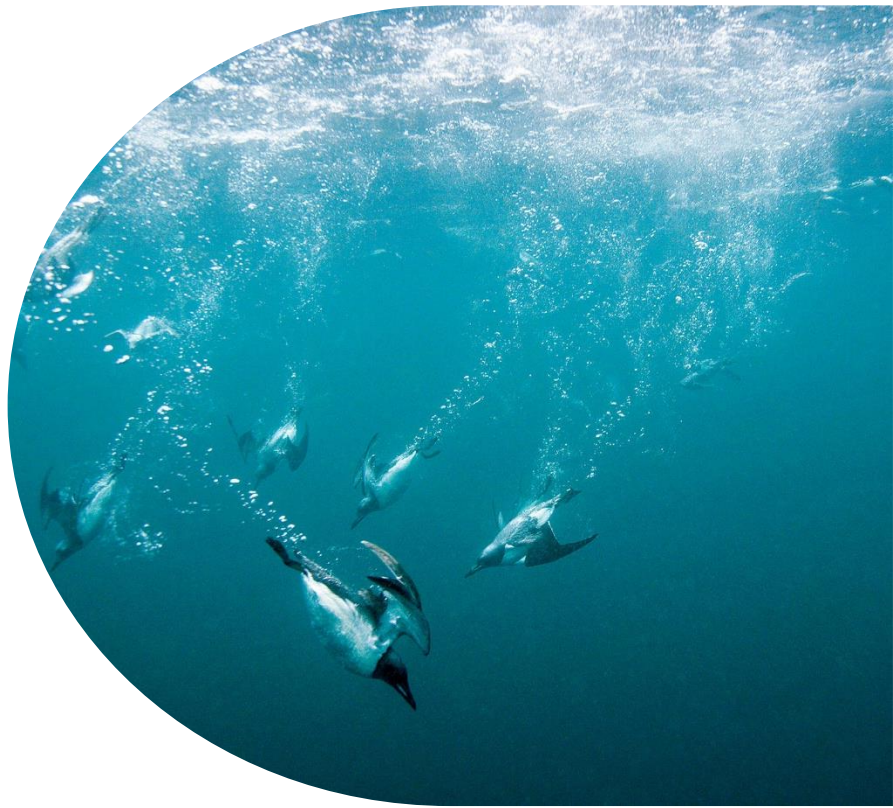# Tackling the bycatch of Marine Megafauna in global gillnet fisheries

Workshop Report

March 2021

Executive Summary

In March 2021, BirdLife International held a workshop examining the bycatch of Marine Megafauna in global gillnet fisheries, joined by nearly 90 multi-taxa and pluri-disciplinary experts from around the globe. We attempted to follow a holistic approach to understand the scale of work required to tackle this global conservation issue: from technical measures, to alternative gears, spatio-temporal fishing restrictions, including socio-economic and ecological considerations, to innovative technologies. Through this workshop, we identified several priority actions to help tackle gillnet bycatch across taxa:

o Enhance collaborations between experts, supported by international platforms or consortiums; improve communication and make data open access (both positive and negative results).

o Put greater focus on pluri-disciplinary and multi-taxa efforts to bycatch mitigation, instead of "siloed" actions.

o Better inclusion of sensory, cognitive and behavioural ecology principles in bycatch mitigation development, as well as ecosystem considerations. Notably, exploring visual capabilities of elasmobranchs, chemoreception for turtles, deterrents for seabirds and acoustic perception in marine mammals. At a broad level, better consideration of multi-sensory and multi-species approaches, habituation, and species' foraging behaviour around nets.

o Continue to explore technical means of mitigating bycatch, including LEDs as a potential cross taxa measure – particularly for turtles and marine mammals (including trade-off for elasmobranchs); expansion of above-water measures for seabirds (predator shaped kites and looming-eyes buoys); enhance testing of acoustic devices (including passive reflectors such as "*pearl nets*") for cetaceans.

o Stronger consideration of socio-cultural and economic realities in bycatch mitigation implementation. Including through inter-disciplinary frameworks such as the *Mitigation Hierarchy*, equity & least-cost considerations, and the *social practice of bycatch*.

o Foster the development of stronger, tailored, and long-lasting incentives for fishing communities to act on gillnet bycatch (including through financial incentives, market-based actions and education)

o Better understanding of gillnet fishing effort around the globe – particularly of small-scale fisheries – including through the use of novel technologies, such as electronic monitoring and i-VMS systems.

o Contribute to efforts to reduce world fisheries dependence on gillnets, through appropriate alternatives. Including gear-switching transition programmes, promoting use of fish traps, pots, and hook-&-line over gillnets, where appropriate. Increasing profitability of alternative gears if necessary (improving CPUE, incomes indexed with catch quality grading, etc.).

o Support the designation and implementation of effective spatio-temporal measures in bycatch hotspots. Consider appropriate scales (both spatial and ecological), as well as dynamic ocean management approaches – including learning from fin-fish management. Systematically involve holistic approaches for a better consideration of marine ecosystems, fishing practices & local knowledge, as well as political and socio-economic dynamics.

Introduction

Bycatch from gillnets is recognized as one of the major threats for a large array of marine organisms. This includes >400,000 seabirds[1], >500,000 marine mammals[2], >100,000 turtles[3,4] and countless elasmobranchs (both targeted and as bycatch)[5]. Those estimates suffer from important data gaps, however, including from poor bycatch reporting and fishing effort monitoring, generally leading to an underestimation of the problem. This is particularly true for small-scale fisheries where vessels are usually <12m in length, which represent 85% of the world's motorized fishing vessels[6].

A huge array of gillnet bycatch hotspots have been identified around the globe; as a relatively easy to use, inexpensive and effective fishing gear, gillnets are among the most widespread and popular means of catching fish, particularly in small-scale fisheries. This popularity, coupled with the associated diversities in ecological and socio-economic conditions in which gillnet fisheries operate, has complicated attempts by conservationists to develop appropriate bycatch mitigation measures for gillnets. It is therefore unsurprising that despite the substantial ecological impacts, very few solutions have proven effective in tackling gillnet bycatch.

On the 30th and 31st of March 2021, BirdLife International and the Royal Society for the Protection of Birds (RSPB) held an international workshop on the bycatch of marine megafauna in global gillnet fisheries. This workshop re-visited where things have gone since the workshop "*Reducing the Bycatch of Seabirds, Sea Turtles, and Marine Mammals in Gillnets*" held in 2015 (report). While this previous event was mainly to address technical approaches to modify fishing gear to reduce bycatch, this 2021 workshop focused on a more holistic and multi-taxa (seabirds, marine mammals, turtles & elasmobranchs) approach to the gillnet bycatch issue. The workshop was structured into sessions covering: 1) cognitive & behavioral systems of susceptible species to inform mitigation measures, 2) technical bycatch mitigation approaches, 3) alternative gear-types to gillnets, 4) social, economic & regulatory aspects of marine megafauna bycatch and 5) spatial and temporal measures to tackle bycatch.

