- **Avoiding orcas area.**
- **Deterring orcas.**
  - Striking a pipe or some part of the boat structure to send repelling sounds through the water.
  - Using the fog horn.
  - Using a pinger especially designed to repel orcas.
- **Protecting the rudder system**
  - Amortizing the helm to reduce the stress into the rudder blade when an orca is pushing it.
  - Installing (not hurting) spikes on the blade rudder if the orcas do not react to the other techniques.

If you have any comments or experiments to share, please do not hesitate to contact Pierre Lang, plang@irisoft.be.

Regulations

I consider that we can do many things as far as we follow the **animal protection regulations** AND that we warrant the **safety of the crew and the ship** (responsibility of the captain following the maritime regulations).

These two laws may seem **contradictory**, but they are less than somebody may assume. Of course each side (biologists, animal protection defenders, sailors, etc.) are looking to one of the two regulations. They do not look at the way(s) to make them compatible with the other.

It is not allowed to approach orcas, throw stuff to them, attract or repel them, etc. However it is not forbidden to the orcas to approach boats, touch them and try to damage them. So, if we use spikes (for example), it is the animal's choice to touch them. It is not our choice to hurt them. They can locate the spikes on the rudder with their eye, echolocation system and skin (carefully). They are many dangerous things into the sea that orcas have to avoid. And they avoid them most of the time.

Let's check regulation in www.orcaiberica.org (GTOA abstract) or the Spanish and Portuguese official documents. In Spain, for example, we cannot search for contact with orcas, use firecrackers or make high-frequency sounds, throw something to them. BUT it is not forbidden to be at sea with anything.

- Spanish Authorities recommendations: www.mitma.gob.es/marina-mercante/seguridad-maritima-y-contaminacion

Is some particular defence really efficient ?

It is very difficult, if not impossible, to demonstrate something in the field of orca interactions.

- There are too few reports to get reliable statistics.
- We do not know which characteristics of the boats and which behaviour of the orca are influencing or not an attack. Many sailors are using human being parameters to try to study the influence of hull or under water colours, etc. while forgetting that orcas are using their echolocation system.
- The reports do not contains enough informations.
- Most interactions are not reported for miscellaneous reasons.
- The number of interactions in 4 years is too small

Why many missing reports ?

- If I am using a possibly illegal way to deter orcas (to save crew members or the boat), shall I publish this experience on a social media ? Shall I take the risk to be sued by ecologists following the animal protection regulations ? Shall I take the risk to be sued by a judge following the marine regulations after an accident or the dead of a crew member ?
- Due to the small number of reports, no valid statistics can be computed.
- In case of an interaction without an attack, it is impossible to prove that the protection means that we used was really effective because we cannot prove that the orca had the intention to attack. And if we used several means at the same time, which of them was the good one?

Why it is so difficult to prove something ?

- It is impossible to prove why something did not happen. It is possible to know that a rudder was damaged, but it is impossible to demonstrate why an attack did not occur. Maybe the orca saw a tuna passing and attacked it ? Maybe it changed is mind ?
- If we used 3 means or actions to try to deter an orca, which of them was or were the reason why it stopped attacking ? Was it too far away from its group ? Was the sea depth too low ? We don't know !

Security, security, security vs. risks ?

If someone is using some device to try to deter an orca and it did not succeed, he will send an attack report and complain to the manufacturer of this device because it was supposed to fail. The right or wrong way the device was used is not reported. Maybe this device was defect. Or the batteries were empty... or switch off !

In reverse, if the orca left the area, a doubt will remain about the actual reason of its departure and not report will be sent. The sailor will be too happy to avoid problems.

The modern world wants an absolute security (promoted by many governments). Sailors want a 100 % successful solution to face the orca's problem. They cannot live in a non-zero risk word !

⇒ That is, if a defence mean **fails in one case**, it will be said **to be inefficient forever** !

Strategy types to face interactions

As far as I know, animals (as well as human beings) are using the following strategies for self-defence : running away or stay still, fighting or repelling.

1a) Running away

Snakes are running away if we do not walk silently. They feel the ground vibrations and run away. It is the current strategy (2023) to avoid orcas interactions. Trying to know where the danger is (orcas), avoiding to sail close to it and run away if the danger approaches.

1b) Staying still

This is a variation of running away. It is **running away at 0 knots!** Some time ago, it was advised by GTOA, authorities, etc. It is running away from moving. Many predators can see better moving prey. So, to save yourself, stay still, wait and pray! This is the "rabbit" strategy or the strategy of a mouse when an eagle is flying in the sky. In the modern world, it is not the best thing to do: the rabbit walking across a road is staying still in the lights of a car until it is crashed.

2) Fighting

If the previous strategy did not work, the prey or the animal in danger (and, of course, the human being) is attacking. The snake will beat and poison us. Many sailors are buying firecrackers to fight orcas. Some of them are dangerous for the ear system of the whales if they explode into the water. The sound wave is dangerous for them (if you use it anyway, fire it above the surface).

At this time the two lower-level archaic animal defences are mentioned : **escape or fight**.

3) Repelling

In this case, the prey is trying to avoid the predator approaching.

The octopus is blowing its black cloud so that the hunter cannot see it any more. This will give more time to "run away" or to "hide". This strategy remains practically unused the right way by sailors. There are no experiments done in a community of many thousands skippers. Repelling strategies remain not effectively studied, documented or reported.

At the end of the day, sailors are claiming that most possible repelling methods are not efficient.

- They say that pingers do not work – but, most of the time, they are used in the wrong way.
- Making sounds is not documented. However some sailors are reporting they deterred orcas successfully, but there is no documented way how to do it.

- Other methods which are very toxic (hypochlorite, ammonia, diesel, etc.) should not be used.
- Firecrackers is not, following me, a repelling tool but a fighting and aggressive tool. It is illegal from the animal protection view, probably with some very good reasons (otherwise we could also speak about guns and bullets).

Consequences

- Most sailors are all using the "running away" strategy.
- Someone is using the controversial "fighting" strategy.
- Almost nobody is using the "repelling" strategy (very few are reporting about it).
- Illegal use of some tactics is, of course, not reported by users.
- If someone reports an accident with an orca to his insurance company, will this company pay the repair? If he does not know the answer, he prefers to mute.

Suggested global strategy

I am a single-handed sailor. I only implemented the following proactive defences. Everyone is free to assume their responsibilities by making other or additional arrangements. They are given to the reader(s) without any kind of warranties or responsibilities.

They are also **not expensive at all**. If a technique costs too much, it will not be used by sailors who are just sailing for one or two weeks in the risky area. In this case, they will use the "running away" strategy and pray to pass without problems.

I distinguished 4 groups of techniques: They will be described in the following sections.

1) Boat set up

- Create a closed space around the rudder tube to avoid possible water leaks invading all the boat.
- Get a high capacity bilge pump and be ready to use it at any time.
- Protect the rudders (see next topic).
- Buy deterring means (see next topic) and be ready to use them before leaving the harbour.

2) Avoiding orcas areas

- Check the Internet for orcas hot spots.
- Choose a secure sailing route.

3) Deterring means

- Striking a pipe or using another way to make deterring sounds with a hammer.
- Using a fog horn.
- Pull a pinger or down it at the aft is the boat is stopped.

I would not be happy to drop under water firecrackers, to trigger no injuries to the animal's ears. And I would not throw toxic stuff as diesel, hydrochloride, ammonia, etc.

Warning: check regulations about animal protection.

4) Protecting the rudder system

- Amortizing the wheel.
- Protecting the rudder with spikes.

Warning: check regulations about animal protection.

1) Boat set up

- Try to get the rudder system in a **sealed area** to avoid water leaks to invade the complete ship.
- Have a **high capacity bilge pumps ready** on board. The bilge pump installed on the boat at construction time is just enough to pump small leaks, not the leak an orca attack can make by breaking the link between the rudder tube and the hull.
- More than usual, the **key word is "anticipation"**. Every defence must be ready to be put into action in seconds. In case of an attack, it is too late, in the panic state, to search for the tools into the ship.

Orcas attacks & possible damages

Dufour 430

Fastnet racing boat (middle and right photos)

Killer whales are attacking the rudder preferably **from below**. It climbs into the water towards the rudder blade. It pushes the **lower edge** vertically. It pushes on it **sideways to turn the rudder**. It starts at the bottom and if the lower part of the rudder blade break, it continues a bit higher until the entire blade is gone.

Breaking the rudder

Turning the rudder can bring it against the port or starboard stop. By forcing the blade when it is already blocked on the stop, it ends up breaking by twisting, because the force exerted by the whale affects 100 % on the blade. This happens more quickly if the construction of the rudder is light (foam core, old ships, etc.).

WARNING: If the autopilot is active, the rudder is blocked by the drive system. In this case, the first attack of the orcas can already damage the rudder blade.

Bending the rudder shaft

It is also possible that the whale pushes on the rudder shaft side. In this case, the shaft can be bent. It depends on the design of the rudder (diameter, length, material, aluminium, steel, etc.). If the shaft is strong enough, the boat will just turn around its hull centre.

⇒ Look at the bent shaft in the middle of the picture, between the upper left corner of the blade and the hull. The blade did not break. The shaft was too small in diameter or the orca hit the blade close to the leading edge.

Breaking the hull

The embedding assembly between the shaft passage tube (*tube de jaumière* in French) and the hull can be broken. This is the most dangerous situation because the water leak can be huge. Three boats sank in four years in this case.

Autopilot OFF !

WARNING !

Before an attack, the first very important thing to do is to **put the autopilot in STAND-BY**, to avoid damages to the rudder and the autopilot drive systems.

It is the reason why it is so important to **carefully watch for orcas**.

If we do not see them **from a distance, it's too late to avoid the first attack shock**.

2) Avoiding orcas areas

Official recommendations

The first action of the skipper should be to **avoid killer whales spots**. At writing time of this document, the recommendations are as follows:

- **Get information** about orcas hot spots. Information sources are not integrated with each other. Use multiple sources.
  - Browse www.orcas.pt is a collaborative Web site for sailors. Register to its members' forum. It is exclusively based on the "running away strategy" which is well done. It does not try to do any research in finding a better solution. It has a conflict of interest between promoting an active boat protection and making money with its on-line shop.
  - Browse www.orcaiberica.org (GTOA – GT Orca Atlántica)
  - Use the Orcinus App on a Smartphone :
    https://play.google.com/store/apps/details?id=co.thenautilusproject.orcinus&hl=fr&gl=US&pli=1
    https://apps.apple.com/us/app/orcinus/id1659221919
  - Register to Facebook groups about orcas interactions
- **Sail only in the daytime**. Attacks can occur during the day as well as at night or in the dark. But it is easier to see orcas coming from far away (and if needed to be rescued by SAR ships).
  Whales are not using their eyes to hunt their prey or attack our rudder. They are mainly using their echolocation system. So they do not look at the colours, mast and sails, etc.
  They are (probably) checking the shape (height, width, thickness, surface smoothness) of the rudders.
  Whales have better ears than us. A killer whale can hear up to 120 kHz (20 kHz maximum in human people)
- **Sail in shallow water**. At the moment, there are practically no attacks in less than 20 m depth.
- **Watch for orcas carefully... from far away** !
  - This gives you more time to prepare yourself and the boat defence.
  - Otherwise an orca can attack the rudder suddenly (it swims by diving to the boat from a distance).
- Set the autopilot in STAND-BY and **steer manually** if orcas are in the area.
- **Run away**. If an orca is seen and in case of a sudden attack, sail as fast as possible to shallow water. If not possible, take the opposite direction of the whales migration.
- **Inform ships around**. Call VHF 16 to all ships with a SECURITY message and, if possible, a DSC message to all ships.
- **Take pictures**. Send pictures of the **dorsal fin** to research groups (GTOA) for identification of the animal.
- **Take video of the scene**.
- **Send a detailed report** to some sailor's groups and authorities. GPS position, boat design, attack or watching stories, etc.

Conflicts of interest

Biologists vs. sailors

These recommendations are coming from research centres (studying and protecting the animals) and official authorities. I see a conflict of interests **between marine biologists and sailors.** Biologists cannot officially be concerned and protect boats and sailors. They would take the risk to lose their credibility inside the scientific and animal protection communities.

