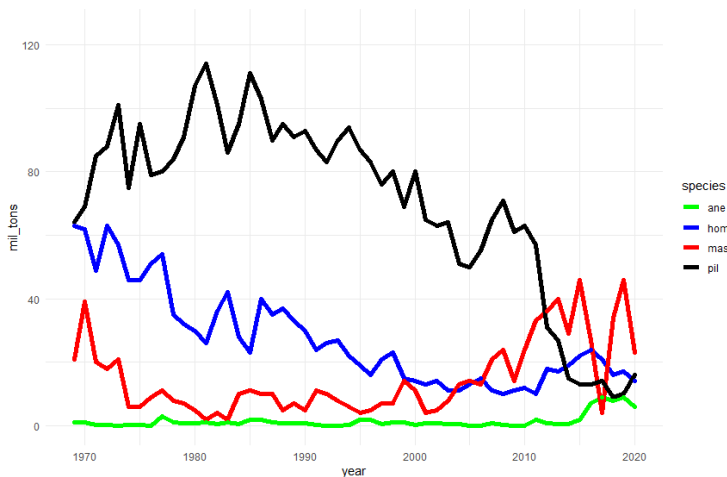


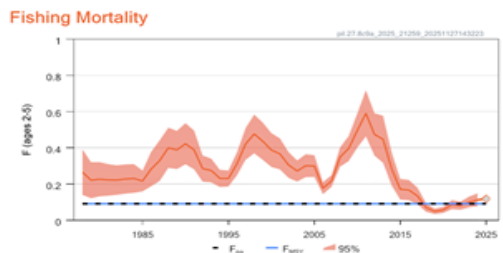
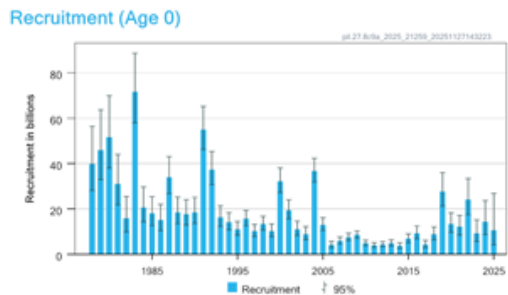
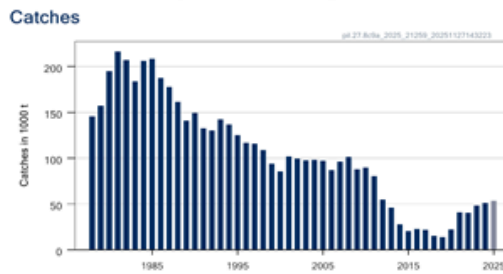
Susana Garrido



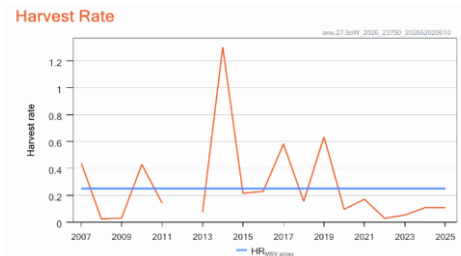
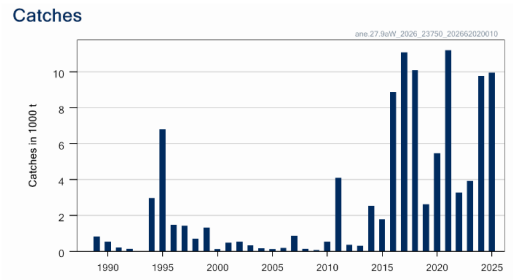
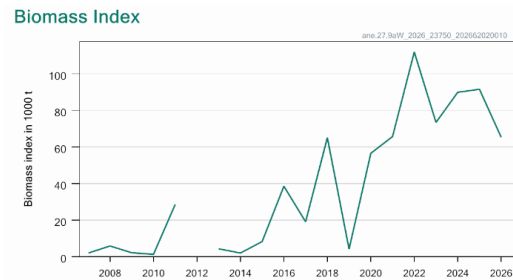
Small Pelagic Fish: Research and Management Priorities



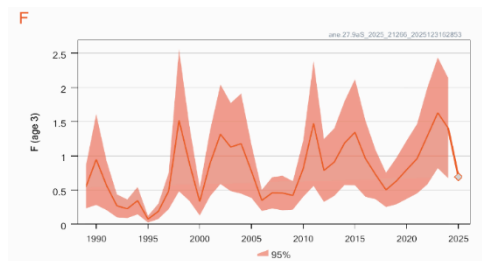
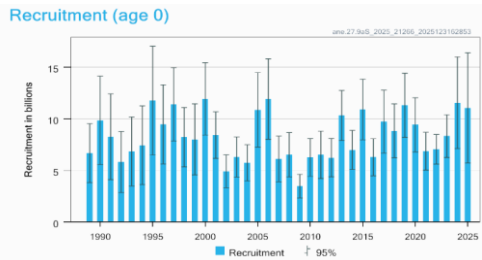
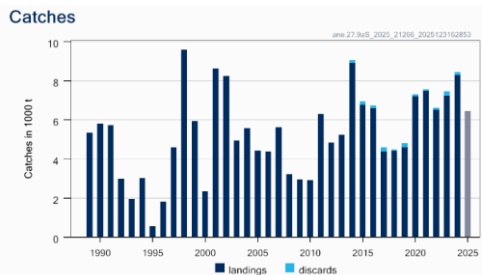
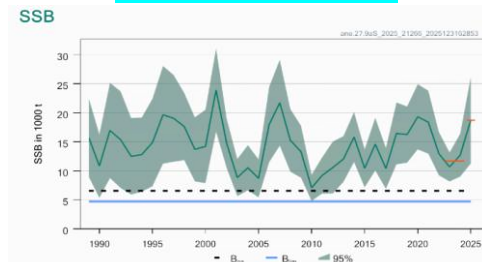
SARDINE 8c9a



ANCHOVY 9aW



ANCHOVY 9aS



Small Pelagic Fish: Research and Management Priorities

Research questions driving our work

1

What drives SPF variability?