A total of nearly 90 international experts were invited to this online event, covering a diverse array of institutions, expertise and geographical areas. 26 presentations were made available to attendees prior to the event, representing over 5 hours of video to inform and support 'live' discussions. Live sessions were structured around Q&A, discussions and activities, lasting about 6 hours in total. Through this event, we gathered collective experience and knowledge to map a path forward by looking at promising mitigation routes, identifying continuing data gaps and – ultimately - galvanizing future projects and collaborative work to address the ongoing issue of marine megafauna bycatch in gillnet fisheries.

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[1] Žydelis, R., Small, C., & French, G. (2013). The incidental catch of seabirds in gillnet fisheries: a global review. *Biological Conservation*, *162*, 76-88.

[2] Read, A. J., Drinker, P., & Northridge, S. P. (2006). *By-catches of marine mammals in US fisheries and a first attempt to estimate the magnitude of global marine mammal by-catch*. WWF-UK.

[3] Wallace, B. P., Lewison, R. L., McDonald, S. L., McDonald, R. K., Kot, C. Y., Kelez, S., ... & Crowder, L. B. (2010). Global patterns of marine turtle bycatch. *Conservation letters*, *3*(3), 131-142.

[4] Alfaro-Shigueto, J., Mangel, J. C., Darquea, J., Donoso, M., Baquero, A., Doherty, P. D., & Godley, B. J. (2018). Untangling the impacts of nets in the southeastern Pacific: Rapid assessment of marine turtle bycatch to set conservation priorities in small-scale fisheries. *Fisheries research*, *206*, 185-192.

[5] Oliver, S., Braccini, M., Newman, S. J., & Harvey, E. S. (2015). Global patterns in the bycatch of sharks and rays. *Marine Policy*, *54*, 86-97.

[6] FAO. State of the World's Fisheries and Aquaculture 2016: Contributing to Food security and nutrition for all. 200 (Food and Agriculture Organization of the United Nations, Rome, 2016).

Session 1 - Cognitive & behavioural approaches to assessment and mitigation of bycatch

Presentations:

Sensory biology & bycatch reduction: elasmobranch fishes

Laura K. Jordan, PhD. Founding Director, World Below the Waves

Visual and cognitive aspects of seabird bycatch

Graham Martin, PhD. Professor at the University of Birmingham

Sensory and Cognitive approaches to Bycatch Reduction for Sea Turtles

Wendy Dow Piniak, PhD & John Wang, PhD. NOAA Fisheries

Sensory and cognitive approaches to bycatch reduction for marine mammals

Marguerite Tarzia. Bycatch coordinator at International Whaling Commission

This session explored the general sensory, cognitive, and behavioral principles of the four taxa, opening the discussion for current and future bycatch mitigation measures. During the live discussions, the main points raised were as below.

The way marine organisms interpret sensory cues underwater is still largely unknown and merits more attention. We also tend to overestimate/mis-interpret what we think they experience, based on a largely anthropocentric perspective and in a medium that often restricts sensory cues (e.g. vision in poor water visibility conditions).

Although LED lights have shown promising results as a multi-taxa bycatch reduction tool in some areas, we do not understand why similar results have not been replicated in other places (e.g. effective seabird bycatch reduction in Peru vs ineffective in Baltic Sea testing). We also do not understand how lights are being interpreted by those animals; are they acting as an attractant? As a deterrent? Are they simply making the net-obstacle more visible?

Some other important sensory approaches could be explored, but they might offer serious technical challenges, more complex than the more established auditory or light emitting devices. This is especially true for elasmobranchs where electric or olfactory signals – among other cues – play an important role. For all taxa, but maybe even more for elasmobranchs, research into multisensory approaches should be encouraged.

We should be wary not to focus exclusively on one single solution when it has shown promise, neglecting other approaches as a result. For instance, with marine mammals, most efforts over the past several decades have been towards acoustic strategies (pingers), which have shown their limits considering species and condition diversity.
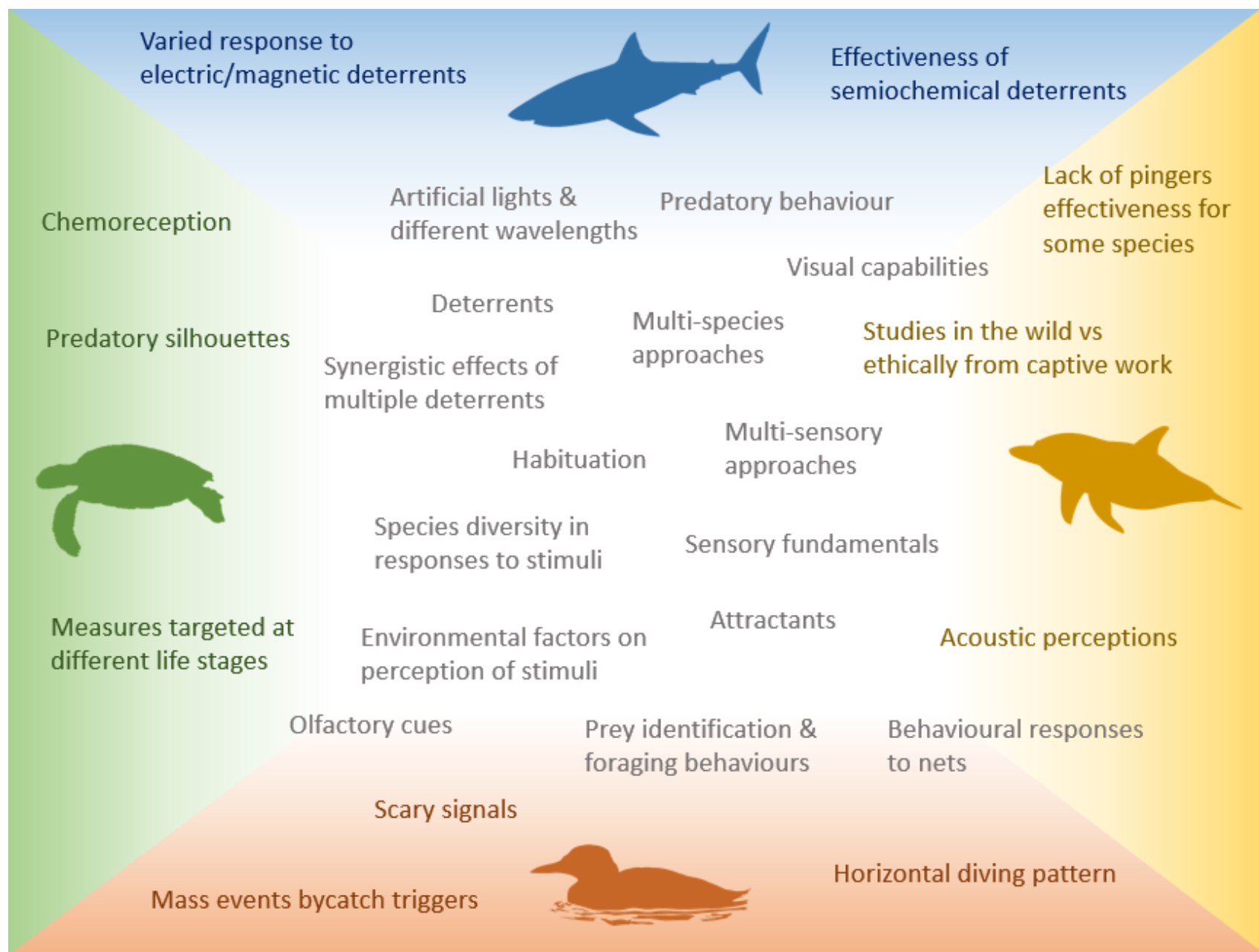
Although focusing on high priority/charismatic species, taxa and areas is important, we should also include more common & less charismatic species into our studies. This should facilitate identification of more holistic solutions.