On-line dedicated forum vs. sailors

The previous recommendations are forwarded to sailors via some channel which can be a private project. In this case, he is getting donations and sell products. The work is to analyse where the orcas are by collecting reports from passing sailors and other information sources about orca activities and interactions. In this case, I see another possible conflict of interests. If somebody is trying to make some money by promoting the run away strategy, **he has no interest for research in an active way to protect boats or deter orcas**. If this solution should exist, he or she would see his work collapse.

That is, following me, it is very important to **prepare ourselves and the boat** to a possible attack. This is the main subject of this document.

Running away strategy

Yachting Monthly wrote (source CIRCE) that

The theory is not just conjecture; it has been tested over numerous encounters in which Nashira has purposefully been 'placed at risk'. The orcas will continue to attack the boat but, once separated from the main feeding group by 0.5 to 1 mile, will give up the chase and return to the family unit.

www.yachtingmonthly.com/sailing-skills/dealing-with-orca-attacks-and-how-to-navigate-orca-alley-94964

How many times will this strategy be successful ?

This is a reason why running away should currently work most of the time. What if all the group is attacking? What will be the behaviour of the orcas next year? Will they learn to follow the boats in shallow waters, etc.?

How to watch for whales & orcas ?

My experience comes from many weeks of whale watching in Husavik (Iceland).

We (human) are keeping about 10 % of the oxygen from the air when we breathe. Whales can get up to 90 % ! It is the reason why they are diving most of the time. They are **diving for minutes** depending on the specie and their behaviour (migrating, travelling, hunting, playing, etc.). They come to the surface to **breathe only for short seconds**. Blue whales dive up to 45 minutes.

Orcas breath every 10 to 35 seconds while travelling and after up to **17 minutes** when diving.

Because they rarely come to the surface, we are lucky if we can see them. The worst way to watch is with a binocular or a camera zoom because the watching angle is much too narrow. Binocular and cameras can only be used to see them when we know exactly where they are (to enjoy them) and to take identification pictures of their dorsal fin (it is important to send them to a research centre).

To watch whales, **we must only to use our eyes** and **scan the horizon quite fast all the time**. We must not focus to a given position but to a large area, a large part of the horizon. This maximizes the chance to see a whale just at the moment it is coming up for a second.

There are several ways we can detect whales

- **See the dorsal fin or the body** (as when we see dolphins).
- **See the breathing blow** when the whale expired. We see like a fog or drizzle above its blow hole. The shape of the blow depends on the specie. For an orca it is a columnar spout, but as it is not that big it can only be seen in nice weather.
- **Hear the breath** of the whale when it is not too far away and the background sea noise or engine is not that much.
- **See many excited birds** flying above a narrow area. They are there because hunting occurs into the water. This gets their prey (small fishes) coming up close to the surface.

So we must **have a large area view (as well in our watching brain !)** and **open our ears**. It is possible to see them from 1 km away or more as we can see cardinal buoys or small fishing boats at a distance.

I met two skippers having an attack with rudder destruction. Both said to me that the orca did not advertise and that it attacked suddenly. Probably **the orca was diving from a distance** to the boat for a minute or so. If we are not watching with great care, we miss the last time it came up to breathe. We need to see them from far away!

So, to forecast a possible attack **we must watch with great care from far away**. When the orcas are quite close, it is too late to detect them before the attack, as it is diving.

Remember, if we see the orca(s) from far away, **we get more time to sail away to shallow depths.**

How to recognize an orca ?

- **It is black and white.**
- **Wide vertical dorsal fin.**
  - Males have a very long dorsal fin up 2 metres in height (less on the Iberica specie which is smaller).
  - Female and young have a broader recurved one.
- There are **white and black well-defined patterns**. White area above and behind the eyes and below the body and the mouth). The limit between black and white area is very clearly delimited.
- There is a **gray area around the dorsal fin** (generally on the side and behind).

(©) Robert Pittman — NOAA
www.afsc.noaa.gov/Quarterly/amj2005/divrptsNMML3.htm]

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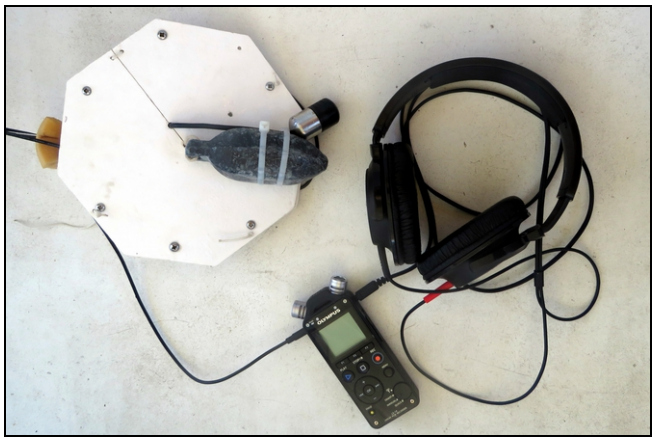
https://commons.wikimedia.org/w/index.php?curid=1433661

3) Deterring means

Recording sounds into the water



The hydrophone with amortizing and weight, recorder and head speaker

The main parts of my recording arrangement are

- The hydrophone itself (the small black and white device).
- The fishing lead near the hydrophone is used to maintain it into the water so that it is less influenced by the boat and the sea movements.
- The white plate is used to avoid the hydrophone to move up and down when the boat is heeling at the surface.
- There is also an amortizing piece of elastic cord into the line to avoid sound transmission from the boat and the line to the hydrophone (not shown in the picture).

- Hydrophone H2A. Frequency <10 Hz to >100 kHz.
- Recorder Olympus LS-14 PCM. Frequency to 44 kHz.

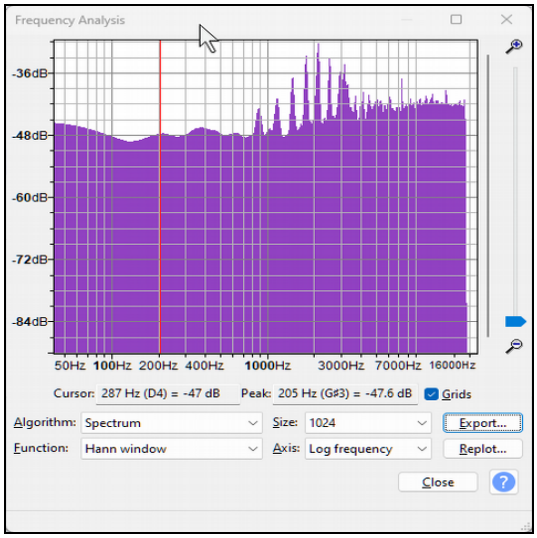
I recorded several sounds from different sources. It was attached to the mooring cleat and was diving two metres deep, approximately 2.5 metres from the source of the noise (measured horizontally).

Making sounds using a hammer

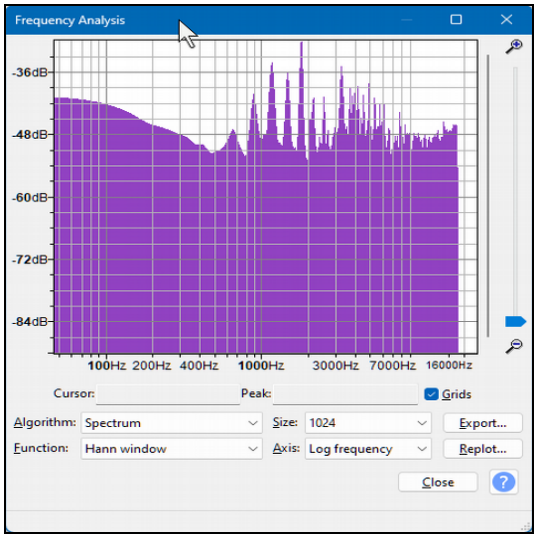
Striking a pipe

Striking a pipe is probably the easiest way to try getting orcas away with an active tool. Some reports show that it is efficient, others not. But reports do not give enough information about the sound source (pipe diameter, length and metal kind ; intensity ; frequency range ; etc.). Synonym: **oikomi-pipes**.

Examples of sounds (Internet source)



oneMinuteOfPings.mp3



twoHangingMethods.mp3

Source : https://orcasound.net/data/processed/anthrophony/oikomi-pipes.
Histograms generated by the open-source software Audacity

The goal is to make impact noises to scare the orcas away. The idea behind it comes from old whaling techniques used in various parts of the world. They have been listed in a scientific study.

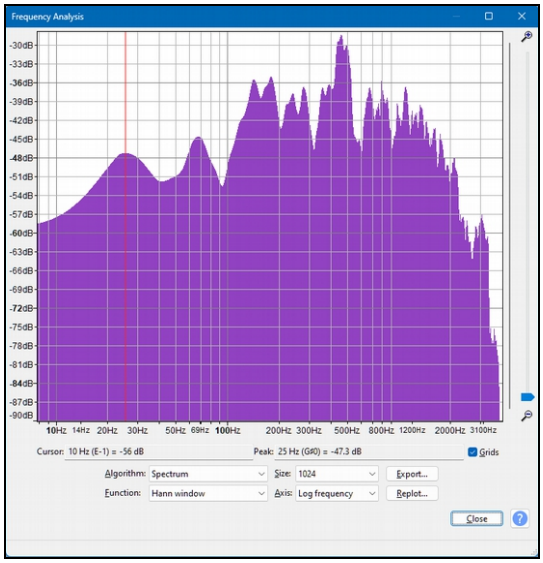
- Study : Hunting cetaceans with sound: A worldwide review. June 2008 IWC Journal of Cetacean Research and Management 10(1)

www.researchgate.net/publication/228697521_Hunting_cetaceans_with_sound_A_worldwide_review.
Or search the Web for "Hunting cetaceans with sound review PDF"

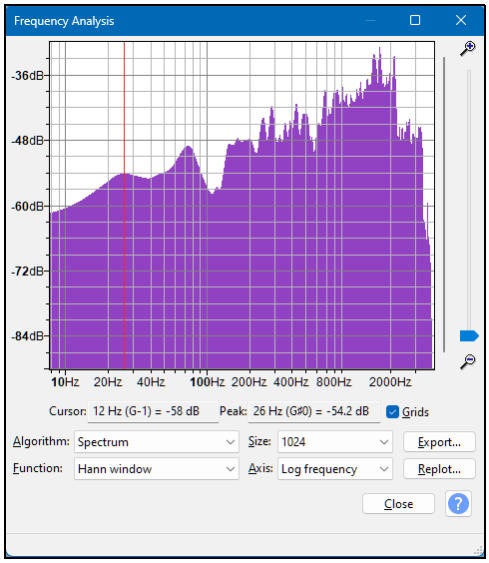
- NOAA link : https://response.restoration.noaa.gov/about/media/how-do-you-keep-killer-whales-away-oil-spill.html

It can be seen that the two sounds cover frequencies from less than 50 Hz to a bit more than 16 kHz. It was probably broader at recording time, because I guess these examples only contains the human-audible part. We can see that there are higher sound peaks between 1 and 4 kHz.

A poor deterring sound ?



Striking the aft shelf with a rubber hammer



Striking the swim ladder with a thick aluminium tube

These 2 trials are not successful (frequency range too low)

Striking a pipe

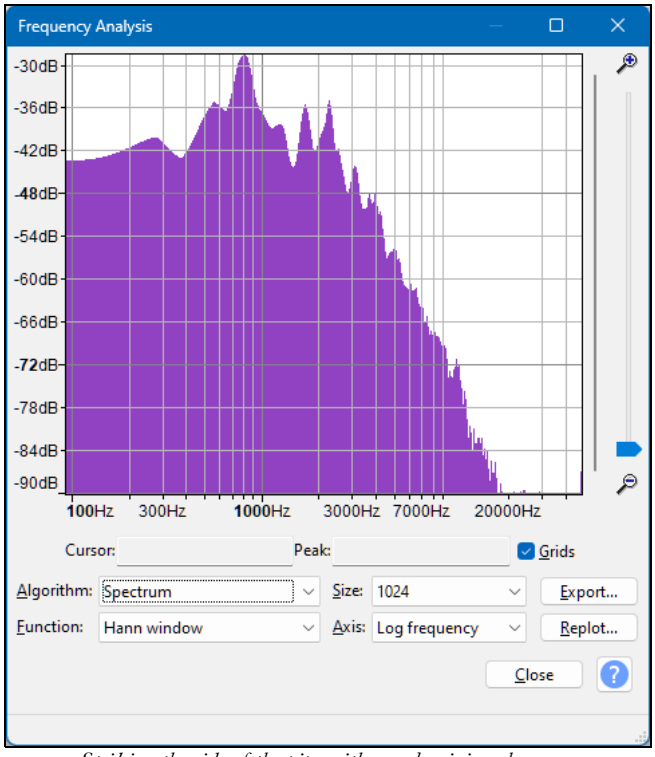
I used what was available on the boat. It is, of course, better to provide an *oikomi-pipe*.

