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DEVELOPING BYCATCH REDUCTION DEVICES IN TROPICAL TUNA PURSE SEINE FISHERIES TO IMPROVE ELASMOBRANCH RELEASE

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SUMMARY

Today most on deck bycatch releases in tuna purse seiners are conducted by hand or simple aids (e.g., canvases, cargo nets). New developments in bycatch reduction devices (BRDs) can assist to decrease impacts on vulnerable bycatch species, including sharks and mobulid rays. Collaborative work with fishers is helping advance in the construction of functional BRD prototypes, which improve crew safety and speed up bycatch release times. New options such as shark velcros, mobulid sorting grids, release ramps, and hoppers with ramps can enhance current release standards. Practical aspects such as low cost, durability, easy handling, and storage can favour their adoption. Designs for some BDRs need to be adapted around individual vessels, and sometimes are limited by available deck spaces and configurations. However, for future purse seiners these selective BRDs should be integrated from the start in the boat design to maximize their efficiency and integration. Finally, we encourage tuna RFMOs to support research and adoption of BRDs for endangered, threatened and protected (ETP) species, incorporating them in their conservation measures and best release practice guidelines.

RÉSUMÉ

Actuellement, la plupart des remises à l'eau de prises accessoires depuis le pont des thoniers senneurs sont effectuées à la main ou à l'aide de dispositifs simples (par exemple, des toiles, des filets à marchandises). De nouveaux développements dans les dispositifs de réduction des prises accessoires (« BRD ») peuvent aider à diminuer les impacts sur les espèces vulnérables capturées accidentellement, notamment les requins et les raies mobulides. La collaboration avec les pêcheurs permet de progresser dans la construction de prototypes de dispositifs de réduction des prises accessoires fonctionnels, qui améliorent la sécurité de l'équipage et accélèrent la remise à l'eau des prises accessoires. De nouvelles options telles que les velcros pour requins, les grilles de triage des mobulidés, les rampes de remise à l'eau et les trémies avec rampes peuvent améliorer les normes actuelles de remise à l'eau. Des aspects pratiques tels que le faible coût, la durabilité, la facilité de manipulation et de stockage peuvent favoriser leur adoption. La conception de certains BDR doit être adaptée à chaque navire, et est parfois limitée par les espaces et les configurations de pont disponibles. Cependant, pour les futurs senneurs, ces BRD sélectifs devraient être intégrés dès le départ dans la conception du bateau afin de maximiser leur efficacité et leur intégration. Enfin, nous encourageons les ORGP thonières à soutenir la recherche et l'adoption de BRD pour les espèces en danger, menacées et protégées en les intégrant dans leurs mesures de conservation et dans leurs directives sur les meilleures pratiques de remise à l'eau.

RESUMEN

En la actualidad, la mayoría de las liberaciones de especies de captura fortuita en cubierta en los atuneros cerqueros se realizan manualmente o con ayudas sencillas (por ejemplo, lonas, redes de carga). Los nuevos desarrollos de los dispositivos de reducción de las capturas fortuitas (BRD) pueden ayudar a disminuir el impacto sobre las especies vulnerables de captura fortuita, incluidos los tiburones y las mantarrayas. El trabajo de colaboración con los pescadores está ayudando a avanzar en la construcción de prototipos funcionales de BRD, que mejoran la seguridad de la tripulación y aceleran los tiempos de liberación de la captura fortuita. Las nuevas opciones, como los velcros para tiburones, las rejillas clasificadoras para mantarrayas,

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las rampas de liberación y las tolvas con rampas pueden mejorar los estándares de liberación actuales. Aspectos prácticos como el bajo coste, la durabilidad, la facilidad de manipulación y el almacenamiento pueden favorecer su adopción. Los diseños de algunos BDR deben adaptarse a los buques individuales, y a veces están limitados por el espacio disponible en la cubierta y las configuraciones. Sin embargo, para los futuros cerqueros, estos BRD selectivos deberían integrarse desde el principio en el diseño del buque para maximizar su eficacia e integración. Por último, animamos a las OROP de túnidos a que apoyen la investigación y la adopción de los BRD para las especies en peligro, amenazadas y protegidas (ETP), incorporándolas a sus medidas de conservación y a las directrices sobre mejores prácticas para la liberación.

KEYWORDS

Bycatch; bycatch release devices; sharks; mobulid rays; survival; best practices; purse seiners; fishers; guidelines

Introduction

Global bycatch rates in tropical tuna purse seine fisheries are low (1-2%, Murua et al., 2021) compared to other fishing gears. However, within tuna purse seine fisheries, the Atlantic Ocean presents the highest bycatch rates, especially in sets on fish aggregating devices (FADs) reaching 7-9% bycatch (Murua et al., 2021). The most sensitive component of the bycatch are sharks and mobulids, with some being listed as threatened or endangered in the IUCN Red List (Pacoureau et al., 2021). Several zones of the eastern Atlantic such as Gabon, Angola or Mauritania have been identified as hotspots for elasmobranch species interactions with purse seiners (Ruiz et al., 2017; Lezama-Ochoa et al., 2018; Clavareau et al, 2021).