While we recognize the need for multi-disciplinary and multi-taxa approaches to tackle this issue (and some common areas of potential are identified in figure 1 below), we recognize that in light of our deep knowledge gaps for each taxon, multi-taxa considerations are not without challenges.

Consideration of the collateral damage from using sensory cues (e.g. acoustic and light pollution) should also be further explored prior to large scale implementation.

Attendees participated in a final brainstorming exercise, trying to identify the key sensory, cognitive, behavioural research gaps for each taxon. Note that the below results reflect the attendees contributions, over a short period of time, and shouldn't be considered as an exhaustive review.

Fig 1 - Key sensory, cognitive, and behavioural principles research gaps for each taxon (colour coded) and in common for all taxa (grey)

Varied response to electric/magnetic deterrents

Effectiveness of semiochemical deterrents

Chemoreception

Artificial lights & different wavelengths

Predatory behaviour

Lack of pingers effectiveness for some species

Visual capabilities

Predatory silhouettes

Deterrents

Multi-species approaches

Studies in the wild vs ethically from captive work

Synergistic effects of multiple deterrents

Multi-sensory approaches

Habituation

Species diversity in responses to stimuli

Sensory fundamentals

Measures targeted at different life stages

Attractants

Environmental factors on perception of stimuli

Acoustic perceptions

Olfactory cues

Prey identification & foraging behaviours

Behavioural responses to nets

Scary signals

Horizontal diving pattern

Mass events bycatch triggers

Session 2 - Technical bycatch mitigation measures

<u>Presentations:</u>

Technology that works for fishermen and the environment

Robert Enever, PhD. Fishtek Marine

Gillnet modifications to reduce bycatch of harbour porpoises

Daniel Stepputtis & Isabella Kratzer, PhD, PhD. Thünen institute

Illuminated Gillnets to reduce bycatch in the small-scale Peruvian fishery

Alessandra Bielli, PhD. University of Exeter/Pro Delphinus

Assessing the importance of net colour as a seabird bycatch mitigation measure in gillnet fishing

Roshan Hanamseth, PhD candidate. University of New South Wales

Above water deterrents as a new approach to seabird bycatch and mitigation in gillnets

Yann Rouxel. RSPB/BirdLife International

In this session we discussed the more tradtional use of "technical" bycatch mititgation measures. Technical measures refer here to any change applied to the fishing gear itself, either through alteration to the netting material (e.g. coloured twines), attachement of emiting devices (e.g. pingers or LED lights), etc.

Besides pingers for marine mammals and LED lights for turtles, few other devices seem to have proven some level of effectiveness to prevent bycatch of marine megafauna in gillnets, and even those have shown some limitation in their effectiveness. Habitation, species specific effects and bycatch increase for other species have all been documented (e.g. in Peru, green LEDs reduced turtle bycatch but increased ray/shark captures – a species of commercial value in the area). More trials in other fisheries and bycatch hotspots need to be encouraged.

In contrast to signal emiting devices – which can be described as "active" -, there is increasing research interest in "passive" mitigation measures for gillnets. For example, "pearl" nets (small acrylic spheres embeded in the net) aim to increase the acoustic reflectivity of nets for marine mammals, and above water detterents (looming eyes buoys, predator shaped kites) have shown promise for seabirds. Further research and trials are needed for those measures, but they could prove a useful addition to more 'traditional' approaches.

To develop effective technical mitigation measures, we collectively recognized an overly-anthropocentric perspective in recent decades. It has often been assumed that marine megafauna would interpret signals the way we do (e.g. pingers as alert signals) or perceive their environment the way we imagine they do (e.g. colour vision in deeper waters). Closer collaboration with sensory, cognitive and behavioural research fields would certainly benefit development of more effective measures.

When technical measures are developed, uptake from the fishing industry is vital. However, it is unrealistic to expect low-income small-scale fisheries to cover the brunt of cost for the implementation of bycatch mitigation measures. Frameworks to provide financial support from the international community/ local governments, should be developed.

Collaboration across taxa and multi-disciplinary experts should be enhanced, maximising the development and testing of mitigation measures, moving away from a siloed "single species/taxa"

approach fuelled by limited capacities and funding. A global bycatch consortium – or similar platform - would facilitate such an endeavor. It would also promote further cross-disciplinary and multi-taxa events.

In below Fig 2, attendees listed technical gillnet bycatch mitigation measures tested or considered, for each taxon. Those were listed under "proven", "having potential/to explore" or "unlikely". Note that the below results reflect the contributions of participating attendees over a short period of time, and shouldn't be considered as an exhaustive review.