Pipe specification

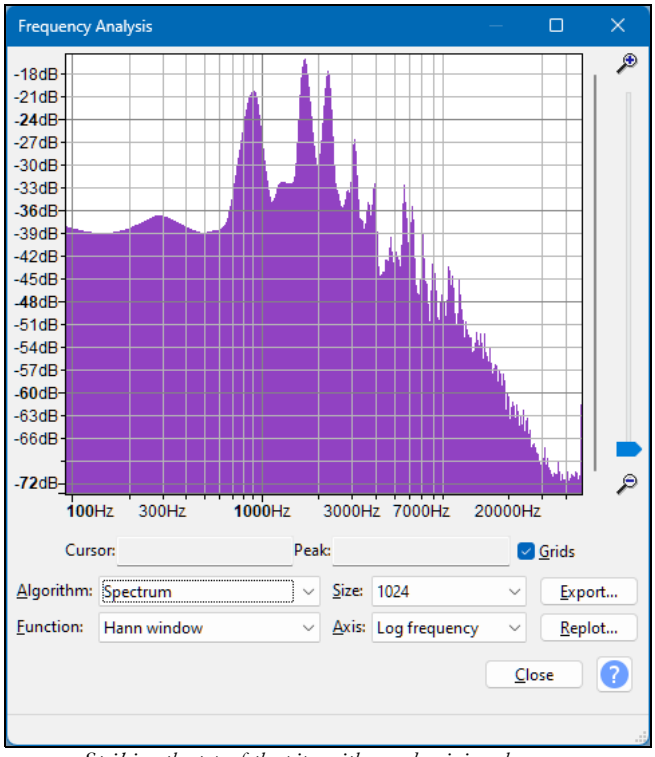
- The pipe is made from aluminium (steel should probably be better but I do not have it on board).
- External x internal diameter : 35 x 20 mm, length : 3 m.
- The top hole of the pipe is closed. I don't know if it is an advantage or not.

Set up & use

- It was installed vertically at the aft of the ship (see picture).
- I struck on the side or on the top, with an aluminium tube or a normal steel hammer. The spectrum of the recordings are here below.

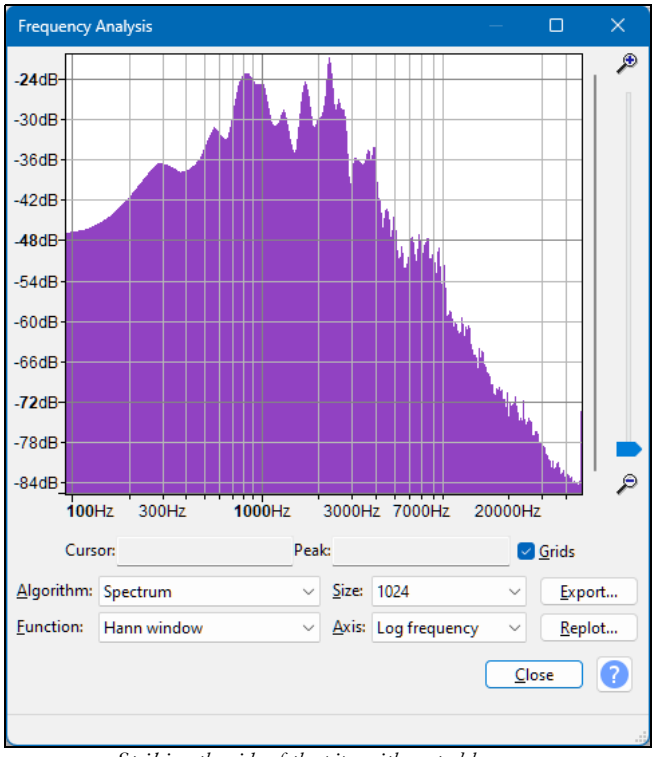


Striking the <u>side</u> of the pipe with an <u>aluminium</u> hammer



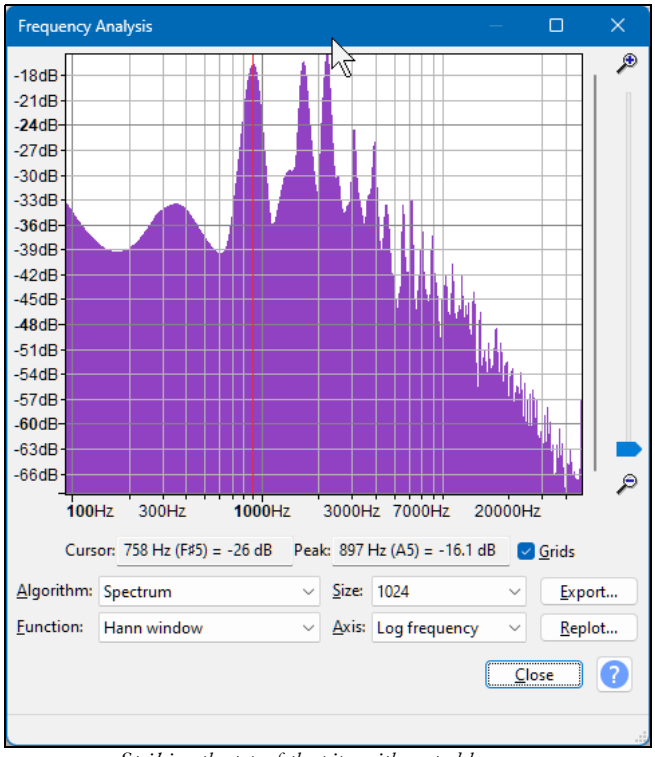
Striking the <u>top</u> of the pipe with an <u>aluminium</u> hammer

⇒ *The sound is <u>louder</u> and the frequency range is <u>wider</u>*



Striking the <u>side</u> of the pipe with a <u>steel</u> hammer

⇒ *The frequency range is <u>wider</u>*



Striking the <u>top</u> of the pipe with a <u>steel</u> hammer

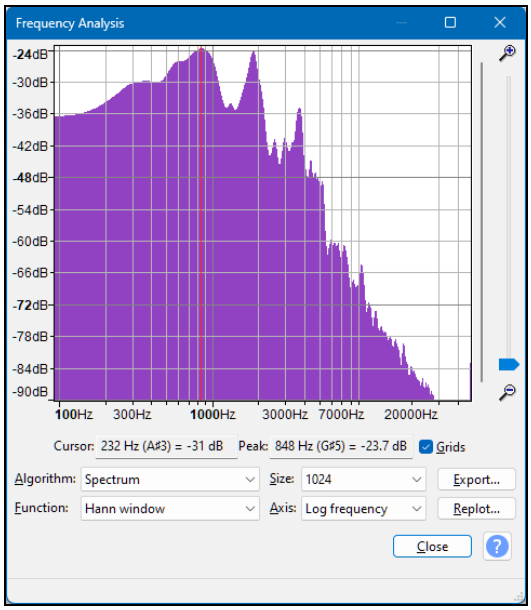
⇒ *The sound is <u>louder</u> and the frequency range is <u>wider</u>*

Conclusion

⇒ Use a steel pipe if possible. It should be more efficient (not demonstrated).
⇒ It is more efficient to **slam on the top of the pipe**.
⇒ It is more efficient to **use a normal hammer** (in steel).

Striking parts of the ship itself ?

I also struck some parts of the ship with an aluminium hammer (to avoid damage to the slammed parts), with a normal steel hammer and with a heavy steel hammer. If you try it, you can only know how the sound behaves if it is recorded with a hydrophone and analysed with software (ex.: open source *Audacity*), to get the frequency spectrum and sound intensity.



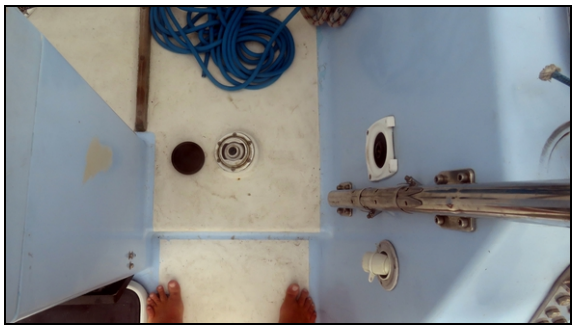
Solar panel stand with aluminium

I tried to hit the solar panel stand. It is made from two stainless steel pipes (d=40 mm, H=2200 mm). They are strongly vertically fixed to the cockpit structure. When the pipe is struck, the generated sound is transmitted to the water via the ship's structure and the hull.

It was first struck with the aluminium tube. The result is not too bad.

Finally, I compared using 3 different hammers.

1=Rubber, 2=normal (steel), 3=heavy (steel)



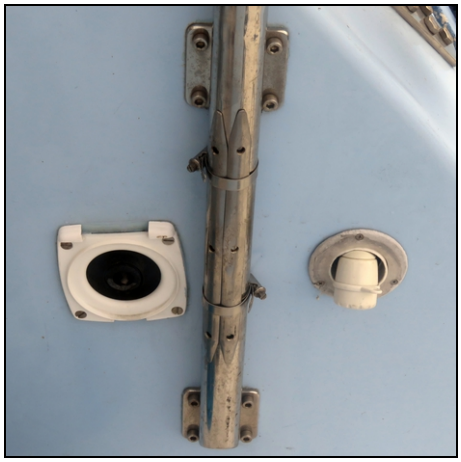
This picture shows the skipper cockpit.

- The head of the starboard rudder shaft is in the middle of the picture with its black protecting cover on its left side.

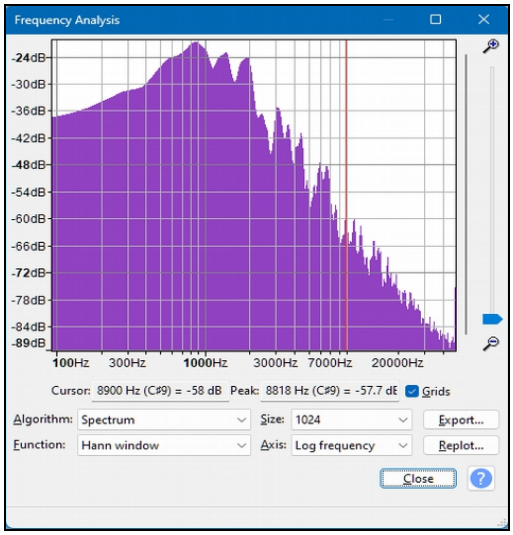
  If we strike on it, the sound is directly forwarded to the entire rudder, then the water and the hydrophone.
- The stand of the solar panels is shown at the right side. It is attached to the cockpit and boat structure with 2 times 4 big screws which cross the plywood wall (detail picture here below).

I compared the three hammers by striking each source with them. Best results came with hammer 2 (normal steel hammer). I do not include all measurements here to keep the document simple (they are available on request).

Striking the solar stand

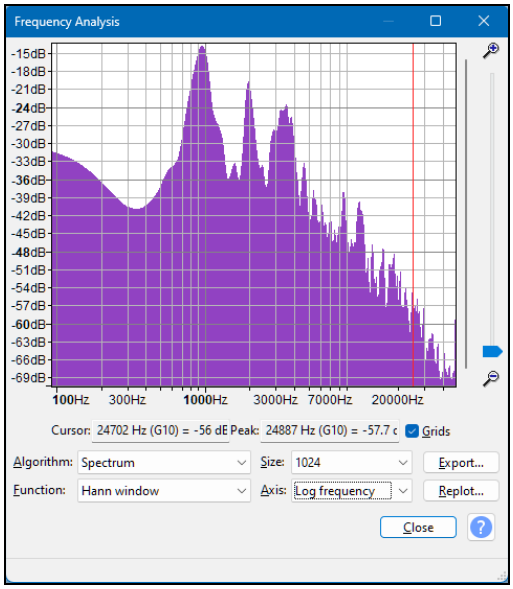


I put a steel protection (martyr) attached with steel serflex collars. So the steel hammers will not damage the stand.



