Acoustic discrimination in tropical tuna purse seine fisheries: state of the art, ongoing projects and future directions

***Ad Hoc* Working Group on FADs**
9th Meeting
La Jolla, California (USA)
28-29 May 2025

DOCUMENT FAD-09-RD-G

Moreno, G., Boyra, G., Uranga, J., Sobradillo, B., Lekanda, A., Martinez U., Cuevas, N., Sancristobal, I., Murua, H., Grande, M., Santiago J., Restrepo, V.

SUMMARY

This document provides an overview of the current state, challenges, and opportunities related to acoustic discrimination in tropical tuna purse seine fisheries. Acoustic discrimination, the ability to differentiate fish species based on their acoustic signatures, holds considerable promise for improving the selectivity of purse seine fishery and supporting fishery-independent abundance indices. A workshop with fishers and scientists revealed that, although scientific understanding and theory of tropical tuna species-specific acoustic responses is well understood , its practical implementation remains challenging . Current buoy models offer only limited species discrimination capabilities; however, newly developed echosounder buoy models with enhanced functionalities, such as double frequency, have recently been introduced to the market. Results of the fishers´ survey highlight buoy performance variability across oceans, fishing zones and brands. This report also documents ongoing international research efforts and capacity-building initiatives aimed at advancing discrimination capabilities and the development of catch-independent indices of abundance. Overall, results underscore the strategic value of acoustic technologies for sustainable tropical tuna management, while calling for continued research and coordination among science, fishing industry, and technology providers.

1 INTRODUCTION

Acoustic discrimination refers to the ability to distinguish between different species or groups of species based on the acoustic characteristics of the echoes they produce when insonified by an echosounder or sonar. This technique is used in fisheries science to support species identification and biomass estimates (Simmonds & MacLennan, 2005). Since the early 1970s, active acoustic methodologies have been systematically applied to survey the pelagic environment, enabling the estimation of fishery independent species-specific abundance indices, for direct integration into quantitative stock assessment frameworks. Additionally, these approaches have been instrumental in advancing fisheries science, particularly in understanding spatial distribution and behavior of pelagic species (Misund, 1997; Fernandes et al., 2002).

In tropical tuna purse seine fisheries, which often rely on Fish Aggregating Devices (FADs), acoustic discrimination is especially valuable. One of the key challenges in these fisheries is the ability to selectively target species in healthy stock condition, such as skipjack tuna (*Katsuwonus pelamis*), while minimizing catches of more vulnerable species like bigeye (*Thunnus obesus*) and yellowfin tuna (*Thunnus albacares*) when there is a need to protect them (IATTC 2024; ISSF 2025). These species frequently coexist under the FADs, and are captured together in a single set, making technological solutions essential for achieving selectivity (Dagorn et al., 2013; Fonteneau et al., 2013; Maunder et al., 2006; Moreno et al., 2019).

Recent advances in fishing technology have significantly transformed purse seine operations, particularly through the introduction of satellite-linked echosounder buoys that remotely estimate tuna biomass beneath FADs (Lopez et al., 2014). These buoys are used to plan fishing trips, locate tuna schools, and optimize catch efficiency (Itano, 2003; Gaertner et al., 2018; Moreno et al., 2019). In addition, these vessels are equipped with both long- and short-range sonar systems, as well as onboard echosounders working at different frequencies.

Scientific studies have shown that skipjack, which lacks a swimbladder, and bigeye, and yellowfin tunas, which possess one, exhibit markedly different acoustic responses at different frequencies: skipjack responds more strongly at higher frequencies (120–200 kHz), while bigeye shows stronger signals at lower frequencies (38 kHz) (Boyra et al., 2018; 2019). Yellowfin tuna, by contrast, display a more uniform response across frequencies (Sobradillo et al., 2024). This consistent contrast opens the possibility to develop multifrequency discrimination algorithms that can estimate species composition at FADs using purely acoustic data.