Fig. 2 - Technical gillnet bycatch mitigation measures tested or considered, for each taxon
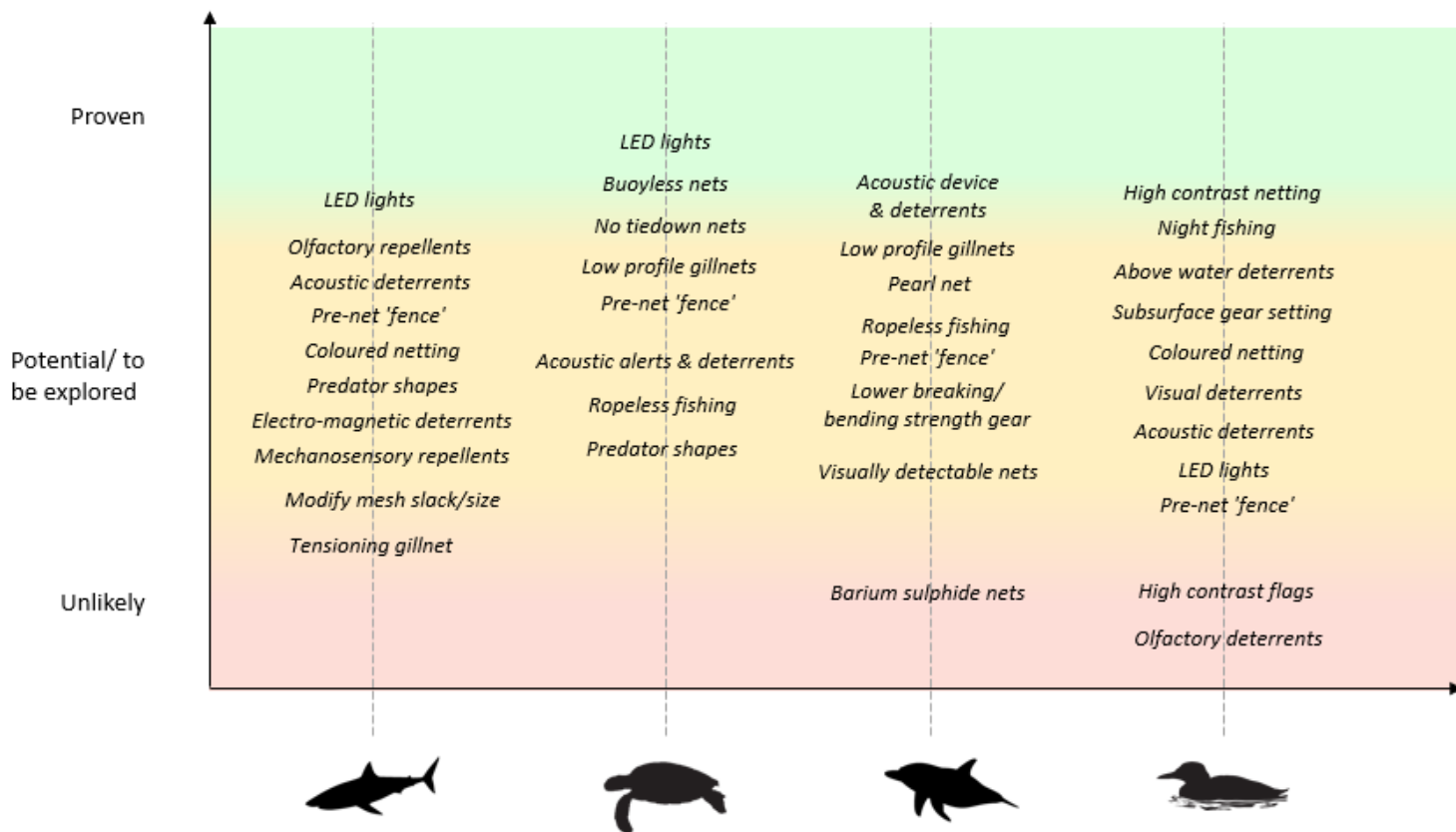
Session 3 - Alternative gear-types to gillnets

<u>Presentations:</u>

Comparison between gillnets and fish traps target catch and bycatch in the Lithuanian coastal fishery

Julius Morkūnas, PhD. Lithuanian Ornithological Society/Klaipeda University

Considerations from visual ecology in fisheries research design

Robert Blackmore. Memorial University of Newfoundland

Fish Traps : An Alternative to gillnet fishery?

Gesine Lange, PhD & Kim Cornelius Detloff, PhD. The Naturschutzbund Deutschland (NABU)

Reducing gillnet bycatch approaches in the Baltic - Alternative passive gears

Jérome Chladek, PhD & Daniel Stepputtis, PhD. Thünen institute

Here we discussed the potential of alternative gear-types to gillnets (AKA gear-switching) as a tool to reduce marine megafauna bycatch. Fish traps, pots and hook & line gears have been the centre of attention in recent years, with some geographical areas – such as the Baltic sea – leading contribution on this research.

Fish traps could be a realistic alternative to gillnets, with a comparable catch per unit of effort of target species, significantly lower bycatch rate of birds (and likely marine mammals) and reduced risk of large bycatch events (in Lithuanian trials). Traps do, however, require more time and effort for deployment and might not be able to target as broad an array of species as gillnets.

By providing higher quality of catch and value compared to gillnets, fish pots offer an interesting alternative for fishers. Current pots do not ensure comparable catch per unit of effort compared to gillnets however, and their use might not be possible in all fishing vessels (e.g. need a rather large deck for stacking). Some research is currently underway to tackle those limitations (exploring pot lighting to attract, new pot entrances, foldable structures, etc.), but further research and support is needed.

It is necessary to look at the entire picture – not just catch rate - when considering gear-switching actions. How is the new gear incorporated into the existing fishing vessels, for example? Is the fishing community in question open to changes?

There is a large variety in how fishing communities approach fishing and innovation in general and restricting the gear-switching question to the single "catch rate" approach would be restrictive. Between fishing communities and within communities themselves, fishers can be future-, present- or past-oriented, resulting in an array of proactiveness and openness towards gear-switching actions. Therefore, clear incentives such as "direct marketing" need to be developed, promoted, and supported to help communities transitioning towards alternative gear-types.

Strengthening direct marketing, catch quality and sustainability as part of the seafood supply chain (from producer to consumer) would help make alternatives to gillnets more popular and attractive among fishers. In areas of high pinniped depredation of fish catch in gillnets, the promise of alternative gear (such as fish pots) tackling depredation could also be very strong leverage to initiate change.

Finally, it is critical to remember that gear-switching actions are not mutually exclusive to other mitigation strategies. Technical mitigation measures can easily be incorporated to alternative gears which do not entirely tackle bycatch alone, or be used in coordination with spatio-temporal restrictions (e.g. only pot fishing allowed near seabird colonies).

Attendees participated in the development of a decision tree on alternative fishing gears to gillnets, exploring limitations, potential solutions and required actions. The below diagram summarises those main outcomes. Again, the below results reflect the present attendees contributions, over a short period of time, and shouldn't be considered as an exhaustive review.