Hammer 2 on the solar stand

Striking the rudder shaft



Hammer 2 on the rudder head

- Both sounds have a **wide frequency range** up to more than 40 kHz (the recorder is limited to 44 kHz)
- The best results are achieved by **striking the rudder shaft** (louder sound). It is unfortunately not accessible from the cockpit of all boats.

Strike several things !

- I got a report from a catamaran which deterred orcas attacking a rudder by using the fog horn against the boat structure (portable air compressed type).
- If you have many crew members on board, hit more than one object !

Using a fog horn

I got some reports about successful use of a fog horn close to the hull.

- Cruising Association (CA) : www.theca.org.uk/orcas/interaction-deterrent-library

  - *Inter153*: Fog horn was efficient 3 times on two boats close to each other. The type of horn is not mentioned nor the way it was used. Boat to be repaired.

  - *Inter146*: Rudder struck several times. No damage. "I placed the fog horn against the hull surface below the water line (hand-held gas fog horn that most people have on their boat) and pressed the leaver a couple of times. I waited to see what would happen and they did not strike again."
- Web site www.orcas.pt, ORCAS DISCUSSION GROUPS (Telegram). "I just spoke to someone it happened to and he said the fog horn worked to scare them off" (by Jenny K).
- I got a report from a catamaran which used a fog horn (portable can type) against the hull.

As we know, there are few reports when the boat was not damaged. So there are maybe more successful uses of the fog horn.

Trumpet horn

Portable compressed gas can horn

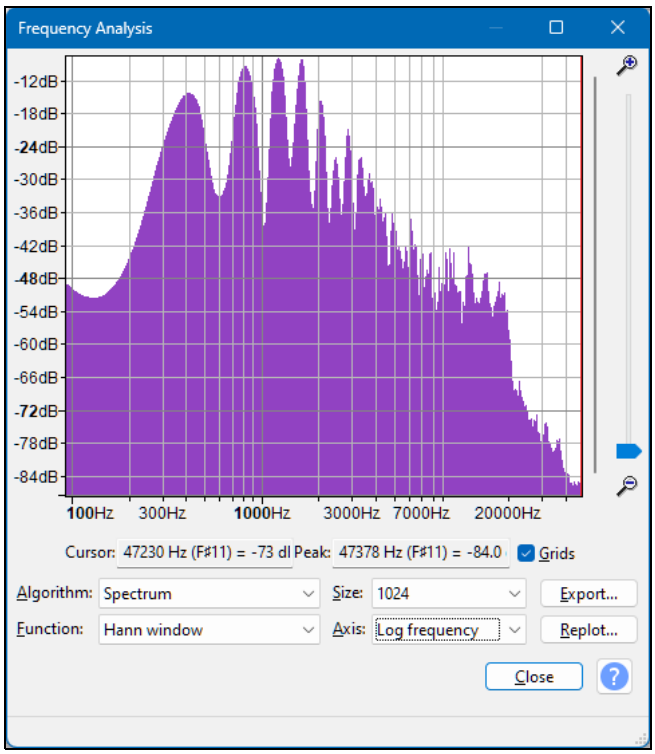
It is not possible to generate underwater sounds with a horn as it is designed to create sound in the air. So, we must use it on the deck/hull side. I recorded the horns with a microphone in the air to get the normal sound. Then I recorded the underwater sounds by using them on 3 different ways, as I would try to deter orcas. The hydrophone was hanging by ±2 m depth :

- Horn above the sea surface (it is not easy to do on all boats).
- Horn into a locker near the aft of the boat.
- Horn on the rudder shaft head (it is not possible to do on all boats).
- Horn on the hull bottom (it was not possible on Thoè).

Notes

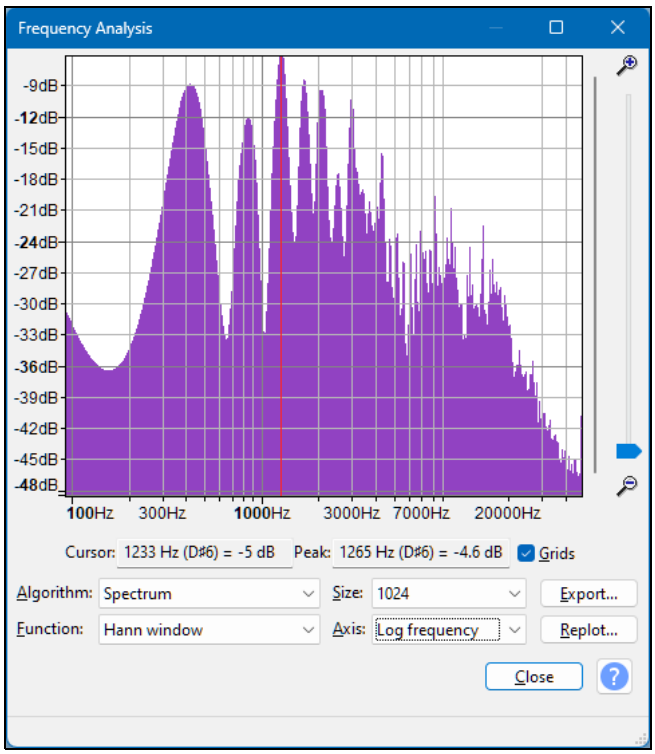
- The tender **inflator can be adapted to the Trumpet horn**, which can make it easier to use.
- Here after, the spectrums are sorted by decreasing intensity, then by decreasing frequency range in the next pictures.

Trumpet horn (left column)

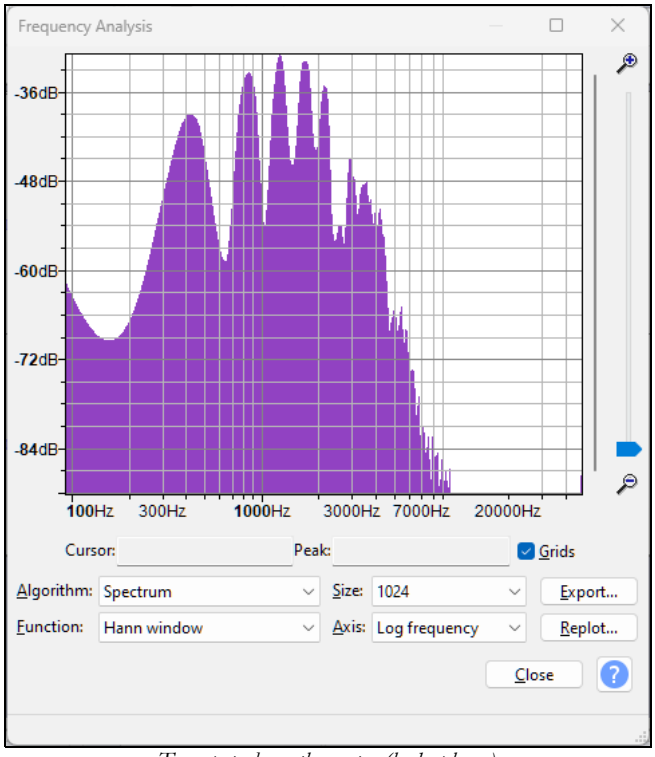


Trumpet in the air (microphone)
Listen the MP3 recording

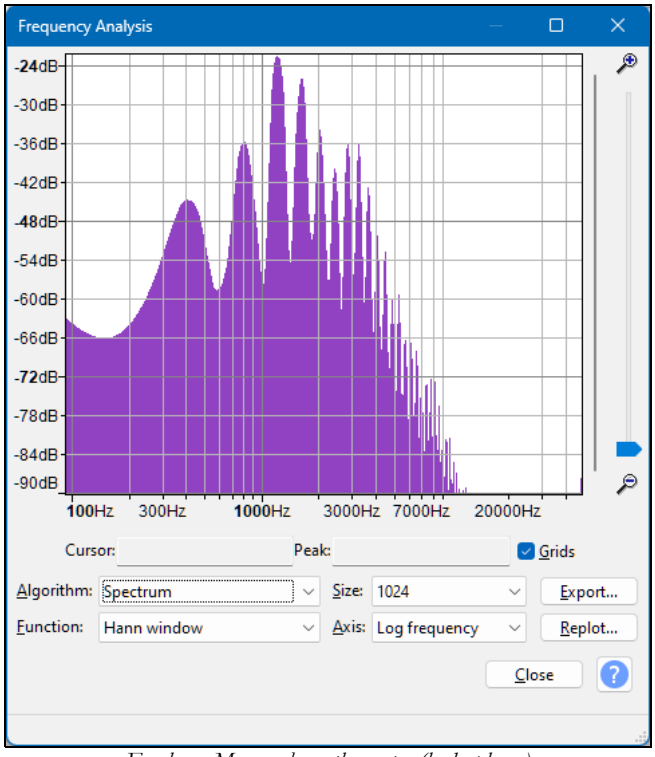
Compressed gas horn (right column)



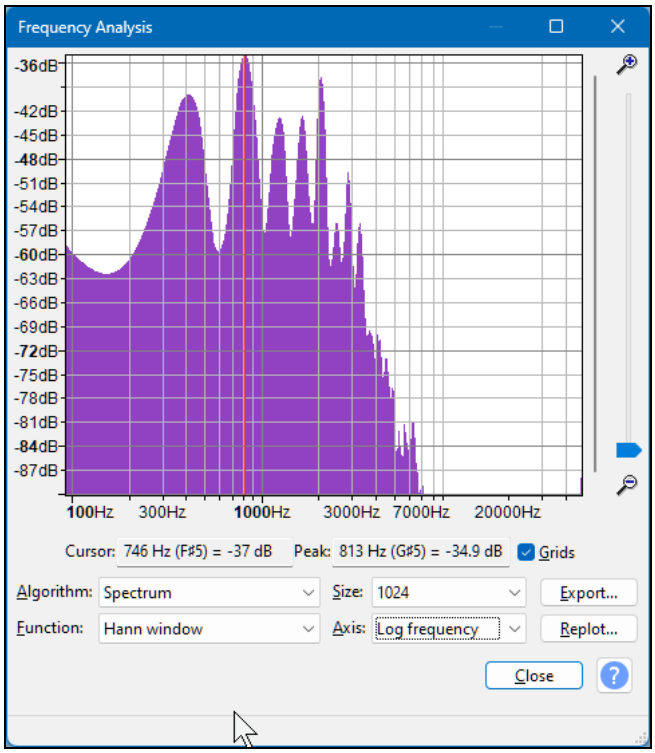
Fog horn Marco in the air (microphone)
Listen the MP3 recording



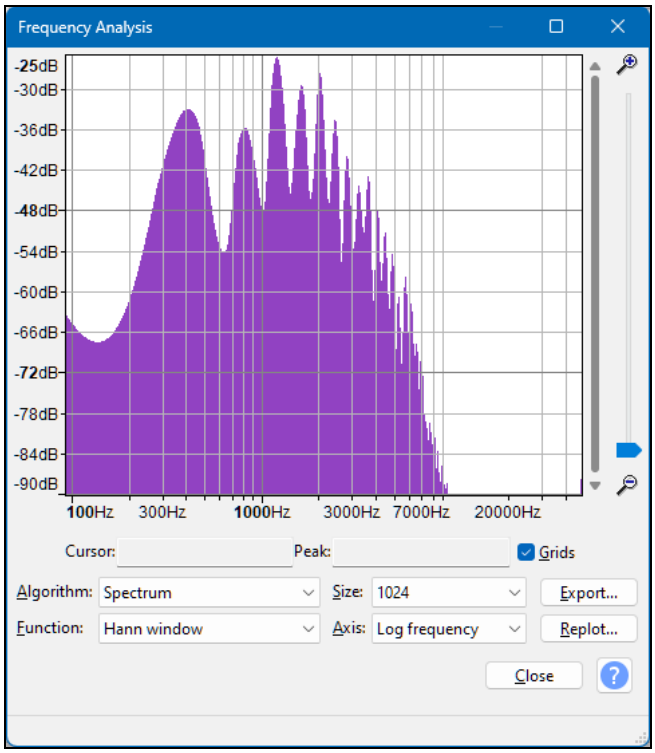
Trumpet above the water (hydrophone)
Listen the MP3 recording