In recent years, the principal tuna purse seine fleets in the Atlantic Ocean (e.g., Spain, France, Ghana) are taking part in fishery improvement projects (FIPs) involving activities to mitigate ecosystem impacts (e.g., non-entangling biodegradable FADs trials, best practice training workshops for skippers) (Murua et al., 2014; Moreno et al., 2020). In this sense, one of the principal actions by EU fleets in the last decade has been the adoption of Codes of Good Practices (Grande et al., 2020; Maufroy et al., 2020), which recommend among other actions that fishers avoid poor elasmobranch bycatch release methods (e.g., inadequate handling techniques such as holding animals by the gills, dragging animals through the floor, or use of gaffs, hooks, and nooses) and instead employ best available practices. However, best on deck release protocols at present are still quite basic, mostly involving manual handling of animals or using rudimentary self-made tools such as canvas stretchers or cargo nets (Poisson et al., 2012). It is perhaps surprising that such technologically advanced “super-seiner” fleets with state-of-the-art fishing equipment (e.g., high-tech sonars, echo-sounders, bird radars, deck winches, etc.) lack sophisticated modern bycatch release devices (BRDs), in opposition to other fisheries which regularly employ them (Jenkins et al., 2012; Glass et al., 2015; Campbell et al., 2020).

While training crew for adequate release techniques has improved prior standards (e.g., avoid handling sharks by the gills or only by the tail), observer data still shows the occurrence of undesirable release practices in some instances. Often this can happen because of difficulty in handling highly dangerous animals (e.g., adult sharks) or very heavy ones (e.g., mobulid rays) (Maufroy et al., 2020). If fishers have no safe and efficient means to return elasmobranchs back to sea, they might be tempted to employ undesirable techniques known to be fast at removing bycatch from deck (e.g., lifting or pulling with nooses and hooks) or delay their release until the animals become less threatening (e.g., leave sharks on deck until less active).

Previous studies have reported that even with good manual handling practices, shark survival in purse seiners is around 15-20% (Poisson et al., 2014; Hutchinson et al., 2015). This statistic would be even lower if poor practices were employed. On the other hand, recent research in the Indian Ocean has shown that the use of good practices complemented with BRDs (in this case an auxiliary release conveyor belt in the lower deck) increased silky shark (*Charcharinus falciformis*) survival rates to 43% (Onandia et al., 2021). Providing fishers with better and safer BRD options is likely to improve the efficiency of elasmobranch release dynamics and their survival rates.

In recent years, AZTI and ISSF fisheries scientists and technologists have been collaborating with the ANABAC and OPAGAC fleet to develop and test various new BRDs that can assist fishers return elasmobranchs and other non-target species back to sea in a more effective and safe manner. This document presents some of the release equipment tools that are being tested at present in this purse seine fleet across all oceans.

Methods

Various BRD prototypes have been developed in recent years by the AZTI and ISSF tuna and fishing technology research teams. The first step in the process was to carefully examine release protocols and identify shortcomings that need improvement. For example, with large mobulids it is difficult to handle them due to their large size and weight (e.g., > 4 m wingspan and 1000 kg), in addition to their slippery and difficult to handle body shape. Even when using cargo nets or canvases for release, mobulids first need to be extracted manually from the brail which can result in inadequate handling (e.g., holding by the head lobes and gill slits) and consume valuable time. With large sharks, manual extraction from the brail can be very dangerous and using nooses to pull them out by the head or tail can result in damage to organs and produce skin lacerations to the animal.

Having identified some release weak points, alternative solutions were proposed. The ISSF Skippers Workshops, conducted among others with the ANABAC and OPAGAC fleet since 2010, have been an important catalyser to facilitate direct scientist-fisher interaction that promotes generation of ideas to solve problems such as bycatch (Murua et al., 2019). Fishers with their deep understanding of fishing gear and species behaviour, make essential contributions that help BRDs be more practical and better integrated in the whole fishing operation. In addition, frequent exchanges with other knowledgeable fishery stakeholders such as ship-owners, fleet managers or shipyard naval engineers have been fostered to promote collaboration in the design and implementation of BRDs.

Detailed knowledge of deck configuration in each fishing vessel is essential to design custom-built tools that best fit available deck spaces and operations. Because most of these tuna vessels operate in distant country ports, various sources of information are employed to understand diverse deck configurations, including detailed vessel construction plans and photographs and measurements taken by fleet inspectors or fishers. A simple and useful method to examine best BRD configuration on deck is having fishers make real size template out of canvas or other materials onboard, to examine available options that can be sent after to scientists or tool building workshops. For some release tools skippers were provided with a simple document where then can record information on bycatch releases with these tools to provide scientists with feedback (**Annex I**).