Beyond its value for selective fishing, acoustic discrimination also contributes to the development of catch-independent indices of abundance. These indices can inform stock assessments by providing independent data to complement catch-based indices (Baidai et al., 2024; Lopez et al., 2024; Capello et al., 2016; Uranga et al., 2024). In addition, acoustic methods can greatly support ecosystem-based fisheries management by providing high-resolution data on the spatial and temporal distribution of tuna and other trophic groups. Providing estimates of biomass, predator–prey interactions, and habitat use, which are essential inputs for ecosystem models. For example, acoustic surveys can track the vertical migrations of mesopelagic fish or detect changes in forage fish abundance for tuna linked to environmental variability, improving our understanding of ecosystem dynamics, thereby promoting the sustainability of tropical tuna fisheries (Bertrand et al., 2003; Brehmer et al., 2006; Tallis et al., 2010; Trenkel et al., 2011).

Scientific studies have established the theoretical basis for acoustic discrimination in tropical tuna fisheries, and empirical work has demonstrated that the differing acoustic responses of species, such as skipjack and bigeye, can be exploited for species identification under FADs (Boyra et al., 2018; 2019; Moreno et al., 2019; Sobradillo et al., 2024). However, the next critical steps lie in implementation: this scientific knowledge must be integrated into commercial acoustic equipment and, once this capability is available, it is essential that fishers interpret and apply the information appropriately in their decision-making processes.

Currently, buoy manufacturers are actively working to enhance species discrimination capabilities, aiming to provide fishers with more accurate species composition estimates. Nonetheless, the actual reliability of these outputs, and the extent to which fishers use them effectively and selectively is still uncertain and requires further investigation and validation.

2 OBJECTIVE

The objective of this paper is to provide an overview of the current state of acoustic discrimination in the tropical tuna purse seine fishery. It aims to highlight the value of acoustic discrimination for species identification and fishery management, identify ongoing projects worldwide and initiatives in this field, and emphasize the need to continue advancing research and development to fully harness its potential. In this context, AZTI and ISSF organized a workshop with the Spanish tropical tuna purse seine fleet in February 2025. The workshop had a dual purpose: first, to test a training curriculum being developed to transfer recent advances in acoustic technologies to tropical tuna fishers; and second, to assess whether the echosounder buoys currently used are capable of discriminating between different tuna species and between target and non-target species. We summarize in this paper the findings of the workshop.

3 ACOUSTIC DISCRIMINATION: A CHALLENGING SCIENCE

Interpreting acoustic signals in pelagic fisheries is inherently complex. The echoes received by echosounders are influenced by a multitude of factors, including species-specific morphology, fish size, orientation relative to the transducer, behavior (e.g., schooling density or alignment), depth, and environmental conditions such as thermocline depth or salinity gradients (Simmonds & MacLennan, 2005; Korneliussen, 2010). This multifactorial dependence complicates the interpretation of acoustic returns, especially in dynamic and heterogeneous FAD-associated aggregations.

Moreover, this challenge becomes even more complex in the context of acoustic buoys, which are subject to greater constraints. These devices rely on low-cost echosounders and must carry out species discrimination and biomass estimation autonomously, without human supervisión, before transmitting data via satellite. In fact, the question of whether echosounder buoys can reliably discriminate between tuna species, or between target species and non-target species, is currently subject to debate. The answer depends largely on the perspective of the stakeholder. Scientists, fishers, and buoy manufacturers each approach this issue from distinct angles, shaped by their respective priorities, tools, and how they generate and validate knowledge.

Scientists typically work with calibrated, research-grade acoustic equipment, and are well aware of the limitations and sources of uncertainty in acoustic data. They emphasize the need for simultaneous multifrequency data, calibrated equipments, standardized processing protocols, and independent validation in order to improve species-level discrimination (Boyra et al., 2018; Moreno et al., 2019). However, under the lens of the scientific method, researchers often strive for perfection, sometimes overlooking the need for practical and timely solutions in operational contexts. This pursuit of the ideal is sometimes not the best, and may lead us to forget that often *the best can be the enemy of the good*.