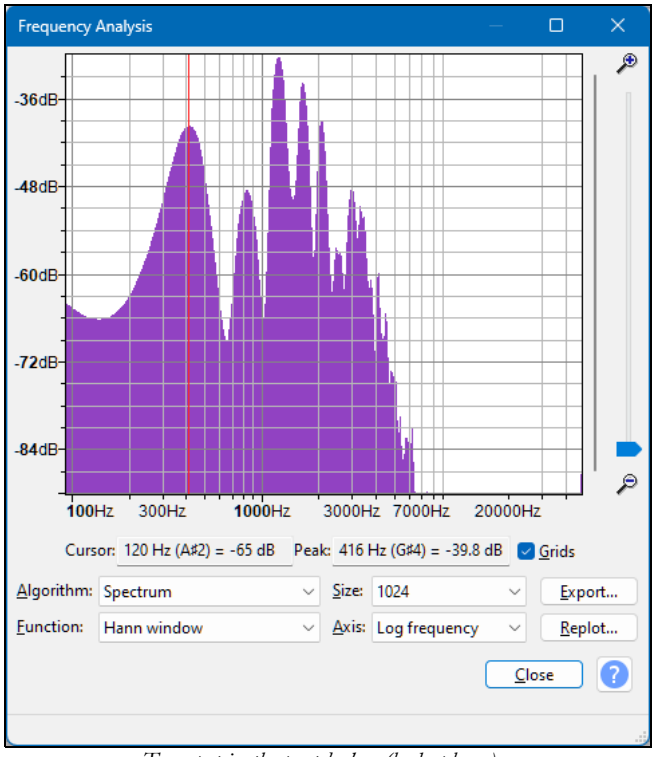
Fog horn Marco above the water (hydrophone)
Listen the MP3 recording



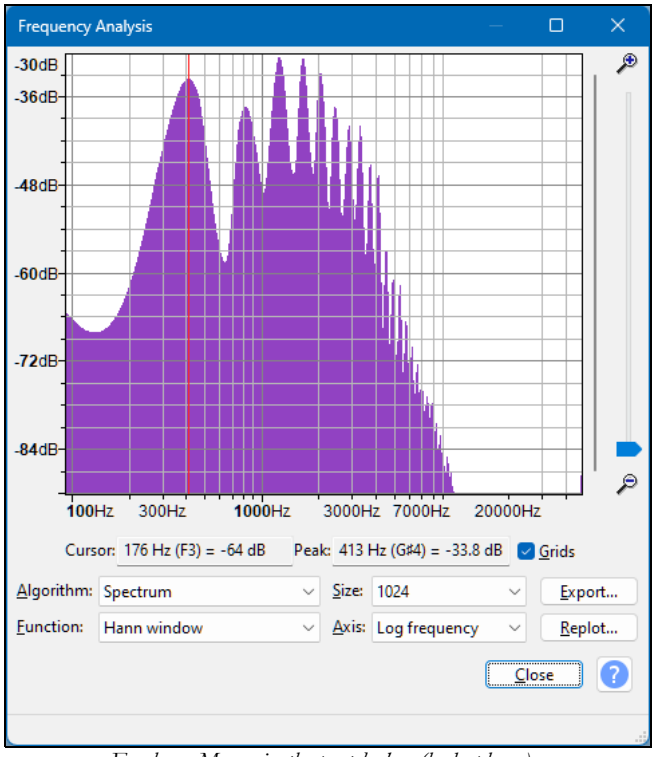
Trumpet at the top oft he rudder shaft (hydrophone)
Listen the MP3 recording



Fog horn Marco at the top oft he rudder shaft (hydrophone)
Listen the MP3 recording



Trumpet in the port locker (hydrophone)
Listen the MP3 recording



Fog horn Marco in the port locker (hydrophone)
Listen the MP3 recording

Conclusions

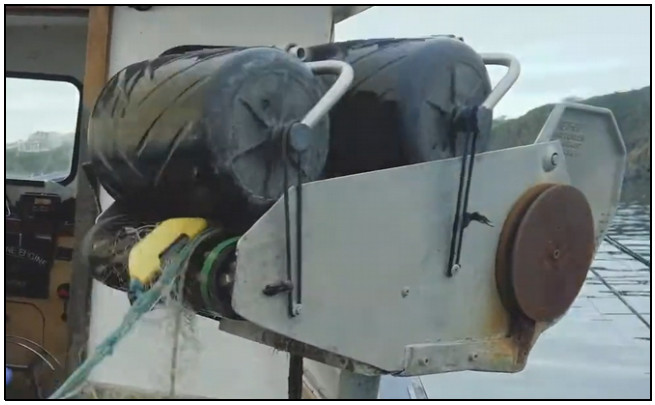
- As foreseen, the sound is maximum in the air.
- An interesting conclusion is that the sound of the trumpet can be compared to the sound of the engine (at least about the intensity and frequency range).
- The sound can pass directly from the air to the water, with an intensity loss of ± 20 dB. The highest frequencies do not pass to the water.
- There is not a big difference between the places where the fog horn is used.
- Best results into the water occurred in this order:
  - Above the water surface.
  - At the top of the rudder shaft.
  - In the port locker.

- The compressed gas horn gives a stronger sound with a higher frequency range compared to the Trumpet horn :
  ± 60 kHz vs. in the air.
  ± 10 kHz vs. ± 7 kHz when transmitted to the water.
- The compressed gas **must be held vertically** : The decompression of the gas produces cold. Some condensation may occur in the diffuser, which is disturbing the sound production.

Pulling a pinger

The Fishtek Marine Banana pinger

Warning: Several pingers are available on the market. Some of them have a shape of a banana. They are installed at about 50 m from each other on the border of fishing nets to avoid dolphins to be entangled. They are not able to dive easily when towed by a boat. Some user reported that they attached a 5 kg diving lead to keep them below the surface while sailing ! This is maybe not the right way to use them. At the end of the day, statistics (!) are showing, by an improper conclusion, that *all* pingers are doing a bad job !

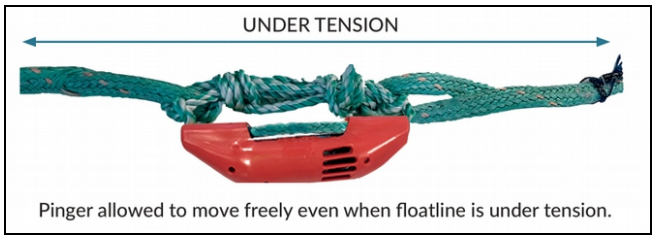


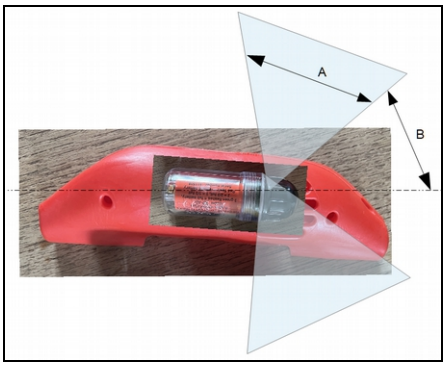
The banana pinger is protected by a rubber envelope to easily pass the fishing nets lifting system. When pulled by a boat, it is very difficult to maintain it at 2 to 4 m under the surface (the water drag is huge!)

I suggest making another well-shaped envelope or no envelope at all.

The manufacturer is advising

- To use the 40 kHz transmitting model which is suitable for "big whales".
- To pull 2 pingers per boat.
- To maintain it as close as possible to the rudder (2 m) and at 2 to 4 metre depth.
- Made by Fishtek Marine (UK), sold in France by ISI-FISH.





The Whale-PAL pinger

This pinger has a torpedo shape and a swimming device (paravan) to maintain it at a given depth under the water surface.

This pinger is designed to protect boats from orcas. The manufacturer can programme it, depending on the targeted whale specie.

It is pulled about 10 metres in the back of the boat. It is sending its very wide frequency range sound each 4 seconds in a limited angle in forward of it. It is mimicking the signal that the orca emits in case of emergency. An additional random sound avoids orcas from habituating.

Reports mention that orcas ran away. Other mentions that the orcas seem temporary stuck as paralysed before leaving.

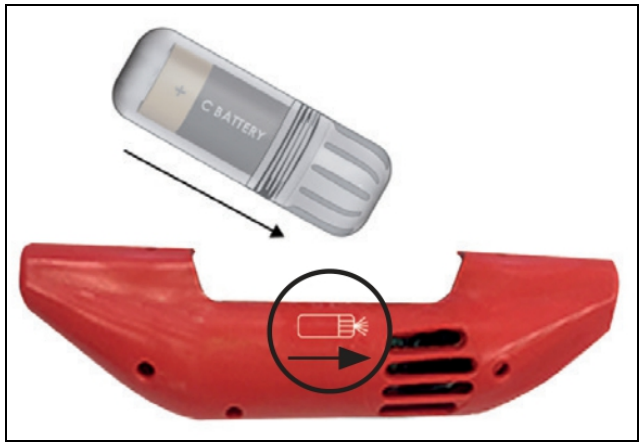
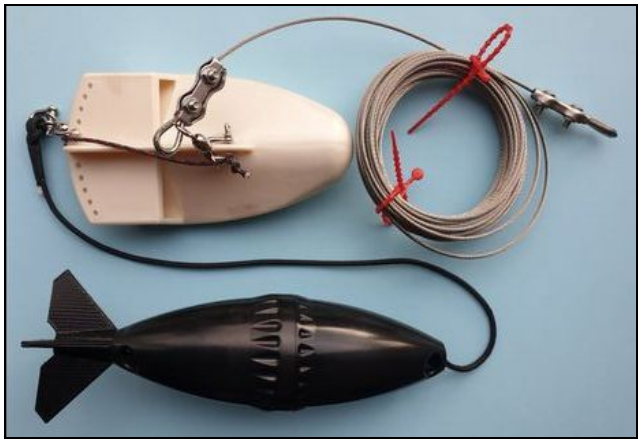
The manufacturer claims 90 % successful interactions without damages and in case of damages, that they are limited.

Reference

- Whale-PAL 2 – www.f3mt.net/whale---pal.html

Note: When the boat is stopped, the pinger must be put at around 2 metres from the sea level with its head above to send its signal up and on its side. This requires to load the tail of the device with at least 60 gr lead.

Banana pinger vs. Whale-PAL v2

Presentation	 *Banana Pinger* Banana shaped with a horizontal rope channel at the top to be attached inline on a fishing line.	 *Whale-PAL v2* The product includes everything needed to be towed by the boat (line, paravane, etc.)
Main characteristics	Made in the UK Specifically designed for fishing gear protection (to avoid by-catches). The frequency has been adjusted to orcas audiogram. A pinger must be installed every ± 50 m. Recommendation: Two pingers per boat. Limited or no user support. Delivered « as is » in case of boat protection. No boat specific documentation. Set-up left to user responsibility. Some skippers are towing it with a weight of 5 kg to keep it under water !	Made in Germany Specifically designed for boat protection (low drag). Salmon shape with paravane to keep it under the water when towed by the boat. Recommendation: One per boat. Good user support.