Results

1. Shark BRDs

1.1. Shark Velcros

In order to avoid potentially dangerous interactions if an accidentally caught large shark appears in the brail fishers usually put a rope loop or noose around its tail and lift it with the crane (**Figure 1**). However, the narrow and tight rope of the noose can damage the animals' skin and potentially cause spinal cord damage. To prevent this poor practice alternative lifting devices have been designed and trialled. One of them we called the "Shark Velcro" consisting of a wide and padded strong canvas surface that easily folds around the shark's tail, in a similar fashion to a surfboard leash. This equipment has Velcro surfaces at the extremes to quickly wrap it around the tail and hold it in place. It also has on the top end heavy-duty straps to connect them to the crane.

Once the shark is rapidly lifted from out of the brail and over the starboard, the device is easily opened from a safe distance by pulling laterally from a connecting rope to separate the adhered Velcro surfaces. Various vessels of OPAGAC and ANABAC have employed the Shark Velcro to release animals during commercial fishing operations. After fishers' feedback an additional strap of velcro has been added to the second prototype to increase holding strength and it has been constructed in three sizes (small 57 cm, medium 62 cm, and large 76 cm lengths) to better adapt to the size range of sharks released. This cushioned non-abrasive lifting tool is thought to be less harmful than rope nooses ("estrobos" in Spanish). Two silky sharks (*Carcharhinus falciformis*) released with the Shark Velcro were monitored using satellite pop-up tags programmed for 60 days during a recent experimental campaign in 2022 in the Indian Ocean, and both survived after the release (**Figure 2; Table 1**).

1.2. Shark holders

Another poor practice that can take place is moving or lifting adult hammerhead sharks by the head with ropes (**Figure 3**). Because of the dangerousness of manipulating lively hammerhead sharks, fishers at times can use nooses to pull from the sharks' head when removing them from deck. This action is clearly deleterious for the animals' health as the noose around the neck strangles them. To prevent this and taking advantage of the hammerheads' T-shaped frontal lobes, tools have been created to enable removing the animal out of the brailer in a safe manner for fishers while avoiding strangling elements. The devices here referred to as "holders" have two curved arms shaped to fit around the frontal lobes of the animal. The holders have a long enough handle to keep a minimum safety distance between the shark and the fisher. The tool can be either used manually by fishers or lifted with the crane to release the animal back into the water. Both ends on each extremity of the holder are round (i.e., not sharp) and are covered by a protective padded coat to prevent injuring the animal (**Figure 3**). The holders are constructed with stainless steel hollow tubes to provide structural strength, lightness, and durability.

1.3. Shark release ramps

Currently most shark release events involve fishers carrying sharks for several meters (3-6 m) by hand from the brail in the centre of the deck to the waters' edge on the starboard. This procedure is risky and severe crew injuries caused by shark bites have been reported. In some occasions heavy and dangerous sharks are dragged across the deck instead of carried in arms. Safe tools that minimize direct contact with sharks while preventing dragging them around, should be a priority. In recent years AZTI has developed and constructed several models of release ramps that reduce handling time and speed up shark releases which potentially increases survival chances. These ramps start next to the brail and connect all the way to the release door in the starboard, helping bycatches rapidly slide down to the water with minimum contact and stress (**Figure 4**).

Different ramp prototypes have been tested (**Figure 5-6**), and their designs are often influenced by particular space and disposition of other fishing equipment on deck in each vessel. Some considerations when building these ramps include providing enough width and inclination so animals can slide down unassisted. However, ramps need to be low enough (i.e., below shoulder level) so that fishers can deposit heavy animals without problem. Simple modifications, such as having a water hose connector to wet the ramp to make it slippery, can increase their efficiency. To manoeuvrer and store ramps after use, it is preferable to make them relatively light and in sections that can be piled or folded to take up minimum space. If constructed in durable materials like stainless steel, the lifetime of these tools can span many years. Compared to other fishing equipment, cost of these ramps is relatively minor (approx. 1,000-4,000 USD; equivalent to 1-4 echosounder buoys).

In some instances, vessels will lack a release door in the starboard sidewall or it might be hidden away behind other equipment (e.g., deck winches, chockers), complicating the design of the ramp. In these cases, it is suggested that, when possible, a new opening or "cat flap" door is created in the sidewall to help with a straighter and shorter ramp design (**Figure 7**).

1.4. Hoppers with ramps

While ramps facilitate release of bycatch in the upper deck, many individuals (e.g., juvenile sharks) end up in the lower deck because they go unobserved in the brail when not located in the upper layers. Note that on average these brails have a 5–10-ton capacity, making it difficult to spot bycatch hidden away between the mass of tunas. Purse seiner statistics indicate that a large proportion of sharks and other bycatch end up in the lower deck, where, unless the vessel has a double conveyor belt for bycatch, releases are delayed resulting in high mortality (Poisson et al., 2014). For this reason, BRDs such as hoppers on the upper deck, which help spread the brail contents on its base, enable better detection of sharks and prevent them going to the lower deck. Importantly, these hoppers must have a stoppage system, such as a door or guillotine, which can stop the flow of fish into the lower deck until incidental species are released. A ramp connecting to the hopper again facilitates safe and rapid return of bycatch back to sea.