Fig. 3 – Summarized "decision tree" from transitioning gillnet fisheries to alternative fishing methods.
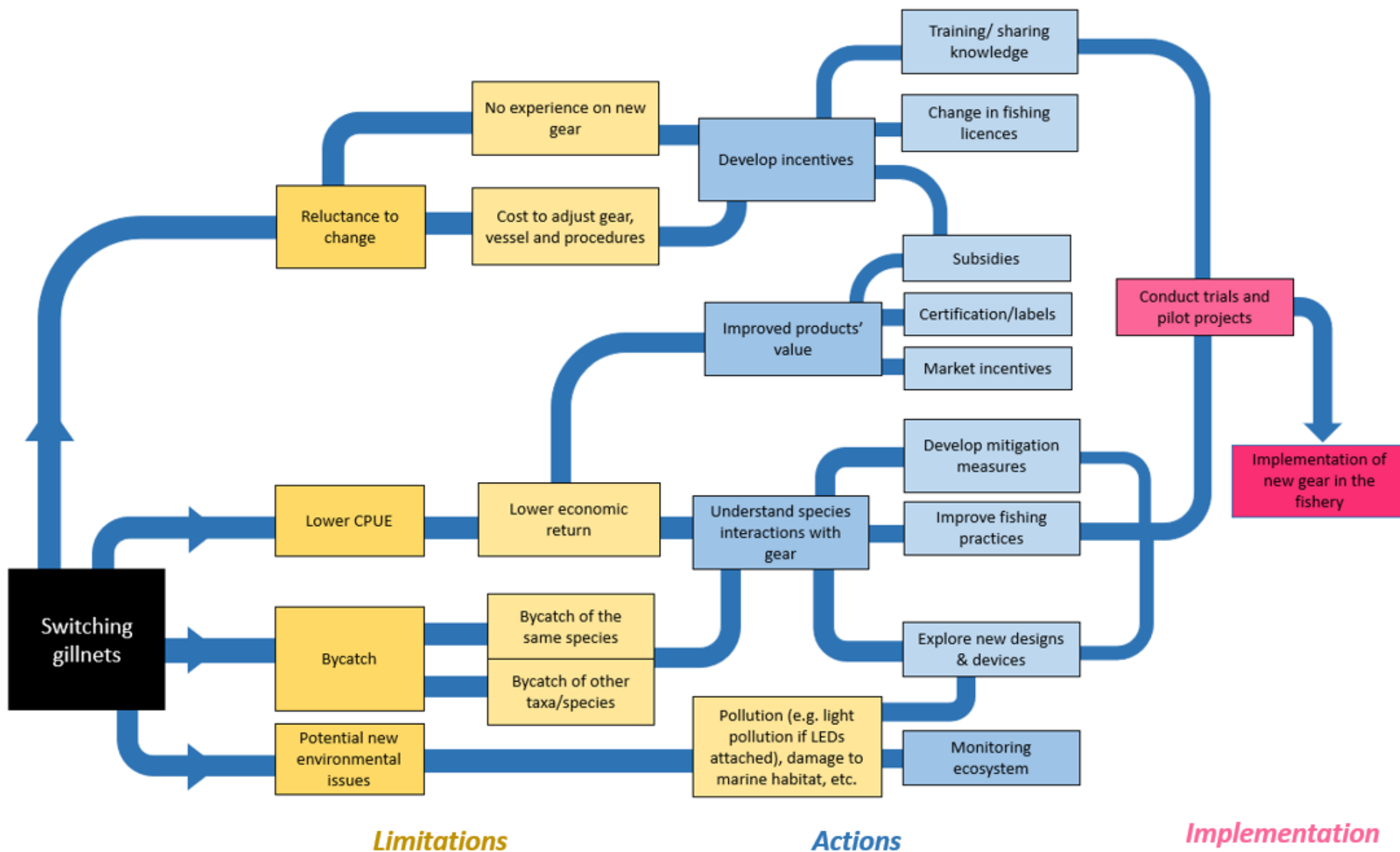
Session 4 - Social, economic & regulatory aspects of marine megafauna bycatch

Presentations:

A matter of perspective - Cooperation with fisheries and what it involves: experiences remote electronic motoring project Dutch commercial bottom-set gillnet fisheries

Marije Siemensma. Marine Science & Communication

People-centred approaches for reconciling trade-offs between fisheries & biodiversity

Hollie Booth, PhD. University of Oxford

Boat's don't fish, people do : about fishers' agency and the social practise of bycatch

Fanny Barz, PhD. Thünen institute

Seabird bycatch in Japan; lessons learnt working with small scale fisheries
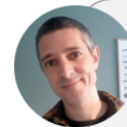
Yasuko Suzuki, PhD. BirdLife International

Contextualizing the coupled socio-ecological conditions of marine megafaunal bycatch

Ellen Hines, PhD. San Francisco State University

Socio-Economic considerations to shark bycatch in India

Trisha Gupta, PhD Oxford University & Divya Karnad, PhD Ashoka University

Monitoring Bycatch using video-based electronic monitoring

Gildas Glemarec, PhD. Danish National Institute of Aquatic Resources (DTU Aqua)

The Equitable and Least-cost Mitigation Hierarchy

Dale Squires, PhD. NOAA

In most fisheries, significant differences in the perception of bycatch between species and taxa exist. Bycatch can be normalized, usually when fishers are experiencing it relatively frequently and thus seen as part of the everyday life at sea (e.g. seabird bycatch in the Baltic sea) or from species of commercial or food security value (e.g. elasmobranchs in India). In contrast, bycatch can also be seen as a more "traumatic" event when bigger, often more charismatic, animals are involved (e.g. whale sharks), and overall, when bycaught animals are "humanized" by fishers (e.g. harbour porpoise calves being hauled onboard). Understanding how bycatch is perceived in a specific fishery is therefore essential to adapt and maximise conservation actions, and equally avoid counterproductive actions. It is particularly important for external actors, notably western NGOs, when setting up projects outside of their cultural spheres. Those local perceptions can be very context specific and deeply rooted in cultural and religious beliefs (e.g. how sea turtles and whale sharks can be perceived in some areas of India). In contrast, and even within their own taxa, some specific species can be negatively perceived by fishing communities, in general when they are seen as "competitors". In the north Atlantic, cormorants and seals are often considered as a nuisance and bycatch events even seen rather positively. For effective and long-term conservation actions on bycatch, it is therefore important to strengthen knowledge of the local context and associated cultural/spiritual aspects associated with marine megafauna in target fisheries. Gillnets are strongly linked to coastal and small-scale fisheries, which compared to industrialized fisheries, can create a deeper connection with the local environment. Utilising those specific connections would help create social licences and local support for bycatch mitigation actions.