Audiogram basis & emission frequency

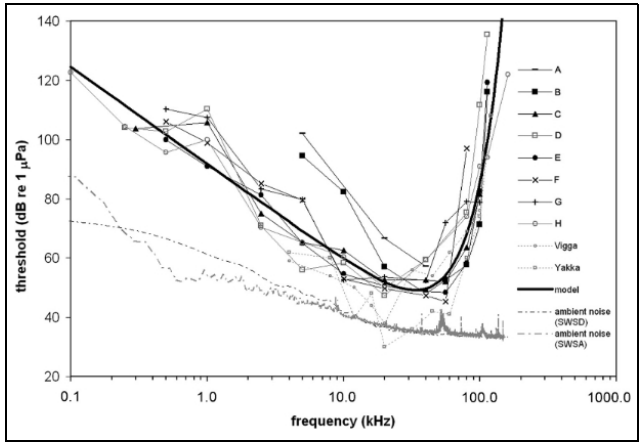


FIG. 3. Audiograms of individual killer whales. Solid black lines represent animals from SWSD and solid gray lines represent animals from SWSA, while dashed lines represent animals from Szymanski *et al.* (1999). The "model" data is a composite audiogram estimated from the procedure discussed. Average ambient noise values are in dB re 1 μPa^2/Hz. Ambient noise was measured with a TC4032 low-noise hydrophone coupled to a VP1000 preamplifier.

- The banana pinger is transmitting at 40 kHz randomized between 4 and 12 s to avoid habituation.
- The emitted sound is said to be based on the greater sensibility of the orca ear.

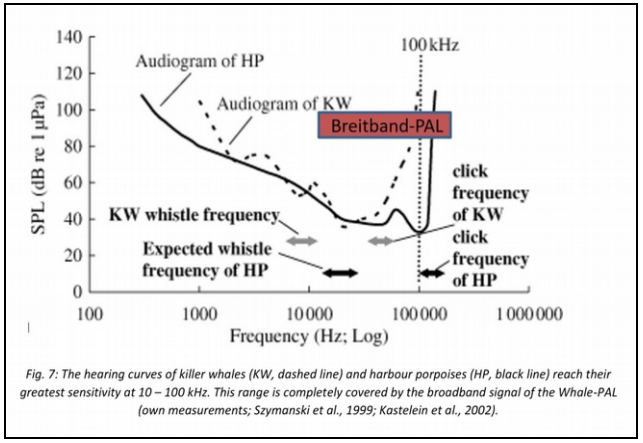
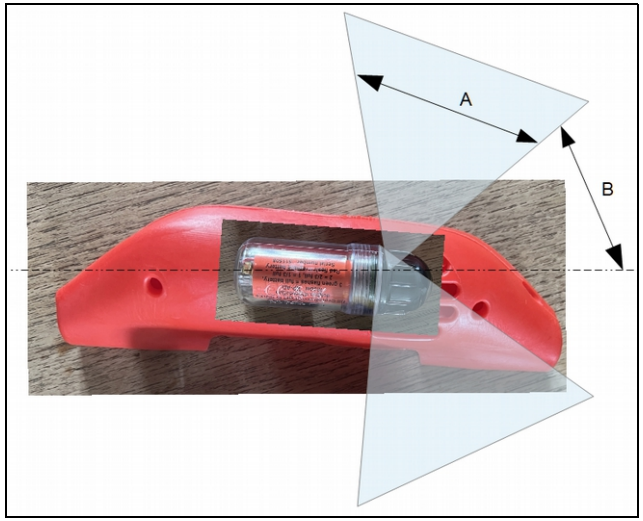
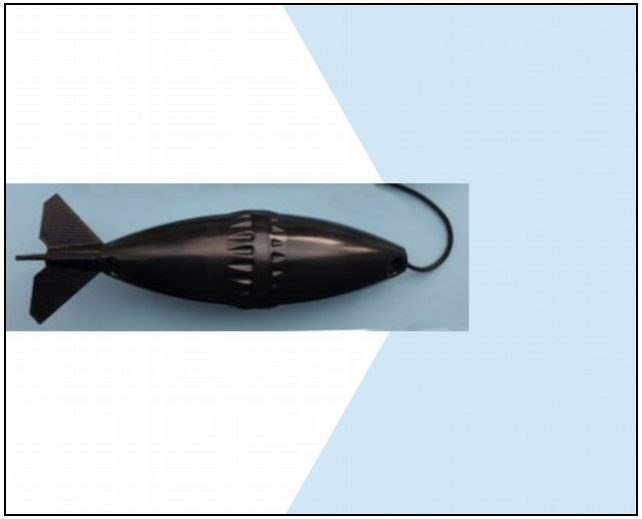
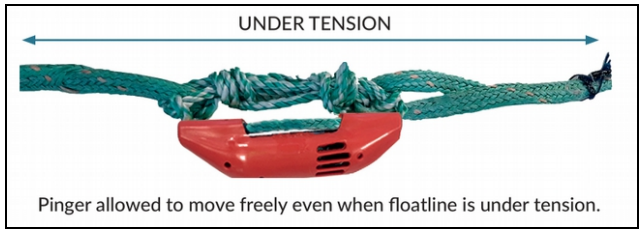
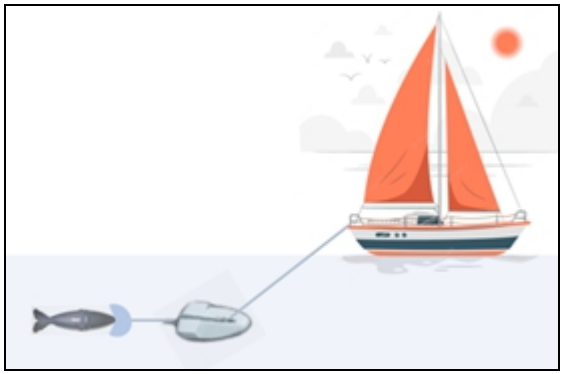
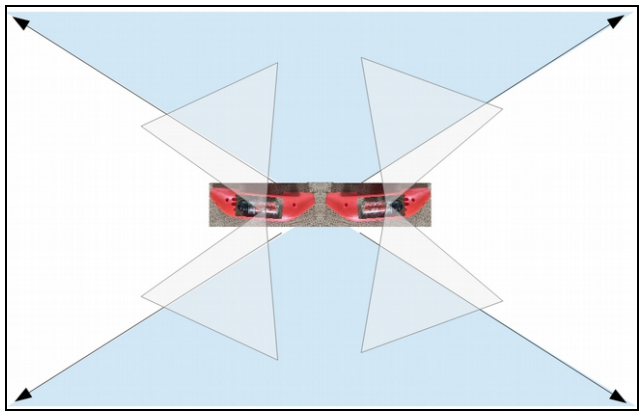


Fig. 7: The hearing curves of killer whales (KW, dashed line) and harbour porpoises (HP, black line) reach their greatest sensitivity at 10 – 100 kHz. This range is completely covered by the broadband signal of the Whale-PAL (own measurements; Szymanski et al., 1999; Kastelein et al., 2002).

- The devices emits two wide-band signals in the range 10 – 130 kHz. Center frequency is at 70 kHz.
- The emitted sound is said to mimic the emergency vocalization of the orcas.
- The standard signal emitted every 4 seconds.
- A secondary signal at 4 – 20 s intervals random.

Emission scheme	 *Laterally, all around, more on the transducer side.* *Angles A and B are unknown/undocumented.* • It is transmitting all around (unknown or undocumented angles A & B) a bit more in forward due to the battery position and the transducer orientation.	 *All around, symmetrically* • The pinger is emitting the sound symmetrically in a 240 ° angle in forward. It is mute in the 120 ° angle in backward. It is protecting the rudder in front of it.
Installation & set up	 *Fishing line protection set up.* ⇒ WARNING : No documentation for boat protection	 • ± 10 m from the boat stern. • ± 2-3 m depth. • When the boat is stopped, the pinger must hang at the depth of the rudder with its head up (the tail must be loaded by a weight of ± 60 to 100 gr).

	 • Some fishers are installing 2 opposite pingers to achieve a symmetric lateral emission when hanging to the fishing line.	
Links & References	*Manufacturer & Distributor's home pages* • www.isifish.fr • www.fishtekmarine.com *Presentation* • www.fishtekmarine.com/reduce-cetacean-bycatch *Instructions* • www.fishtekmarine.com/wp-content/uploads/2019/07/EN_Deterrent-Pingers-fitting-instructions-1.pdf *References* • The Banana Pinger Trial. Investigation into the Fishtek Banana (by Abby Crosby, Nick Tregenza and Ruth Williams, October 2013) www.ascobans.org/sites/default/files/document/NSG4_Inf_4.3_BananaPinger.pdf	*Manufacturer's home page* • *www.f3mt.net* *Presentation & references* • www.f3mt.net/whale---pal.html *Review by the manufacturer* • www.f3mt.net/uploads/1/1/0/9/110974389/orca_attacks.pdf

4) Protecting the rudder system

Reducing stress into the rudder

Autopilot ⇒ OFF

When using the autopilot, the rudder system is looking as being blocked by the system. If an orca strikes the rudder, a shock force is directly transmitted to the **rudder blade** and the **autopilot power system** (electric or hydraulic). To avoid any damage at the first attack, the autopilot must be switched off **as soon as possible**.

It is the main reason why **we must carefully watch for orcas coming at a distance**.

VERY IMPORTANT NOTES

In case of attack risk, the very first thing to do is to **put the autopilot in STAND-BY**.

If an orca is on the area, we must **steer manually**.

Be careful to **avoid injuries** when the helm is moved violently by the orca.

Sailing fast

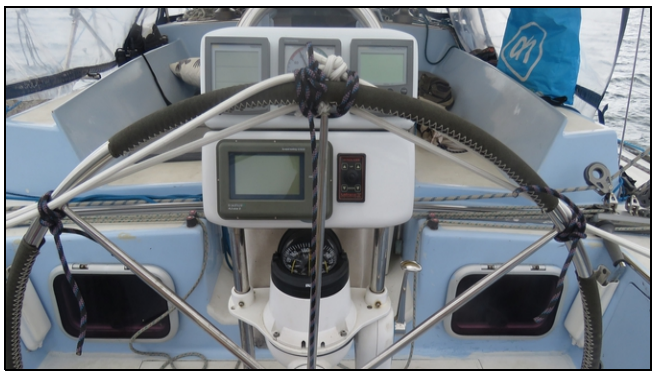
In the event of an attack, it is recommended that navigators sail as quickly as possible towards a shallow area (if possible) or in the opposite direction to that of the killer whales (which, in principle, follow their prey). This is justified by the fact that, at high speed, the angle of attack of the rudder is ± 45°. This would **halve the effort exerted by the orca** on the rudder blade.

Sailing circles ?

This is an improvement that I could try to use if needed. This idea is inspired by (1) the **sailing fast** technique and (2) an **erratic route strategy** (to avoid the orca habituation to the boat course).

- Turn the wheel and **sail fast** while making **circles of small diameter**. I hope the attacking orca will have to adapt its course all the time and take the risk to be hit by the propeller. It will see the rudder to go away at any time. Maybe it will become a bit crazy and give up. Of course, I could strike a pipe at the same time.
- I can change the **direction of the circle** from time to time. So the orca will not be able to anticipate the position of the rudder.

Amortizing the rudder system



Amortizing in action

Sandows attached on the wheel itself 2023-09-18

The question then is how to steer (manually) without being injured when the orca is turning the helm violently while attacking. My answer is to amortize the helm with a sandow. In this case, the helm returns to the centreline after each attack, instead of remaining blocked by the rudder stop on the port or starboard side.

As an attack occurs when the helm is blocked by the stop, the risk of breaking the blade is maximum. It is better to keep the helm on the centreline at any time and amortize the action on the rudder.