Hoppers are used by various fleets especially in the Pacific (e.g., USA, Ecuador, Mexico, etc). Originally, they were employed to discard unwanted fish and to control the flow of fish into the lower deck before conveyor belts were installed. Nowadays, with 100 % observers in purse seiners this practice has been discontinued and it is used to release bycatch. The type of hopper employed by these fleets is a "mobile" one, which is positioned either on the portside or the starboard depending on the vessel configuration and skippers' preferences (**Figure 8**).

Hoppers have been less frequently employed in the Indian and Atlantic Oceans. An exception is the French fleet which has several vessels that have hoppers, but instead of being mobile, they are centred over the unloading hatch. Therefore, these hoppers are "integrated" and usually not removed after sets. The problem with these hoppers currently is that they lack a stoppage door, and contents unloaded on the hopper rapidly move down towards the lower deck, often too quickly for fishers to get hold of the bycatch species (Maufroy et al., 2020). Integrated hopper designs with sliding doors, either operated manually or hydraulically, are being developed to prevent accidental fall of sharks and other bycatch from the hopper into the lower deck (**Figure 9**).

In the last two years, several hoppers with regulated doors and ramps have been constructed for Spanish company vessels in the Atlantic, Indian and Pacific Oceans, and are considered the BRDs with the greatest potential to reduce shark release times and improve their survival rates. Research cruises with satellite tagging and lactate measurements are planned in 2022 to estimate survival rates in vessels employing hoppers with ramps. The first tagging trip with hoppers will take place in May 2022 onboard a Bolton Group vessel in the Eastern Pacific and in collaboration with IATTC scientific staff.

Because hoppers can take up an important part of the available space on the upper deck, fishers that are new to this BRD are initially reluctant to employ it. However, fishers accustomed to work with hoppers in general see it as a useful selectivity tool to prevent unwanted catch reaching the wells. Implementing hoppers in all purse seiners might not be possible, as some vessels with small working decks have little space available or have deck configurations which make it difficult to incorporate this BRD (e.g., extended working boat decks, winches and chockers in awkward positions, etc.) (**Figure 10**). It would be much easier to incorporate hoppers with ramps in newly built vessels, where on deck equipment distribution could be adjusted to integrate this BRD.

2. Mobulid ray BRDs

2.1. Mobulid sorting grids

Compared to other oceans, the Eastern Atlantic is the region where more mobulids are accidentally caught by tuna purse seiners (Hall and Roman, 2013). Due to their large size and weight (e.g., adults reaching > 4 m wing disc, > 1000 kg) manipulating these animals by hand is complicated, and in the past fishers employed hooks through the gill slits to lift them with the crane. Several tRFMOs prohibit this practice in their regulations.

Nowadays, the recommended practice is to lift the mobulids using a canvas or a cargo net (Poisson et al., 2012). This practice is an advance over previous protocolos, but still has some inconveniences as the animal requires to be extracted by hand from the brailer, which is not simple and can take several minutes. Often fishers will have to get inside the brail to push the mobulid out, holding it from the frontal lobes or gills to drop it on the deck floor where the canvas or cargo net is laid out. Also some home-made canvases or cargo nets can be small and when lifted with the crane, excessively fold the animal’s wings.

To prevent some of these drawbacks, AZTI scientists have been working on manta sorting grids which are positioned over the unloading hatch when a mobulid is spotted in the brail. The sorting grid consists of a rigid supporting frame and a series of ropes or chains crossing each other to form a grid or sieve. In this way brail contents are emptied over the sorting grid and the fish filter through while the mobulid stays on top. With the help of a deck crane, the sorting grid is lifted and rested on the starboard sidewall, where the mobulids are released into the sea (**Figure 11**). Trials in the Atlantic demonstrated that the whole release procedure with this BRD averaged just over 1 minute and required no direct manual handling by fishers (Murua et al., 2020). In addition, the brailer remained free to continue operating for fish loading during the release maneouver.

The frames of the grids have been usually built in hollow stainless steel to make them lighter, so they can be positioned on the unloading hatch between 2-3 fishers by hand. The price of these BRDs is fairly economic (approx. 500-2,000 USD depending on materials and sizes) and once constructed will last permanently. The design of the sorting grids can be adapted in shape, size and number of grid cells, to accommodate to the circumstances of each vessel or set type (e.g. free school vs FAD). Alternative desings such as circular sorting grids to fit in the rim of the unloading hatch are being tested, as are foldable sorting grids that can be stored under the hopper when not used (Figure 12). Other parallel initiatives, such as a NOAA sponsored project leaded by ISSF, is currently testing mobulid sorting grids in the USA fleet.