In many areas of the world where any catches have commercial or food security value, the distinction between target and bycaught species is not well defined, if not entirely absent. Often situated in lower-income fisheries, where fisheries management capacity is low, an alternative approach to strict bycatch reduction legislations is needed, on top of greater government efforts in the longer term. In such conditions, raising awareness among fishing communities can prove fairly successful in reducing bycatch when backed with compensation schemes (e.g. financially supporting fishers to cut nets and release bycaught whale sharks) and with a focus on "practical" actions rather than top down approaches. Incorporating fisher's inputs and local knowledge into mitigation measure development is equally essential and increases uptake by fishers.

Fisher compensation to help tackle bycatch seems particularly important, yet this needs to be context specific and respect three conditions to achieve the best conservation outcomes. Their financing needs to 1) be sustainable (long term); 2) adapted to the situation with public (e.g. observer programmes) and/or private compensations (e.g. eco-labels) and 3) actually going to fishers. Incentives can take many forms – such as direct monetary compensation, "credit schemes" (in kind compensation), be market driven (e.g. effect of US Marine Mammal seafood import rules), but to be fully effective, fishers' perception that mitigation measures are mutually beneficial is particularly important; this perception can be strengthened through awareness and educative actions.

Ensuring compliance with bycatch legislation, where this exists, is another big challenge for gillnet fisheries around the globe. For relatively rare species of marine megafauna, estimated optimum observer coverage should range from 20 to 100% of the fleet's fishing effort to estimate bycatch, but reaching these targets for most small-scale gillnet fisheries is technically impossible (e.g. boats too small to have observers on board, observer programmes too expensive, etc.). Recent improvements with Remote Electronic Monitoring (REM) systems could, however, help tackle this issue (e.g. see Dutch[7] and Danish[8] REM case studies). Although further improvements are needed for REMs to be adapted to the smallest vessels, technology is continuously evolving and will soon be an important tool for bycatch and mitigation measure compliance monitoring. Promoting collaboration between conservationists, fishers, engineers, and regulators on REM deployment in key gillnet bycatch fisheries is an important objective.

Bycatch reduction is ultimately a site-specific problem, which requires an understanding of *how* and *why* interactions between marine megafauna and human activities occur. For this reason, inter-disciplinary frameworks - such as the "mitigation hierarchy"[9,10,11] - are crucial to support the design of bycatch mitigation interventions tailored to their specific context. Including environmental justice ("equity and fair division"[5]) in such interventions is also critical to ensure local distributive justice (considering those who can and cannot bear the economic burden of measures).

With the high-level variation in marine habitats, species, cultures, economic models, etc. between fisheries, it seems clear that holistic approaches are increasingly needed for the development of bycatch mitigation measures which fit their specific environment and context. Although local actions have primacy, there is also a clear need for improved international leadership pushing for initiatives around gillnet fisheries and the bycatch of marine megafauna, ensuring a collaborative platform for interdisciplinary and multi-taxa experts around the globe, to come up with innovative solutions to this global-yet-local issue.

[7] Scheidat, M., Couperus, B., & Siemensma, M. (2018). *Electronic monitoring of incidental bycatch of harbour porpoise (Phocoena phocoena) in the Dutch bottom set gillnet fishery (September 2013 to March 2017)* (No. C102/18). Wageningen Marine Research.

[8] Glemarec, G., Kindt-Larsen, L., Lundgaard, L. S., & Larsen, F. (2020). Assessing seabird bycatch in gillnet fisheries using electronic monitoring. *Biological Conservation*, *243*, 108461.

[9] Booth, H., Squires, D., & Milner-Gulland, E. J. (2020). The mitigation hierarchy for sharks: A risk-based framework for reconciling trade-offs between shark conservation and fisheries objectives. *Fish and Fisheries*, *21*(2), 269-289.

[10] Arlidge, W. N., Squires, D., Alfaro-Shigueto, J., Booth, H., Mangel, J. C., & Milner-Gulland, E. J. (2020). A mitigation hierarchy approach for managing sea turtle captures in small-scale fisheries. *Frontiers in Marine Science*, *7*, 49.

[11] Squires, D., Ballance, L. T., Dagorn, L., Dutton, P. H., & Lent, R. (2021). Mitigating Bycatch: Novel Insights to Multidisciplinary Approaches. *Frontiers in Marine Science*, *8*.

Presentations:

Assessing fishing intensity, resource dependency and marine traffic for small-scale fisheries in Mediterranean MPAs and IBAs

Robin Snape, PhD. University of Exeter

Seabird Maps and Information for Fisheries

Allison Anholt & David Wiedenfeld, PhD. American Bird Conservancy

Getting to the bottom of bycatch ; A toolbox to reduce bycatch of marine megafauna in developing countries

Ellen Hines, PhD, San Francisco State University & Gregg Verutes, PhD candidate. Universidade de Santiago de Compostela

Time-area fishing restrictions and gear-switching as solutions for reducing seabird bycatch in gillnet fisheries

Cate O'Keefe, PhD. Fishery Applications Consulting Teams

Modelling entanglement rates to estimate mortality of marine birds in BC commercial salmon gillnet fisheries

Douglas F. Bertram, PhD. Environment and Climate Change Canada

Participants identified a series of limits currently affecting the implementation of effective spatio-temporal measures in tackling marine megafauna bycatch from gillnet fisheries. They also suggested a series of potential actions for improvement.

"Effective measures are those that can be modified with changing conditions"

The static nature of many fishing restrictions – in both time and space - and the difficulty in delimiting the appropriate scale and scope of bycatch hotspots, have been identified as major limiting factors in the effectiveness of spatio-temporal measures, particularly in data-poor conditions. Once an area is managed or simply closed, there is also often a lack of follow up monitoring to assess if goals and objectives are met. Spatio-temporal measures should consider finer scale modelling and mapping, as well as a dynamic ocean management approach in their design and management (e.g. flexible areas). The bycatch dynamic occurring both inside and outside of those spatial measures (e.g. "spill over" effect and/or displacement effects) should be systematically integrated within management measures. Finally, there is a lot we can learn outside the marine megafauna realm, with more research examining the effect of spatio-temporal measures on fish bycatch, and if the unintended consequences really outweigh the bycatch mitigation benefits. This experience could directly benefit mitigation of megafauna bycatch impacts in gillnet fisheries.