Benefits of amortizing

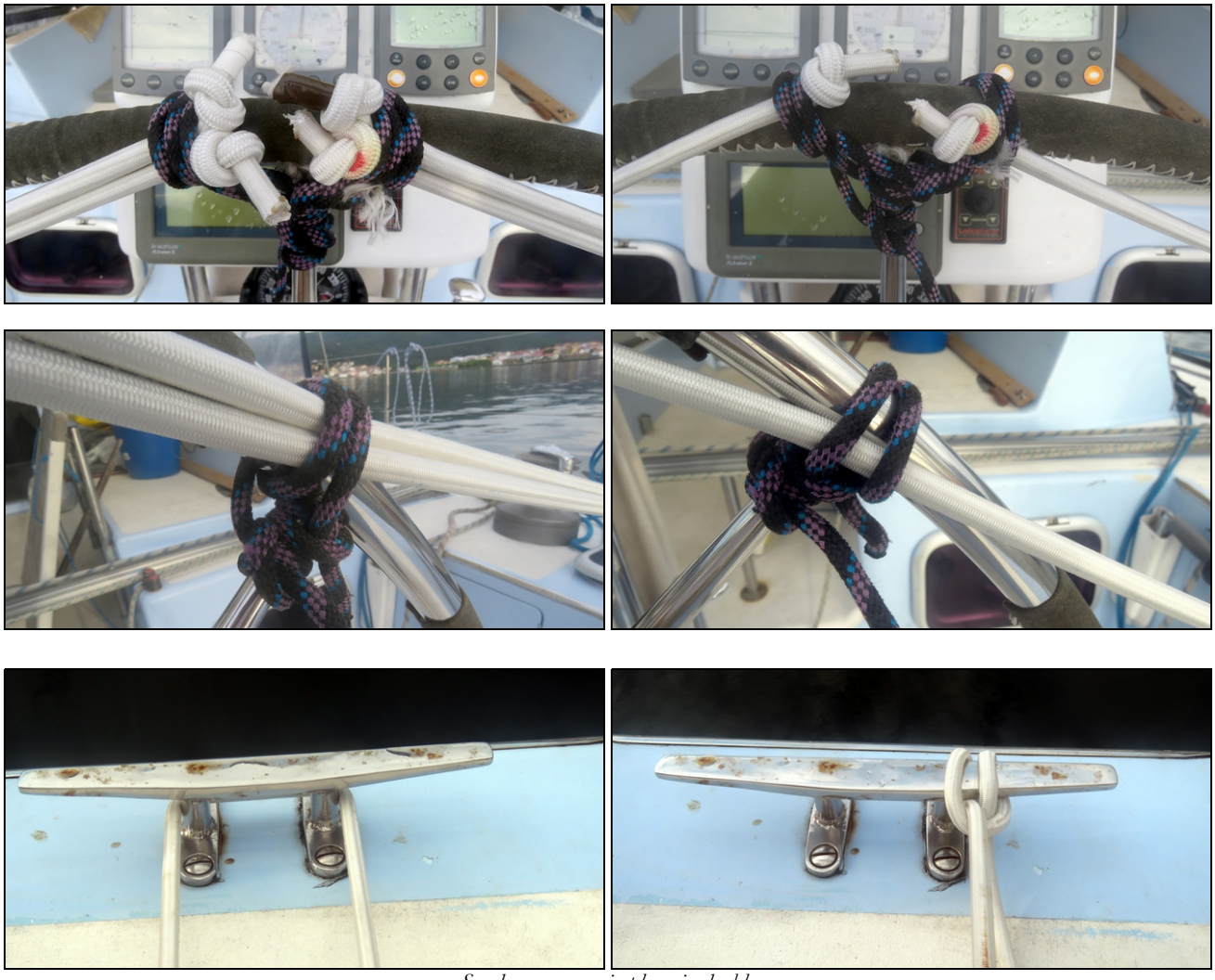
- In the event of an attack, the orca pushes (turns) the rudder to its stop. Normally, he doesn't break the blade on the first hit. But next attacks will occur on the already blocked rudder, maximizing the chance that the subsequent strokes will break it. The number of strokes probably depends on the design and construction quality of the rudder. The sandow which brings the helm back after each attack therefore amortizes the shock delivered by the killer whale. It must restart its stupid job from scratch for each attack.
- If the helm is maintained with a sandow, the autopilot can continue to steer (if there are no killer whales in the area). The extra effort it must develop is less than that the one he must develop in heavy weather.
- Similarly, the skipper can continue to steer manually.
- When the danger is over, just attach the sandow to the helm itself to restore a normal steering.

Example (Thoè)

The assembly described here is that of Thoè (12.7 metres; 10 tons; 2 rudders; steering wheel; the steering transmission includes rigid arms). This boat has a wheel about 110 cm in diameter. For other dimensions or for a tiller, it will probably be necessary to adjust the system.

⇒ NOTE: Thoè's wheel makes ± 1.5 turns between the neutral position and the port or starboard stop. If a wheel makes several turns, it may be that the simple principle described is not sufficient.

Double sandow set up *Simple sandow set up*



Sandow can run simple or in double
This allows adjusting its restoring force

I used a 9 mm sandow bought in Muros (Galicia).

- Its length is **twice the distance** between the two rear mooring cleats (2 x 3.8 m). On Thoè, they are almost in the plane of the wheel.
- The elastic cord is cut in two parts of the same length. A stop knot is strongly tied at each end (sandow is slipping easily).
- The helm is set in neutral position (straight).
- The knots are tied at the top of the wheel with a piece of rope.
- Sandow must remain against the circumference of the wheel when it turns, otherwise it comes to nest against the axle when the wheel turns, which prevents it from exerting its returning force. It is therefore necessary to tie the sandow at the edge of the wheel with small ropes. Two dead turns around the wheel and two half hitches on a radius are fine (care must be taken that the elastic does not loosen the knot).

Setting neither too much nor too little resistance

The tension of the sandows must be adjusted for maximum effectiveness, but the adjustment results from a compromise between opposing constraints:

- The helm must be able to easily return to the neutral position (boat axis) after having been turned by the orca. It's imperative ! Just try manually that this is working well.
- The tighter the sandow, the harder the killer whale will have to push to bring the rudder to the stop. The amortizing is maximum.
- But the stronger the amortizing, the greater the torsional stresses in the blade, with the risk it breaks. So, the resistance of the sandow must not be sufficient to damage the blade. If so, it's safe to assume the orca will break the rudder before long !

If two sandows are too strong, just use one (tie a single strand on the wheel and block this strand on the mooring cleat with a double knot.

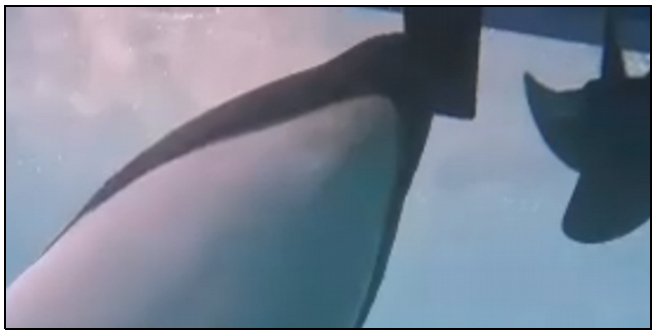
On the way

NOTE: The elastic amortizing being attached to the mooring cleats (or other fixed position) it is, of course, possible to put it into action only in the event of an imminent risk of attack. Just remove it from the cleat when there is no risk.

CAUTION: In the event of an attack, the most URGENT action is to **put the autopilot in STAND-BY**, otherwise the orca may break the rudder transmission system or the rudder drive system.

Protecting the rudders with spikes

How is orca attacking? (2023-09-17)



Pushing the lower side of the rudder to turn it

Touching the lower edge
Ocean Race 2023
www.youtube.com/watch?v=E1rqcI2jULY

Principle

Here, it is a question of preventing the killer whale from touching the rudder blade. If it pushes on a pin attached to the rudder, it will take the risk to hurt itself, which hopefully will deter it from doing it again. After a few unfortunate experiences of this type, it is hoped that groups of orcas will learn from each other to give up this harmful behaviour. This ultimate goal can only be achieved if a majority of boats implement this type of defence.

This ultimate technique is looking the most aggressive to human people, but it is not true :

- It is less intrusive than putting a GPS tag on the body of the animal with a special gun, which is largely accepted under the name of animal protection.
- The animal can see the spikes on the rudder with its eyes and its powerful echolocation system. It is its choice to touch any part of the boat or anything being into the water.

Animal protection point of view

- Whale watchers must approach whales from their back in a limited angle. They must stay at a distance of the whale. Then, the whale can decide to leave the area or approach the ship (and eventually touch or attack it). As we do not approach it, it is its exclusive choice to try touching the rudder.
- The spikes can be chosen or implemented by avoiding sharp edges to avoid harming the animal's skin.

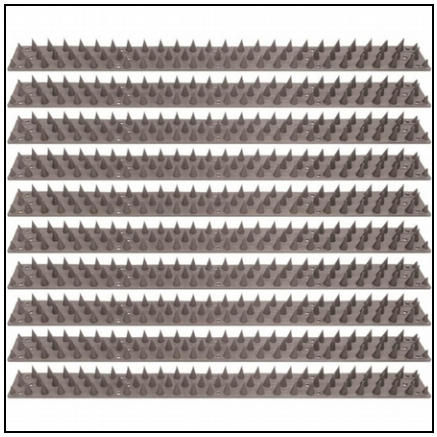
Sailing activity point of view

- The captain of the ship is legally responsible for the crew and the ship security. He can do many things to achieve this responsibility. If he fails, he can be sued.

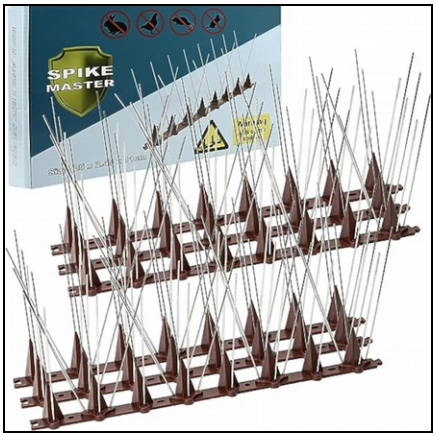
So the two regulations seem to be opposite to each other. At the end of the day, the decision remains on the captain's side (see regulation topic here above).

Material

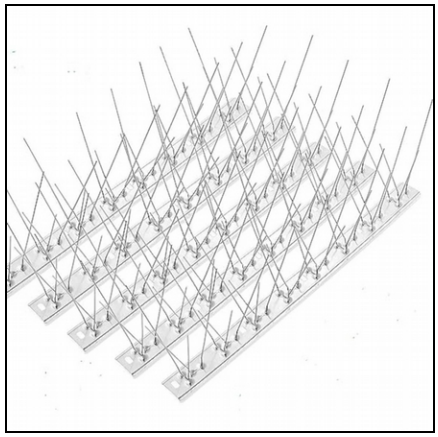
Anti-pigeon spike strips



(1) Plastic



(2) Steel on plastic



(3) Steel

The total assembly cost is less than about €50 for 2 rudders. The spikes I used for testing were bought for ± €25 on Amazon:

- (1) *ELRO ACS77-10 Anti Grimpant Piques pour Murs et Clôtures - Gris - Paquet de 10*
  www.amazon.com.be/dp/B0792RTY9K?psc=1&ref=ppx_yo2ov_dt_b_product_details
  The experience is showing the band containing the spikes is too fragile.
- (2) FORMIZON 3.5 Metros Pinchos Antipalomas, Pinchos Anti Pajaros...
  www.amazon.es/dp/B0BNV8DKR3?psc=1&ref=ppx_yo2ov_dt_b_product_details
- (3) AOKKR Répulsif Anti-pigeons.
  www.amazon.com.be/gp/product/B096LTKVNB/ref=ox_sc_act_title_2?smid=A1XJY3CMNJUIGW&psc=1

Assembly (type 1)

Strips type 1 are breaking quite easily as they are made in plastic. I prefer using the type 3.

Strips type 2 & 3: the **spikes can be cut and/or bent** to shorten them to about 20-30 mm.

CAUTION

When cutting the steel wire, its tip becomes sharp. It can hurt the skin of the animal. It is why it is important to bend the wire so that the animal will only touch the smooth curve of the wire.

All strips can be assembled a similar way. There is another possibility described in the next section.

1) Start assembling

Now, we have to group the strips two by two. Be sure they are identical and the attaching holes are face to face (the middle strip of type 1 is slightly different from the two others).