Discussion

Through research and trials new BRDs for elasmobranch accidentally caught by tropical tuna purse seiners are gradually gaining momentum to improve release protocols and some companies are voluntarily starting to employ them during their commercial trips. BRD prototype tests are overall yielding positive results, offering better alternatives to undesirable release practices. In addition, because many of these tools have been developed based on skippers’ ideas or refined using their feedback, adoption by fishers is easier as they feel stewards of the solution development process.

Nowadays many tuna fleets are involved in eco-certification programs and working towards improving bycatch mitigation, such as implementing best on deck release practices. Similarly, some tRFMOs have been adopting resolutions that directly address vulnerable elasmobranch bycatch releases in purse seiners (e.g., IOTC, Res. 19/03; IATTC, C-15-04; WCPFC, CMM-19-05). Note that ICCAT is currently the only tRFMO lacking specific release measures for groups such as mobulids or whale sharks. Nevertheless, current conservation measures focus primarily on avoiding undesirable practices (e.g., prohibiting hooks or gaffs or nooses to manipulate animals), while recommended guidelines only offer limited alternatives (e.g., canvases, stretchers) which cannot always guarantee crew safety or a rapid release. Most tRFMOs refer to the guidelines produced by Poisson et al. in 2012, which at the time meant an advance over previous release standards but has not been revised in the last decade. Given the scope for improvement of these protocols, AZTI and ISSF scientists, in collaboration with ANABAC and OPAGAC purse seiners, have been working on the design, development and trials of BRDs for better crew safety and elasmobranch survival. Because there is a variety of species caught as bycatch in FADs, which can greatly vary in shape and size, a battery of tools may be necessary to address this circumstance. Even individuals from a same species might appear at various times of the fishing operation (e.g., entangled in the fishing net, in the brail, in the lower deck) and release tools might need to be adapted to deal with each scenario. Nevertheless, the objective of these BRDs is not to overcomplicate protocols, thus designing tools that assist with the release of multiple species simultaneously is the preferred option (e.g., hoppers with ramps).

While these BRDs try to be as practical as possible and result in the least amount of extra work for fishers, at times there will be trade-offs. For example, shark velcros might take a few extra seconds to wrap around a shark's tail compared to a noose, or fishers might have to spend a few minutes setting up and removing mobile hoppers and release ramps before and after brailing. Note however, that the use of the BRDs will result also in substantial benefits to the crew. For example, once the hopper and ramps are set up, releases will require less effort as sharks do not require to be carried by hand one at a time from the upper or lower deck to the water. Similarly, with the manta ray sorting grid, fishers will avoid having to extract by hand these large animals from the brail to deposit them on deck on the canvas. This lower need by crew for direct manipulation of elasmobranch species, results in reduced injury chances for fishers. In addition, the important decrease in handling and time spent out of the water should help elasmobranch individuals achieve higher survival rates.

Little is known about the effects of handling trauma and time out of the water on sharks and mobulids under fishing conditions, or even the influence of factors such as set size, time in the sac, etc. on mortality. Some studies indicate that animals released earlier in the fishing manoeuvre (e.g., first brails vs later brails) show greater survival rates (Hutchinson et al., 2015; Onandia et al., 2021). Presumably preventing long air exposure and inadequate handling, can reduce stress levels in elasmobranchs arriving on deck. For example, trials with mobulid sorting grids in the Atlantic showed that individuals could be released in 1-2 minutes, whereas average times for releases with other methods (e.g., by hand, with canvases) on average took several more minutes (Murua et al., 2020). Other tools, like the padded Shark Velcros to lift up large and dangerous sharks from the brail can help replace rope nooses, which can potentially cause skin lacerations and damage to the spinal cord. Initial satellite tagging of sharks released with velcros in the Indian Ocean appear to indicate good survival rates when employing this device. More velcro released shark tagging data is needed to corroborate these findings.

While these BRD prototypes will probably still undergo adaptive modifications to better fit the necessities of different vessel types (e.g., round mobulid sorting grids), they already represent an important advance in the state of release equipment and protocols, and some elements found to work well across various oceans could start to be incorporated into the best practice guidelines of RFMOs or other management bodies (Annex 2). Notice that for other gears, such as tuna longliners, conservation measures stipulate vessels carry on board specific bycatch release utensils (e.g., dehookers, dip nets, etc.) or shrimp trawlers having to fit in their nets turtle excluder devices (TEDs). A similar approach for tuna purse seine vessels in which a minimum kit of BRDs is required (e.g., a ramp and a sorting grid) would be advisable. For example, if all vessels had ramps next to the brail when extracting bycatches, it helps fishers to take a more consistent approach towards releases whereby all non-target species encountered are automatically deposited on the ramp. This potentially reduces chances of sharks being left on the side of the deck to be dealt with only after the fish loading operation has concluded.