Fishers, on the other hand, rely heavily on empirical knowledge accumulated through extensive experience at sea. Their acoustic interpretations are informed by real-time observations of both catch composition and echograms during fishing operations. Over time, this leads to the development of tacit knowledge, non-formalized but highly operational expertise, based on thousands of observations of acoustic data in real-world conditions. Although this knowledge may lack the precision and validation of the scientific method and is potentially subject to bias, it offers a valuable perspective on the practical use of acoustic information. Such experiential insights can complement formal research by revealing patterns or interpretive cues that may not yet be captured by existing models or algorithms.

Buoy manufacturers possess in-depth technical expertise regarding their proprietary systems and are actively investing in the advancement of species discrimination capabilities. Ongoing efforts include the optimization of transducer frequencies, refinement of biomass estimation algorithms, and the integration of machine learning techniques to improve species-level classification. Their primary goal is to develop reliable and competitive tools that meet the operational needs of the fishing industry. However, due to the strong commercial competition among manufacturers and the naturally resulting lack of transparency in certain methodological aspects, the consistency and reliability of species discrimination performance remain uncertain.

In order to better understand the current state of acoustic species discrimination in tropical tuna fisheries, ISSF and AZTI organized a dedicated workshop and group exercise involving the Spanish purse seine fleet. The objective was to gather firsthand insights from fishers on the performance of the three most widely used echosounder buoy brands (i.e., *Zunibal*, *Marine Instruments* and *Satlink)* and to identify perceived strengths, weaknesses, and opportunities for improvement.

4 RESULTS FROM THE WORKSHOP ON ACOUSTIC DISCRIMINATION

The workshop was held in Spain on February 18, 2025, and brought together 42 stakeholders. Participants included 23 captains and navigators operating in the Indian, Pacific, and Atlantic Oceans; eight technicians and engineers from fishing companies, some of whom specialize in acoustic equipment used on board, while others focus on sustainability issues; one representative from the ANABAC fishing association; and eight scientists from AZTI, ISSF, and CLS (see Appendix I, for the list of attendees). Additionally, two representatives from Seapix, a manufacturer of acoustic equipment installed on the bridge of purse seiners, also attended. They were invited, along with Simrad, to provide insights into the capabilities of their current technologies. However, no representative from Simrad was able to attend. Buoy manufacturers were not invited to this workshop in order to facilitate open discussions among participants regarding the performance and capabilities of the different buoy models. We remain in regular contact with the three main buoy manufacturers, who were informed about the workshop and the rationale for not including them in this particular event. They expressed interest in the outcomes, and we will share the main results and conclusions with them.

Fishers have varying levels of expertise as a result of their own experience and interests: some have in-depth knowledge of net behavior, others specialize in tuna behavior, and some are experts in acoustics, etc. While some possess a strong understanding of acoustic data and are proficient at interpreting echograms, others have more limited experience with these tools. Similarly, attitudes among fishers vary, some individuals are highly confident in their interpretations, while others show more caution and acknowledge the limitations of their understanding.

To account for this variability and ensure productive discussions, participants were organized into working groups balanced in terms of acoustic knowledge and operational experience in a given ocean (see Appendix II for visual documentation of the workshop). This structure was designed to encourage peer-to-peer learning, foster dialogue, and maximize both the reliability and diversity of the feedback collected. Thus, fishers and technitians from the fishing industry were divided into four working groups of approximately 7–8 individuals. Scientists specialized in acoustics did not take part in the group discussions to ensure that responses from the fishing sector were genuine and uninfluenced. Groups 2 and 4 included fishers operating in the Indian Ocean, Group 1 in the Pacific Ocean, and Group 3 in both the Pacific and Indian Oceans. Each group was asked to respond to a structured set of questions concerning the species discrimination capabilities of the echosounder buoys they regularly use. The main results of the workshop are summarized below:

- **Q1: Do acoustic buoys discriminate bycatch from tuna?** Responses from fishers indicated that current buoy technologies exhibit limited capability in automatically discriminating bycatch from target tuna species. In the Pacific Ocean (Group 1), partial discrimination is reported for Zunibal and Marine Instruments, though effectiveness is described as insufficient. Satlink buoys received slightly more favorable assessments, yet still require further improvement. In the Indian Ocean (Group 2), fishers consistently reported that discrimination is not performed by the buoy itself but is instead reliant on user interpretation of the acoustic data. Groups operating across both the Pacific and Indian Oceans (Group 3) reinforce this observation, noting that species identification is based primarily on subjective analysis of echogram characteristics rather than explicit outputs from the buoy. Preliminary feedback from one group working with newer models in the Indian Ocean (Group 4) suggested potential improvements in discrimination capabilities with specific devices, such as Marine Instruments' M3iGo and Satlink's ISD; however, these impressions were inconclusive, as participants indicated they still needed more experience with the equipment to draw firm conclusions.Overall, current buoy systems across brands and regions do not provide reliable autonomous discrimination between tuna and bycatch, with greater dependence on operator expertise particularly evident in the Indian Ocean.

- **Q2: Do acoustic buoys discriminate skipjack from yellowfin and bigeye?** Reports from fishers across operational regions indicate that buoys currently offer limited functional discrimination between skipjack and the other major tropical tuna species (yellowfin and bigeye tuna). In the Pacific Ocean (Group 1), although all buoy brands (Zunibal, Marine Instruments, and Satlink) report having some level of discrimination capabilities, yet fishers consistently state that such discrimination is not evident in practice. In the Indian Ocean (Group 2), Zunibal buoys were reported as unable to distinguish between species, while Satlink was perceived to offer partial discrimination, though reliability was rated as low. Similar feedback is observed in the Pacific/Indian group (Group 3), where fishers reported that, although species discrimination is theoretically claimed by the manufacturers, it is not evident in operational contexts. In Group 4, operating in the Indian Ocean too, only Satlink's ISD+ model was considered to offer this capability to some extent, while the SLX+ model was reported as unreliable in species discrimination. Overall, current buoy systems do not consistently support reliable discrimination of skipjack from yellowfin and bigeye under field conditions, regardless of brand or region. However, some fishers considered Satlink brand to offer partial discrimination.

- **Q3: Do acoustic buoys discriminate yellowfin from bigeye?** According to fishers' assessments, current buoy technologies show no consistent or operationally reliable capacity to distinguish yellowfin from bigeye tuna. In the Pacific Ocean (Group 1), fishers stated acosutic buoys do not discriminate yellowfin from bigeye tuna. Similar conclusions were reported in the Indian Ocean (Group 2), where both Zunibal and Satlink buoys were regarded as unable to differentiate between the two species. In the Pacific/Indian group (Group 3), the same conclusion was reiterated: no discrimination is detected, regardless of brand. In the case of Group 4, fishers indicated that Satlink's ISD+ model theoretically offers this functionality, but they had not observed it in practice. Overall, the data suggest that none of the buoy systems currently provide effective or observable discrimination between yellowfin and bigeye tuna under real-world fishing conditions.

- **Q4: Do acoustic buoys work the same in different zones within an ocean?** Fishers consistently reported that the performance of a given buoy model varies across different areas within the same ocean, and that each buoy brand also responds differently depending on local environmental conditions. Across all regions and buoy brands, respondents indicated that acoustic detection and data reliability vary with geographic location. In the Pacific Ocean (Group 1), all buoy types (Zunibal, Marine Instruments, Satlink) were considered to perform differently across zones. In the Indian Ocean (Group 2), the same conclusion was reached, with no buoy demonstrating stable performance across different areas. The Pacific/Indian group (Group 3) added that differences in buoy performance are often linked to specific oceanographic conditions: for instance, Marine Instruments was reported to perform better in areas with a strong thermocline, while Satlink buoys performed better when the thermocline is deeper. Group 4 reported that Marine Instruments and Satlink also exhibit inconsistent performance across zones. In conclusion, intra-ocean performance variability is a widespread issue observed across all buoy brands.

- **Q5: Up to what depth are reliable acoustic buoys?** Overall, the data suggest that buoy depth reliability typically falls within the 100–130 meter range, with slight variations depending on brand and oceanographic conditions**.**

- **Q6. Does plankton cover the tuna image in acoustic buoys?** Plankton interference is reported primarily in the Pacific Ocean, where all buoy brands are affected, especially at night. In contrast, no interference is reported in the Indian Ocean.