2) Sandow 4 or 6 mm

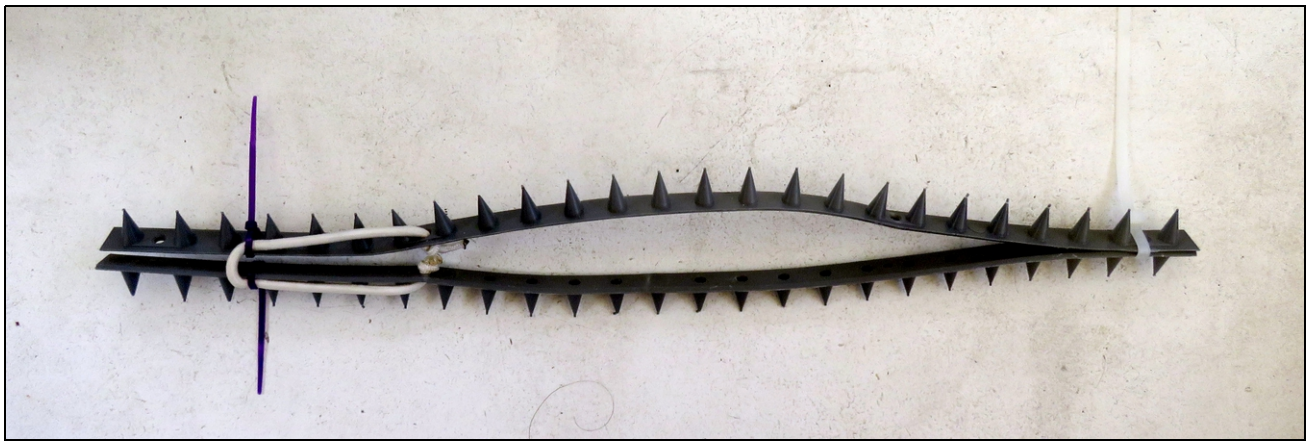
For Thoè, the strips of spikes correspond roughly to the width of the rudder blade (45 cm). I then used 22 cm of sandow per set of two strips. It is attached a few centimetres from the end of the strips. It goes through the original 4 mm diameter hole, widened to 4.5 mm with a drill for easier insertion. A very simple knot blocks it.

3) Electrician's collars (Colson)

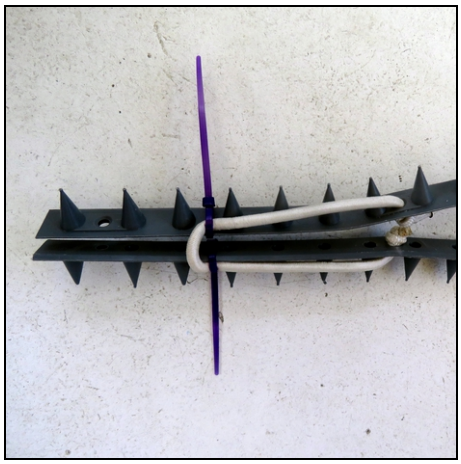
- On the side of the trailing edge of the blade, the two strips are joined by a collar of sufficient size.
- Two small collars (purple colour in the photo) are used to guide the sandow along the strip of spikes, as this is the front side of the assembly. The flow of water must not move the two stripes apart.

4) Small rope (red in the photos)

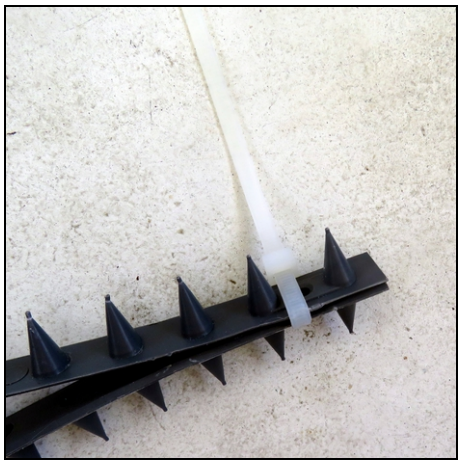
It is used to maintain the spacing of the protections on the blade and to avoid losing them if the sandow slips or the strip break.



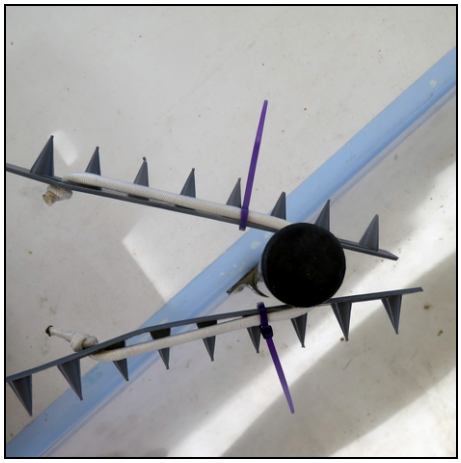
Type 1



The sandow is fixed a few centimetres from the end (white). Electric collar holding the sandow along the spikes (purple)

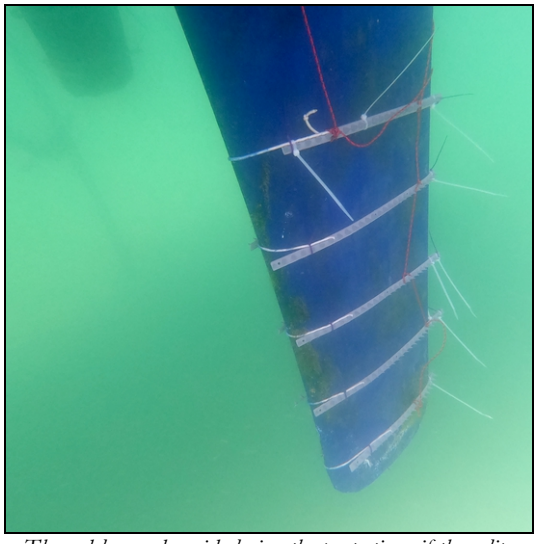


Collar on the trailing edge side of the blade



Simulation of the installation on the rudder blade.
The black circle symbolizes the front edge of the blade.

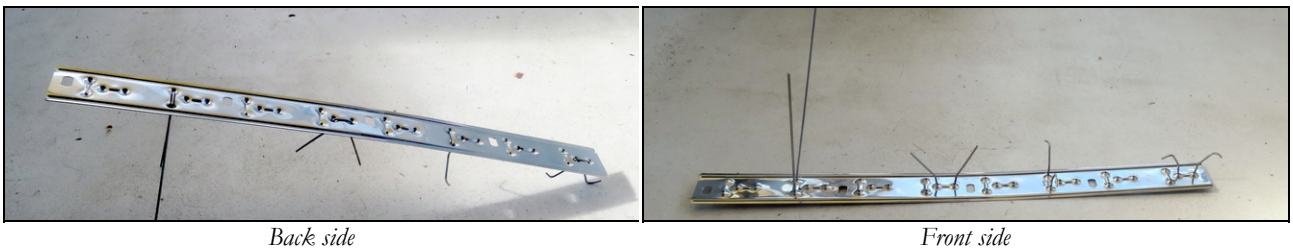
Two groups of 5 protections.
The protections at the right side have a small green collar to remind that they will go to starboard.



The red lanyard avoids losing the protections if they slip.
It goes, for example, around the rudder shaft to return to tie on the upper protection

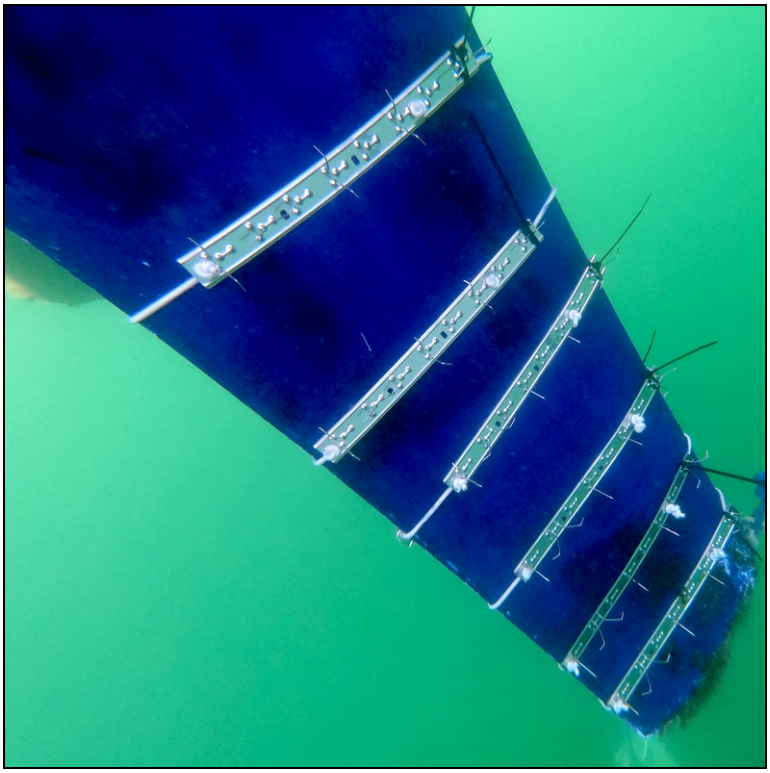
No more comments...

Assembly (type 3)



Back side *Front side*

The shipped pins are put in the holes from the strip. There are several possible arrangements.
After insertion (see left on the second picture), the pins can be cut to leave 20-30 mm active (see middle on the second picture).
To avoid the end of the pin to be sharp and hurting, they are folded close to their end (see right on the second picture).
This will satisfy the animal protection defenders.
The sandow diameter is 6 mm.



Important note

- Following the advice of a scientific expert in orcas interactions who commented this picture, **the most important place to be protected is the lowest edge of the rudder**.
- So, next year I will add 3 or 4 vertical stripes to protect the edge. They will be folded around the edge to protect both sides of the blade. They will be maintained in place by attaching them to the last horizontal strip.

Assembly on a plate

The principle (untested) is to put spikes across an *extruded polystyrene* plate (thickness 5 mm) which has a bit less than the dimension of the rudder blade. Extruded polystyrene is marketed as Forex and other names. It has nice physical properties in boat making.

- **Light and floating**. Density of about 0.85 (1.02 to 1.03 for sea water and 1 for clear water)
- **Does not absorb water**.
- **Easily cut** with a simple cutter.
- **Easily worked with woodworking tools** (does not make dust).

Assembling the plate and the spikes

- Spikes are in a shape of U. The base of the U will be on the backside of the plate. The two tips on the orca's side.
- Draw lines on the plate to get the grid where the spikes must be inserted. The distance between spikes can be ± 10 to 15 cm to avoid the orca to push the rudder in between.
- Drill holes per group of two into the plate. The distance between the holes depends on the U-shape of the spikes.
- Insert the two tips of U spikes into the holes.
- Cut the spikes to keep about 20-30 mm on the orca's side.
- Bend the spikes to the back side to avoid them to catch weed while sailing in forward.

Assembling two plates per rudder

- Each rudder blade will be enveloped with two spiked plates, one on the port side and one on the starboard side.
- On each vertical border of the Forex plate, we will drill some 7 mm holes at ± 1 cm from the border. Their number depends on the height of the rudder blade. They should be at ± 20 to 30 cm from each other.
- Insert a sandow into these holes to get a pair of socks to be set on top of the rudder blade on shore or by diving.

Benefits & drawbacks

Compared to the previous assembly:

- We can **define the position** of the spikes on the area of the rudder blade.
- The system is more **reliable and stable**. The spikes rows cannot move with the water flow and waves.
- It is more uneasy to be installed by diving.

Installation

These protections are not attached to the rudders. The sandows are keeping them in place. It is therefore possible to install them in the event of a risk of encounter, remove them when the danger has passed or to clean them. Just dive 1 metre ! They are reusable. We do not modify the rudder. Easy to clean...

Easy diving ?

Diving along the rudder is not easy if we are not weighted down by a lead belt. We come to the surface like a cork!

A trick is to hang a heavy chain or, better, an anchor. Instead of swimming to dive or exhausting ourselves by holding on to the rudder, we can climb down (!) by pulling the chain.

- All we have to do is put the protections on the blade one by one and position them at the desired height. Put more protections at the bottom than at the top, because the orca attacks from below.

Adjustment of the length of the protection

If the sandow is too long, the protection will not be sufficiently maintained on the blade. It is then necessary to shorten the protection on the side of the trailing edge :

- Prepare an electric collar by roughly closing it so as to create a loop (this is easier to do before diving).
- Dive and pull the spike protection backwards so that the sandow is sufficiently taut.
- Pass the collar around the protection and tighten it between two spikes in order to (virtually) shorten the protection.
- The part protruding from the trailing edge can remain. It will also disturb the orca!