Of all BRDs examined, hoppers with ramps and mechanisms to control the flow of its contents, show the greatest potential to reduce elasmobranch and other non-target species mortality. This is because hoppers enable incidental species to quickly be released from the upper deck, preventing them entering the lower deck, where survival is greatly compromised. In addition, hoppers can have other benefits such as improving species and size catch composition data, because emptying the brail on this wide tray facilitates viewing all the catch contents. In the future, hoppers in conjunction with electronic monitoring systems equipped with artificial intelligence automatic species recognition (Lekunberri et al., 2022), could result in precise catch composition statistics in near real-time.

Because each vessel has a unique deck configuration and during brailing some decks will have less free space available, some of the larger BRDs need to be designed with these limitations in mind. Also, distribution of working equipment on deck such as winches, chockers or davits can complicate or obstruct adequate inclusion of BRD like hoppers and ramps. It might well be that some purse seiners are unfit to install a hopper on deck. When these purse seiners were constructed in the past, there was no consideration on how to distribute fishing equipment on deck to allow enough space for BRDs. However, for smaller BRDs like ramps or sorting grids, some minor to medium scale structural changes to the vessel's deck (e.g., opening a "cat flap" on the sidewall, or moving the position of a speedboat davit) can be recommended clear space that allows for release equipment installation. In the future, newly constructed vessels should not only be designed to maximise fishing power but also for release efficiency of non-target species. If inclusion of BRDs were to be considered in the initial stages of future vessel's designs, these elements could be easily distributed in a more functional and integrated manner with the whole fishing operation.

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Table 1. Satellite tagged data for two silky sharks released with a shark velcro in Indian Ocean experimental campaign.

Species	*Tag type*	*Days at liberty*	*Initial position*	*Final position*
C. falciformis	SPAT-355H	60	6.15 N 53.49 E	4.48 N 50.0 E
C. falciformis	SPAT-355H	60	4.50 N 56.10 E	4.36 N 54.24 E

Figure 1. Poor release practices with sharks lifted out of the brail with ropes (left) and pulled across deck with rope (right).

Figure 2. Satellite tagged shark released with a shark velcro (left), small, medium, and large size shark velcros (right) (Echebastar/AZTI©).

Figure 3. Shark holder prototypes 1 and 2 built for manipulating hammerhead sharks (AZTI©).

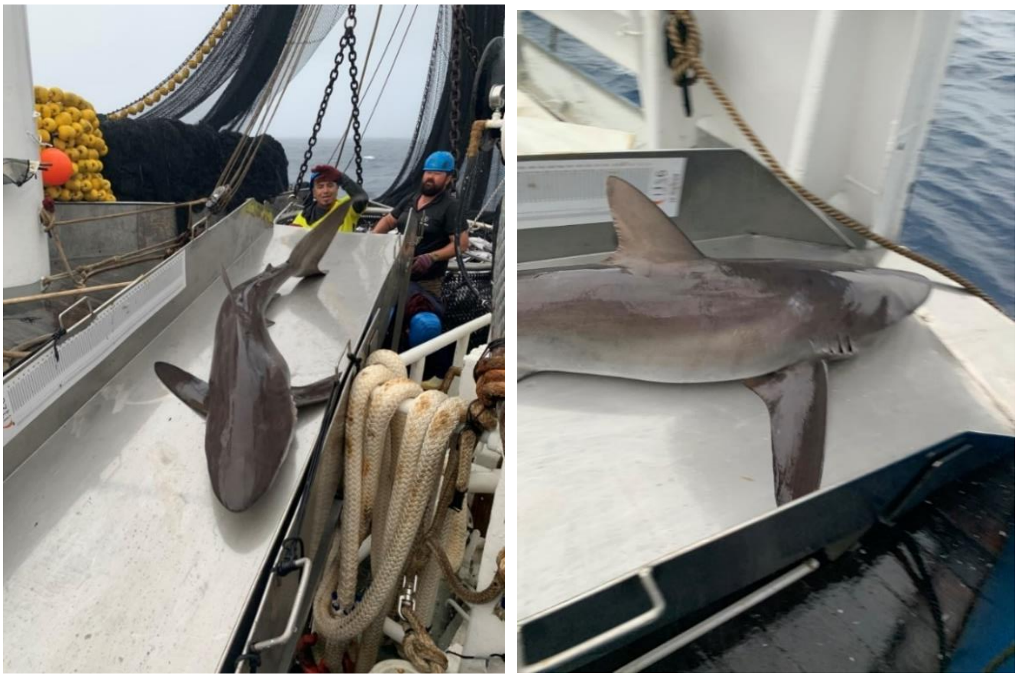


Figure 4. Shark released on deck from the brail sliding down the ramp towards the water through the starboard door (Albacora/AZTI©).

Figure 5. Release ramp folded for easy storage and extended for working (Pevasa/AZTI ©).

Figure 6. Retractable ramp and adjustable height with horizontal initial section to deposit and measure bycatches (Jealsa/AZTI ©).