- **Q7. Are acoustic buoys comparable in terms of biomass estimation?** Perceptions regarding the comparability of buoy-based biomass estimates varied across regions. While Group 2 (Indian Ocean) reported that buoys provide comparable biomass data, Group 1 (Pacific Ocean) disagreed. Groups 3 and 4 either did not respond or provided inconclusive answers. Overall, there is no consistent conclusion across groups, indicating uncertainty or limited consensus on the comparability of biomass estimations across buoy systems.

- **Q8. What would you like to change/improve about the acoustic buoys?** Most fishers emphasized the need to improve species discrimination, particularly the ability to differentiate tuna from bycatch. This was consistently mentioned by Group 1 (Pacific) and reinforced by Group 3 (Pacific/Indian), who also highlighted the need for greater reliability. Group 2 (Indian Ocean) focused primarily on enhancing reliability, while Group 4 suggested improvements in data accuracy and the addition of direct vessel communication features. Overall, the primary priorities across regions were improved discrimination capabilities and increased operational reliability.

5 DISCUSSION

Across the four groups surveyed, there was broad recognition of the utility of acoustic buoys as operational tools; however, current systems were perceived to have significant limitations in species-level discrimination. The most frequently cited improvement need pertains to enhanced acoustic discrimination, particularly the capacity to distinguish target tuna species from bycatch and among tuna species themselves. Several respondents also emphasized the importance of improving the overall reliability of acoustic outputs. These findings suggest that advancing buoy performance will require a multidisciplinary effort, including closer collaboration between buoy manufacturers and fishers to align technological capabilities with operational needs.

Some of the results led to the following point of discussion regarding the future use of acoustics for selective fishing and to support fisheries management through species-specific indices of abundance:

On selective fishing:

- *Integration of Scientific Knowledge into Commercial Buoy Systems:*
  Recent developments by buoy manufacturers increasingly incorporate findings from scientific research on tropical tuna species, including collaborative efforts with research institutions and universities. Nonetheless, the operational implementation of this knowledge into cost-effective buoy platforms, typically constrained by the absence of advanced features such as split-beam transducers, continues to present substantial technical challenges. Despite these constraints, there is considerable potential for improvement. Integrating data on fish behaviour and school morphology with artificial intelligence (AI) holds promise for enhancing species-level classification, as demonstrated in previous applications targeting anchovy and sardine discrimination (Lekanda et al., 2024). Notably, some buoy manufacturers have already initiated the integration of AI-based processing into their systems. In the near future acoustic data may be presented in probabilistic terms (e.g., likelihood of a certain species presence), and they will probably be contextualised using knowledge of fish behaviour, fishing zone, school morphology, and aggregation dynamics.

- *Adoption Curve and Transition Time for New Technologies*:
  The fishers stated "*some of the new buoys seem to offer improved discrimination, but they still need to be tested*". Certain recently introduced buoy models exhibit promising technical capabilities. However, effective adoption in operational settings requires a transition period during which fishers can become familiar with the interpretation of acoustic outputs. As with any new technological tool, unlocking its full potential depends on sufficient time for user training and hands-on experience to develop proficiency in interpreting the data these new systems provide.

- *On the ability to discriminate size*:
  The issue of size composition was not raised by fishers, and it was not discussed. However, it remains a relevant topic for future exploration, particularly given its implications for selective fishing.

- *Incentives for the use of acoustic discrimination:*
  A key recommendation from fishers was to improve the ability of buoys to clearly distinguish non-tuna species from tuna. The primary motivation is operational efficiency: unnecessary travel to FADs dominated by bycatch

represents a cost in fuel and time. Beyond economic drivers, regulatory mechanisms such as species-specific quota management may further encourage the adoption of selective acoustic technologies. It is worth noting that both echosounder buoys and sonar systems installed on purse seiner bridges are of scientific-grade quality. While some manufacturers of these systems have been approached to improve species discrimination capabilities, dominant suppliers, already holding a substantial market share, have shown limited interest in investing in such enhancements, likely due to continued strong sales of existing models. In contrast, smaller or emerging manufacturers have expressed greater willingness to innovate in this area, viewing improved discrimination performance as a competitive advantage. In this context, increased demand from fishers for more selective tools may serve as a critical driver to incentivize further development among equipment providers.