"Understanding gillnet fisheries better is essential"

Monitoring megafauna bycatch and enforcing fishing restrictions is directly restricted by low capacity and resources within many gillnet fisheries. Bycatch monitoring options are too limited and often considered as too costly to be implemented (e.g. observer programmes are expensive). In the meantime, gathering reliable data on fishing effort and bycatch are essential to design effective spatio-temporal measures. Further research and adoption of Remote Electronic Monitoring (REM) technologies – such as cameras on board vessels and tracking devices – particularly adapted to small boats is a clear priority.

Low cost "off the shelf" technologies are increasingly being used and can help a subset of fleets, at a fraction of the cost of traditional monitoring programmes or even REM. In the meantime, other technologies, such as bycatch modelling approaches using limited data, have been developed (Bayesian

approach to estimate seabird bycatch in British Columbia[12], Canada) and could revolutionise bycatch management and better inform certification schemes (e.g. Marine Stewardship Council). Bycatch risk assessment tools and methods can also contribute in filling those information gaps, such as the *Bycatch Risk Assessment* (ByRA)[13] - an open- source GIS toolbox – which helps in characterizing bycatch risk based on animal distribution, fishing patterns, and interaction rates. Informative and collaborative platforms – such as the American Bird Conservancy Seabird Maps and Information for Fisheries[14] – can help support knowledge sharing and foster actions within the industry and regulators.

"Re-shaping political involvement and collaborations"

Fishery regulators are seen as often lacking awareness regarding megafauna bycatch, with many fisheries agencies having no mandate for non-commercial/non-targeted species. In national waters, inaction is seen as the result from political short-term thinking and unwillingness to regulate or cause financial harm, fearing political backlash. Areas beyond national jurisdictions are also seen as lacking comprehensive international management frameworks to implement and enforce mitigation measures. It is suggested that further international commitments on marine megafauna bycatch are vital to foster collaboration and gain support. Effort should particularly focus on regulators and the general public, to better acknowledge the bycatch issue and its impact on vulnerable species. Actions could follow examples from terrestrial based incentive schemes, incentivizing bottom-up approaches as well as adopting higher standards for seafood imports/exports (e.g. US Marine Mammal Protection Act). Aligning industry and conservation spheres (e.g. actors and tools), should also be a priority to foster collaboration.

"Better consideration of ecosystems and species specificities"

Lack of knowledge on the sensory, cognitive and behaviour ecology of many marine megafauna species prone to bycatch is seen as impeding – or at the very least slowing down - research towards effective mitigation measures. Species of interest are also rarely considered within their entire environment when it comes to bycatch mitigation, with an absence of consideration of cumulative and population level impacts from bycatch, as well as knock-on effects for other species (e.g. discard management measures negatively impacting other species). Less charismatic species and non-listed endangered species are also under-represented when it comes to mitigation actions and poorly supported by funding schemes.

Gillnet bycatch research should adopt holistic approaches whenever possible, integrating an ecosystem-based approach and extend efforts towards less-charismatic species and not only those which are iconic. Research should explore both individual, group and population ecologies to inform the best mitigation measures at the appropriate scale. Time area closures need to look at many scales, both spatial and ecological (e.g. MPAs off California are in strategically spaced networks, considering inclusion of shoreline topography, larval spawning areas of fish, etc.[15]). The design and implementation of spatio-temporal measures must adopt a multi-disciplinary approach to be effective and carefully balanced with what fishermen need.

"Socio-Economic considerations should not be overlooked"

Implementing spatio-temporal restrictions in fishing grounds is likely to have significant socio-economic consequences that need to be addressed fully. Lack of socio-economic equity as well as fear of change from fishing communities, among other concerns, should be particularly addressed during implementation phases. As a result, it is crucial to develop the right incentives for fishing communities and implement cost-effective measures to be viable in the long term. Those can be economic, such as

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[12] Bertram, D. F., Wilson, L., Charleton, K., Hedd, A., Robertson, G. J., Smith, J. L., ... & Song, X. J. (2021). Modelling entanglement rates to estimate mortality of marine birds in British Columbia commercial salmon gillnet fisheries. *Marine Environmental Research*, *166*, 105268.

[13] Hines, E., Ponnampalam, L. S., Junchompoo, C., Peter, C., Vu, L., Huynh, T., ... & Verutes, G. M. (2020). Getting to the bottom of bycatch: a GIS-based toolbox to assess the risk of marine mammal bycatch. *Endangered Species Research*, *42*, 37-57.

[14] https://www.fisheryandseabird.info/

[15] Murray, S., & Hee, T. T. (2019). A rising tide: California's ongoing commitment to monitoring, managing and enforcing its marine protected areas. *Ocean & Coastal Management*, *182*, 104920.

compensatory mechanisms, but should also explore the cultural and belief characteristics of the communities, to enhance social licence and the sense of ownership regarding the bycatch issue. Better understanding human behaviour from the target group (e.g. conservative vs opportunistic fishers) should help in implementing the most effective measures. In areas historically lacking fishery management measures, legislation, and enforcement, - as well as the recognition of fish stocks declining as a direct result - fishing communities have been seen as relatively open to collaborations in tackling fisheries bycatch.

Conclusion:

In addition to some of the more detailed actions developed in each session, attendees identified a series of overarching priority objectives to help tackle marine megafauna bycatch in global gillnet fisheries (Fig. 4). First, the need for a more pluri-disciplinary and multi-taxa approach to bycatch mitigation efforts, in opposition to current efforts which – for the most part – are seen as having a "siloed" approach to the problem (focusing on one taxa or species, in one area). Enhanced collaboration between experts, with open sharing of expertise, promotion of joint actions and peer-to-peer interactions (e.g. between fisheries experts) was recommended. Further, there was strong support for open access to data, including of negative results, to prevent duplication and enhance research synergy. Echoing these needs, attendees proposed the creation of an international platform – or consortium – to support large scale collaborations, communication, and uptake of measures. They identified an urgent need for global or at least regional structures - potentially in the frame of the United Nations Food and Agricultural Organisation – to scale up the global profile of megafauna bycatch from gillnets and to support public outreach and awareness campaigns. This structure should increase capacity at all levels (local to global) to monitor fisheries and implement solutions. Alongside scientists and fisheries stakeholders, this consortium should involve high-level government bodies – and aim to support various actions (e.g. observer programs, mitigation trials, etc.). There is a clear need to address widespread ignorance of the gillnet bycatch reality and take appropriate and equitable actions to tackle the problem as a matter of urgency.

Attendees suggest a stronger consideration of socio-cultural and economic realities should be made, to support realistic and long-lasting bycatch mitigation actions on the ground. Social science tools should be promoted in conservation projects involving fishing communities (e.g. anthropological surveys), integrating local knowledge and values to action plans. One proposal was to "stop talking about fishermen", but to bring them to the table and use their knowledge to give a sense check to ideas being put forward. It is recommended to use the examples of indigenous fisheries, for example in Canada, to further incorporate socio-cultural values to fisheries management globally.