Figure 7. Starboard upper deck door (yellow arrow) behind two chockers and suggested new "cat flap" opening (red square) on sidewall to facilitate releases with a straight ramp.

Figure 8. Shark release sequence using mobile hopper with ramp positioned on the starboard (Bolton Group/AZTI ©).

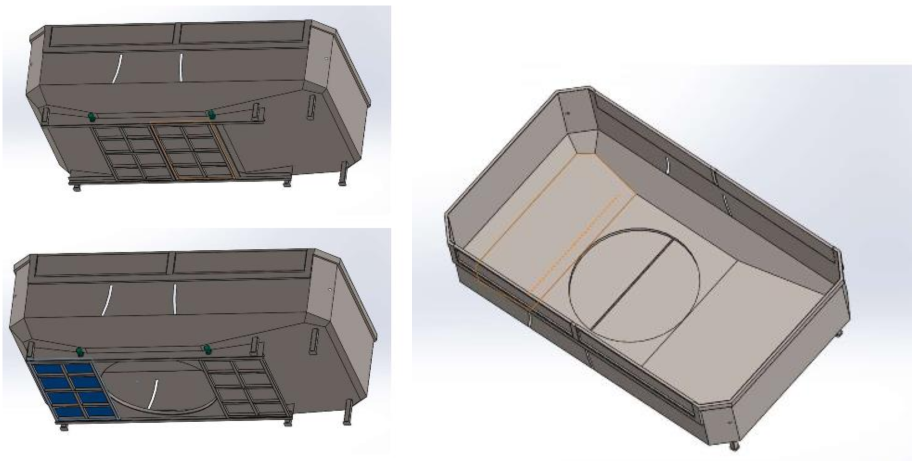


Figure 9. Lower and top view of integrated hopper desing with opening door to control bycatch releases from the upper deck

Figure 10. Small deck with little space for a hopper during net hauling (left) and hopper tarpaulin template to discuss with skipper preferred design and location on deck (Pevasa/Calvo/AZTI ©)

Figure 11. Mobulid sorting grid operation sequence showing the release of three adult Chilean devil rays (*Mobula tarapacana*) simultaneously over the starboard (Albacora/AZTI ©).

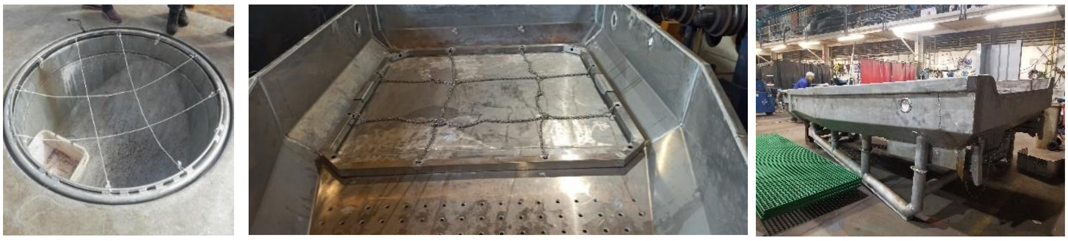


Figure 12. Round sorting grid on unloading hatch (left) and square sorting grid extended on hopper tray (middle) and stored folded underneath (right) (Pevasa/Jealsa/AZTI ©).

ANNEX 1 – Elasmobranch Bycatch Release Device Release Form

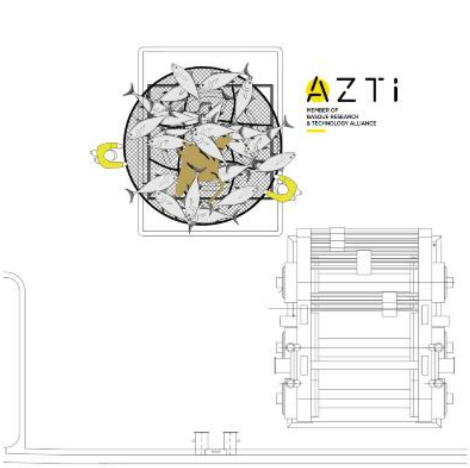
BRD RELEASE EVENT REPORT

This form will be filled when encountering an elasmobranch and released using a BRD. If in addition the elasmobranch has also been tagged the tag information should be provided.

1. VESSEL NAME:
2. TYPE OF SET (FS/FAD):
3. SET DATE & TIME:
4. SET POSITION:
5. SET SIZE (T):
6. BRAIL NUMBER IN WHICH THE ELASMOBRANCH ARRIVED ON DECK (1st, 2nd, …):
7. BRD EMPLOYED:
8. ELASMOBRANCH SPECIES RELEASED:
9. NUMBER OF INDIVIDUALS IN THE BRAIL (IF MORE THAN ONE):
10. APROXIMATE TOTAL LENGTH:
11. TIME FROM ARRIVAL ON DECK TO RELEASE (MIN):
12. STATE OF THE ELASMOBRANCH: GOOD / INTERMEDIATE / POOR/ DEAD
13. ANY DIFICULTIES WITH THE RELEASE? IF THE BRD DID NOT WORK, DID YOU HAVE TO USE OTHER RELEASE METHOD (BY HAND, CARGO NET, ETC.)?
14. DID YOU TAKE PHOTOS, VIDEOS? (Y/N) (PLEASE SEND IF YES)
15. HAS THE ELASMOBRANCH BEEN TAGGED? (Y/N)
16. IF TAGGED PLEASE ADD TAG SERIAL NUMBER:

ANNEX 2 – Elasmobranch best release illustrative guidelines with BRDs

Mobulid ray sorting grid



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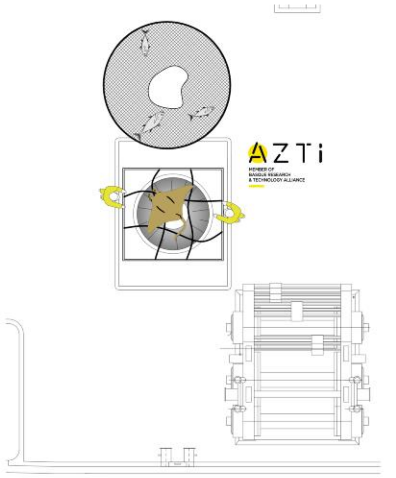

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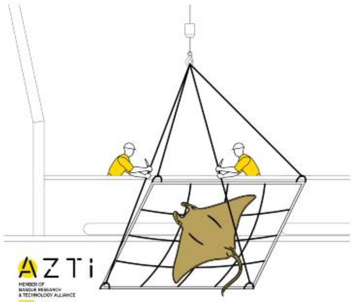

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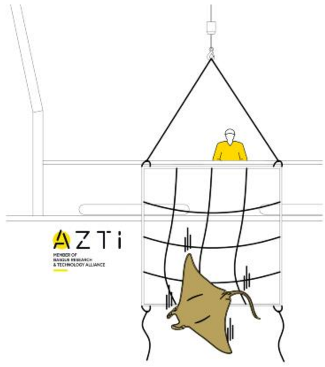

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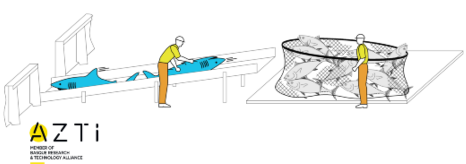
Shark ramps



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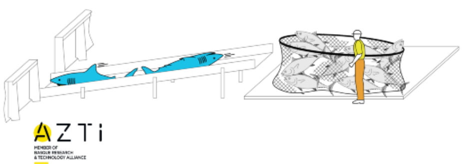
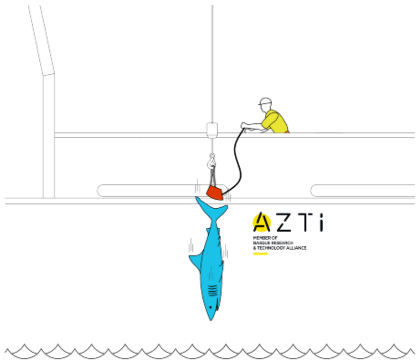


2

Shark velcros

1



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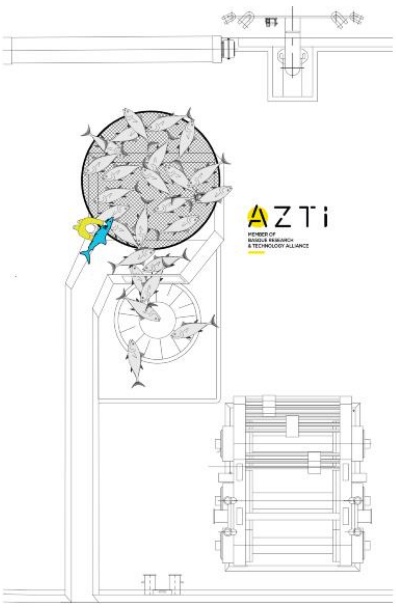
Hopper with ramp



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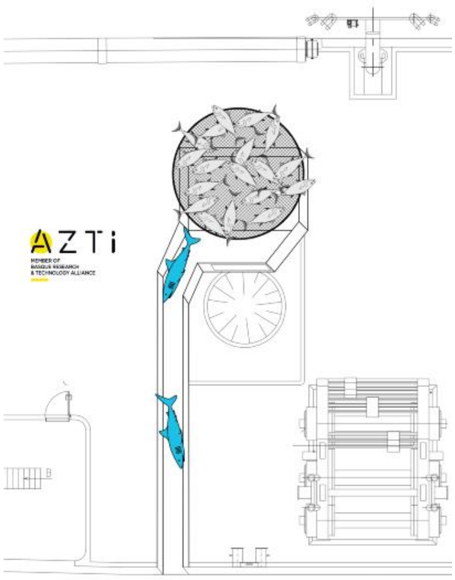

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