On the development of indices of abundance:

- *Spatial variability in buoy performance*:
  Differences in buoy performance across fishing zones, even within the same brand and buoy model, were identified as a critical issue. This spatial heterogeneity may introduce biases or noise into biomass estimates derived from acoustic buoys, thereby affecting the robustness of abundance indices. Identifying ocean regions where signal responses are more homogeneous could facilitate model stratification and improve calibration procedures. Incorporating environmental and spatial variability explicitly into estimation models would be desirable to mitigate these effects.

- *Standardization across buoy brands and models*:
  Different buoy manufacturers employ distinct algorithms to convert acoustic signals into biomass estimates. This lack of standardization limits comparability and complicates the integration of data across fleets using different technologies. Intercalibration efforts among buoy models and brands would contribute to more consistent and standardized biomass estimates, thus strengthening the reliability and interoperability of indices derived from multiple sources.

- *Cross-referencing acoustic data with catch data*:
  It is essential to continue developing approaches that integrate acoustic buoy data with corresponding catch data. This cross-referencing is fundamental to understanding the variability inherent in acoustic readings and their relationship to actual fishing outcomes. Such integration not only enhances the interpretability of the data but also provides a basis for developing correction factors or probabilistic frameworks to better account for variability and improve the reliability of acoustic biomass abundance indicators.

On the study of tuna dynamics and the environment that supports them:

- *Tuna dynamics at FADs*:
  Acoustic buoys typically provide data limited to the upper ~130 meters of the water column. This represents only a partial view of the vertical habitat used by tropical tunas, which are known to exploit deeper layers, as demonstrated by vertical movement studies (e.g., Aldana-Flores et al., 2018). However, skipjack, as well as Age I and II bigeye and yellowfin tuna, which are generally the size classes most commonly associated with FADs, tend to exhibit a more constrained vertical distribution when aggregated under FADs, typically remaining within the upper 130 meters of the water column (Forget et al., 2015; Schaefer & Fuller, 2013).Therefore, echosounder buoys could offer valuable insights into how different tuna species interact with FADs across regions, contributing to a better understanding of spatial and behavioral dynamics and thus fisheries management. Tagging experiments using acoustic tags to obtain simultaneous data on individual tuna at FADs, specifically their vertical behavior in relation to echosounder buoy readings, will be of particular interest. This knowledge remains a shared challenge for scientists, fishers, and managers (Dupaix et al., 2024; Moreno et al., 2015).

- *Plankton detection and ecosysstem indicators:*
  While plankton is detectable by buoys and may interfere with the clarity of fish signals, most systems incorporate filtering algorithms designed to mitigate this interference. Importantly, acoustic detection of plankton may provide useful information beyond noise reduction: it can serve to monitor prey availability and a set of ecosystem indicators, such as spatial and temporal tuna-prey interaction. Developing environmental indicators from echosounder buoy data would represent a valuable advancement, not only to better understand the environmental drivers of tuna aggregation at FADs, but also to monitor ecological shifts under ongoing climate change scenarios (Bertrand et al., 2003; Trenkel et al., 2011).

6 ONGOING RESEARCH ON ACOUSTIC DISCRIMINATION OF TROPICAL TUNA SPECIES

In other regional fisheries organizations, some of which have a management mandate while others focus solely on scientific advice, the use of acoustics are central in biomass estimation and spatial distribution of species. For instance, the International Council for the Exploration of the Sea (ICES) is a global leader in using acoustic methods for the assessment of pelagic species such as herring, mackerel, anchovy, and blue whiting. There are relevant working groups on acoustics such as the Working Group on Fisheries Acoustic, Science and Technology, focusing on acoustic methodologies, calibration and technology developments. In the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), acoustic methods are crucial for assessing Antartic Krill.