Developing strong new incentives for fishing communities to collaborate and engage in bycatch mitigation actions is required, with economic and policy incentives working in synergy. It is recommended that engagement with regulators and fisheries is increased, bringing them into the discussion to promote cost-benefit analyses and consider trade-offs, and aim for geopolitical approaches - such as trans-national partnerships. Lack of bycatch data shouldn't be left as an excuse for inaction by local governments (both monitoring, and mitigation actions, can and should be promoted in synergy).

Research exploring sensory, cognitive and behaviour ecology of marine megafauna should be promoted and used systematically to inform bycatch mitigation measures. Better understanding species' behaviour in their local habitats is also crucial to tailor appropriate spatial and temporal mitigation measures and could be used to better adapt fisheries management.

Lack of information regarding global gillnet fishing effort is recognized as a major limiting factor for mitigation actions and prevents understanding the true scale of marine megafauna bycatch. All gillnet fisheries, irrespective of their size, should be appropriately monitored. Effort should be made to support

global best practices for bycatch data collection and innovative approaches (e.g. using smartphones, pocket size trackers, etc.). New technologies should be mobilized to fill this essential fishing effort knowledge gap for small-scale gillnet fisheries in particular; Remote Electronic Monitoring (REM) in particular could play a crucial role if costs are brought down and adapted to all fisheries, as well as GIS technology to help identify areas of greatest interactions.

Finally, participants recommended continuing to support research into technical means of bycatch mitigation. For example, advancing testing of LED lights to mitigate the bycatch of turtles, sharks and cetaceans across a broader range of fisheries and impacted species; advancing exploration of above-water deterrents to prevent birds becoming entangled in gillnets; and use of reflective nets (e.g. pearl-nets) to prevent cetacean bycatch. However, it is suggested that researchers should stop testing bycatch reduction techniques without proper validation from an ecological perspective established *a priori*.

Further research is needed for gear modifications, gear alternatives and the identification of attractants/deterrents to marine megafauna. Fish pots, traps or hook-&-line gears – which have shown potential as gillnet-alternatives in Baltic fisheries and globally – alongside spatio-temporal measures tailored to the specific local conditions (both ecological and socio-economic), should receive substantial financial support from government institutes and funders to be implemented in key bycatch hotspot fisheries; in particular where no other technical mitigation measures have proven effective at tackling gillnet bycatch.

All those efforts would help create a solid yet adaptative toolbox – or "palette" - of mitigation measures to mix and match in order to meet bycatch reduction objectives. Overall, it is suggested to foster an ambitious program to reduce the world's fisheries dependence on gillnets and further develop appropriate alternatives.

Fig 4 - Priority objectives to help tackle marine megafauna bycatch in global gillnet fisheries
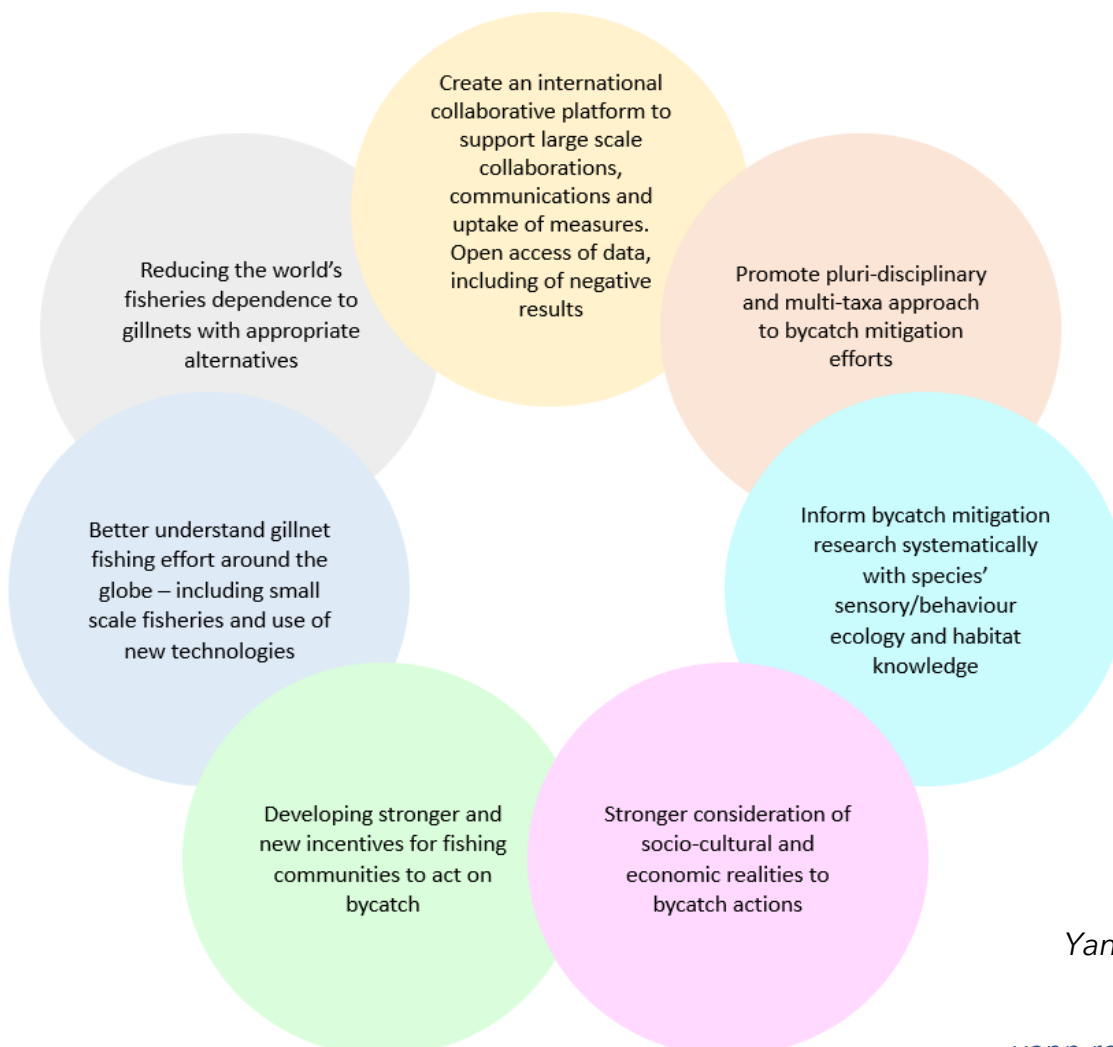
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