These institutions began working with acoustics as far back as the 1960s, while studies on tropical tuna´s acoustic discrimination, only started around a decade ago. The use of echosounder buoys attached to dFADs in IATTC, ICCAT, WCPFC, and IOTC, represents one of the most extensive acoustic sampling network in tropical oceans. These buoys provide near-continuous, geo-referenced acoustic biomass data on tuna aggregations and other non-tuna species, across vast spatial and temporal scales, offering an unprecedented opportunity to monitor biomass dynamics, spatial distribution, and behavioral patterns in near real-time. This potential needs to be unlocked, and doing so will require continued research in this field.

Current research projects on tropical tuna acoustics known to the authors are listed below. We acknowledge that other relevant studies may exist and apologize for any omissions, as the present overview is limited to the authors' knowledge of ongoing or published work on acoustic properties and species discrimination in tropical tunas:

6.1 Advancing tropical tuna´s acoustic discrimination

Multiple institutions and buoy manufacturers are currently engaged in initiatives aimed at improving the tropical tuna acoustic discrimination. These efforts include both technological upgrades and capacity-building initiatives targeting end users:

- **AZTI, ISSF, and Buoy Manufacturers (Spain)**
  Collaborative projects are underway between AZTI, ISSF, and three buoy manufacturing companies to enhance the species discrimination performance of the buoys.
- **Ocean University of Shanghai (China)**
  Researchers led by Jianfeng Tong are conducting studies on acoustic discrimination of tropical tuna species.
- **Marine Fisheries Research and Development Center (JAMARC) (Japan)** Oshima et al. have been working on the acoustic characterization of tropical tunas in cages.
- **Faculty of Fisheries and Marine Science, at the Department of Marine Science and Technology (Indonesia)** Islaminingdiah et al. are also contributing to the field through research on the differentiation of acoustic signals among tuna species.
- **ISSF and AZTI – Training Initiatives (Spain)** In parallel, ISSF and AZTI are co-developing a training curriculum to disseminate the latest research findings to fishers and to strengthen their interpretation skills regarding acoustic discrimination.

Many other countries possess extensive expertise in acoustic science. For instance, Peru has significant experience in acoustic research through long-standing work on anchoveta (*Engraulis ringens*). Although these efforts focus on non-tuna species, such researchers represent a valuable potential resource for future collaborations on tropical tunas.

6.2 **Development of Indices of abundance**

- **AZTI and IATTC (Spain, USA)**
  Collaborative work is being carried out to derive biomass indices of tropical tunas in the Eastern Pacific Ocean using data from echosounder buoys (Uranga et al., 2024).

- **AZTI** is working to derive biomass indices of tropical tunas in the Atlantic and Indian Ocean using data from echosounder buoys (Uranga et al., 2024).

- **Institut de recherche pour le développement (IRD) (France)**
  Using French fleets data IRD is working on the use of echounder buoys to asess tuna abundance (Baidai et al., 2024, Capello et al., 2016)

Although research on acoustic discrimination and the use of echosounder buoys for abundance estimation is relatively recent, the growing interest and ongoing initiatives reflect the potential of these tools to contribute to more selective and sustainable tropical tuna fisheries. Strengthening collaboration among research institutions, fisheries scientists, fishing industry and technology providers is essential to accelerate progress.

7 CONCLUSIONS

While recent years have seen promising advances in the field of acoustic tuna discrimination and biomass estimation, results from the present study highlight that current echosounder buoy systems remain limited in their ability to reliably distinguish tropical tuna species or provide standardized biomass outputs across regions. Nonetheless, there is strong evidence of growing scientific, technological, and operational engagement across institutions, fishers, scientists, and manufacturers, all bringing complementary perspectives and expertise to this field, and their collaboration is critical to unlock the full potential of acoustic tools.

As with many scientific innovations, implementation requires time, iterative improvement, and sustained support. In the context of tropical tuna fisheries management, we must avoid focusing solely on short-term pressures and difficulties at the expense of long-term vision. The development of new observation systems, methodologies, and environmental indicators is essential to adapt to ecological changes and to support more selective, adaptive, and ecosystem-based fisheries management. Maintaining this strategic focus on innovation will allow us to prepare and respond to future challenges.

8 RECOMMENDATIONS FOR TUNA RFMOs

- Ensure access to echosounder buoys´ historical acoustic data, as these datasets are essential to understand long-term trends, and support model development for indices of abundance.
- Continue investing in acoustic research, particularly in the transformation of acoustic signal into biomass, with a special focus on the use of artificial intelligence to improve tuna species discrimination.
- Support interdisciplinary collaboration, combining expertise in fisheries science, acoustics, and fish behaviour to maximize the value of acoustic data to progress towards a more selective fishing.

Acknowledgements

We would like to thank the Spanish fishers and shipowners from OPAGAC and ANABAC for their valuable participation and insights during the workshop. We also acknowledge the support of the Food and Agriculture Organization of the United Nations (FAO), Common Oceans Tuna Project and other funders. Finally, Ekoetxea Urdaibai (Torre Madariaga) for providing logistical support.

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Appendix I. Workshop attendee list

ID	Name and surname	Position*	Company
1	Ander Bustinza	Deck supervisor	Inpesca
2	Jon Ander Garcia	Captain	Inpesca
3	Jose Felix Intxausti	Captain	Inpesca
4	Josebe Erdaide	Quality manager (Office)	Inpesca
5	Jon Martinez	Technitian (Office)	Pevasa
6	Iker Garai Fernandez	Captain	Albacora
7	Aitor Santiago Ortega	Fishing Master	Albacora
8	Arkaitx Basabe Abaroa	Navigator	Albacora
9	Xabier Larrocea Beitia	Fishing Master	Albacora
10	Iosu Arana Iñarra	Captain	Albacora
11	Francisco Javier Azkaray Oleaga	Fishing Master	Albacora
12	Julen Barainka Amillategi	Navigator	Albacora
13	Gorka Abasolo Toja	Captain	Albacora
14	Jon Pino Basabe	Navigator	Albacora
15	Markel Andikoetxea Arriaga	Navigator	Albacora
16	Unai Reinoso Isasi	Captain	Albacora
17	Josu Bilbao Gabancho	Fishing master	Albacora
18	Aitor Urquidi Saguri	Fishing master	Albacora
19	Jose Manuel Gabantxo Basabe	Fishing master	Albacora
20	Mikel Martin García	Navigation officer	Albacora
21	Julen Kortazar Gaubeka	Fishing Master	Albacora
22	Aitor Roman Santiago	Navigator	Albacora
23	Alexander Basterrechea Lozano	Electronics Technician (Office)	Albacora
24	Jone Mujika Mujika	Electronics Technician (Office)	Albacora
25	Iratxe Díaz Zarate	Biologist (Office)	Albacora
26	Asier Agote Fradua	Fishing Master	Calvo
27	Patxi Artechevarria Cearreta	Fishing Master	Calvo
28	Luis Enrique Castillo Palomino	Captain	Calvo
29	Ane Iriondo	Scientist (Fishing company Office)	Echebastar
30	Mikel Monasterio	Technitian (Office)	Echebastar
31	Andoni Garabieta	Technitian (Office)	Atunsa
32	Nekane Alkorriz	Scientist (Fishing company Office)	Anabac
33	Jon Uranga	Scientist	Azti
34	Guillermo Boyra	Scientist	Azti

ID	Name and surname	Position*	Company
35	Beatriz Sobradillo	Scientist	Azti
36	Udane Martinez	Scientist	Azti
37	Nagore Cuevas	Scientist	Azti
38	Gala Moreno	Scientist	ISSF
39	Aitor Lekanda	Scientist	Azti
40	Igor Sancristobal	Scientist	CLS
41	Patrick Scheneider	Manufacturer	Seapix
42	Christophe Corbieres	Manufacturer	Seapix

*Note that on the spanish purse-seiners, the licensed captain is in charge of administrateive paper work and offloading operations and assits in fishing operations but remains secondary to the fishing master, who directs all fishing operations and the overall vessel movements. The navigator is the third-ranking officer on the bridge, supporting both the captain and the fishing master with paperwork and fishing-related tasks. (Moreno et al., 2007).

Appendix II. Visual documentation of the workshop


ISSF / Nando Rivero


ISSF / Nando Rivero


ISSF / NANDO RIVERO


ISSF / Nando Rivero