Environmental drivers of interannual changes in abundance, recruitment and distribution.



2

How are climate change and extreme events affecting SPF?

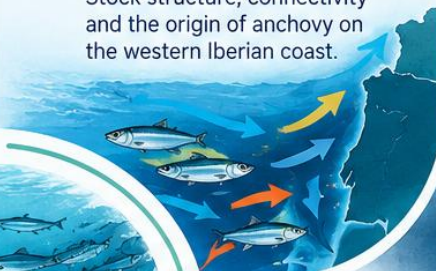
Warming, marine extremes, phenology and productivity.



3

Where are stock boundaries – and where do the fish come from?

Stock structure, connectivity and the origin of anchovy on the western Iberian coast.



4

How can we improve SPF assessment and management?

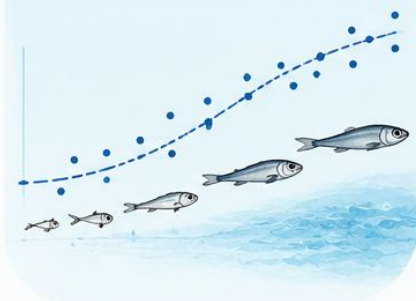
Better knowledge, better data and innovative management approaches.



5

Can we improve assessment of data-limited stocks?

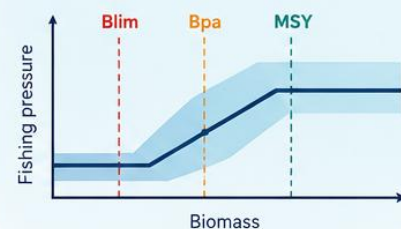
Developing new methods for anchovy assessment.



6

How can we design more robust management rules?

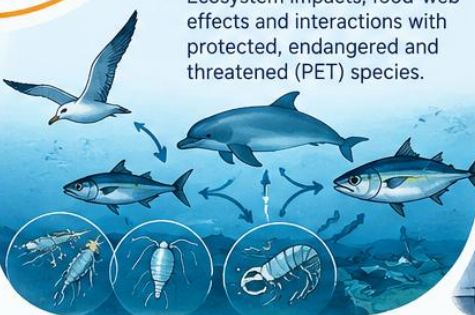
Developing and testing new HCRs for the Iberian sardine Management Plan.



7

What information is needed for sustainable fisheries certification?

Ecosystem impacts, food-web effects and interactions with protected, endangered and threatened (PET) species.



8

How can international collaboration improve SPF science and management globally?

Sharing data, methods, expertise and management experiences.



IMPROVE KNOWLEDGE

From environment to ecosystems



IMPROVE ASSESSMENT

Better data and methods



IMPROVE MANAGEMENT

Sustainable fisheries and healthy oceans

Small Pelagic Fish: Research and Management Priorities

Talk:

1 – SPF research at IPMA (Portugal) – Project SARDINHA2030



2 – ICES/ PICES Working Group on Sustainable Pelagic Forage Communities (WGSPF)



Small Pelagic Fish: Research and Management Priorities



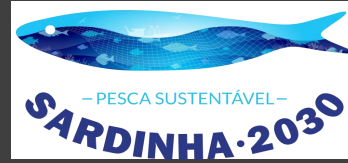
SARDINHA2030 – Stage 1: 2024-2025

SARDINHA2030 – Stage 2: 2025-2027

Objective
Conduct research to better understand and predict pressures and impacts on the pelagic ecosystem, supporting the sustainability and resilience of purse-seine fisheries, the restoration of pelagic habitat biodiversity, and the sustainable optimisation of resource exploitation, while considering the sector’s economic profitability.



Activity 2 - Knowledge transfer with the fishing sector



T1. Promote outreach activities with the fishing sector, the administration and the general public

Meetings within the framework of the Sardine Commission and with fisherman to disseminate the App.

T2. Engagement with the sector in the development of management rules for the purse-seine fishery

Identify and test sustainable management strategies for the ecosystem that are robust to system uncertainties through a Management Strategy Evaluation (MSE) process (Action 12)

T3. Implementation of a pilot project for data collection by the fishing sector

Improving information on fishing effort and bycatch of sensitive species (marine mammals, seabirds and reptiles) with the collaboration of fisherman (CCMAR/SPEA)



Activity 3 – Physical environment and productivity



T1. Identify the environmental variables and oceanographic processes most relevant to the biology, distribution, abundance, and recruitment of small pelagic fish.

Science of the Total Environment 881 (2023) 163421

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journal homepage: www.elsevier.com/locate/scitotenv

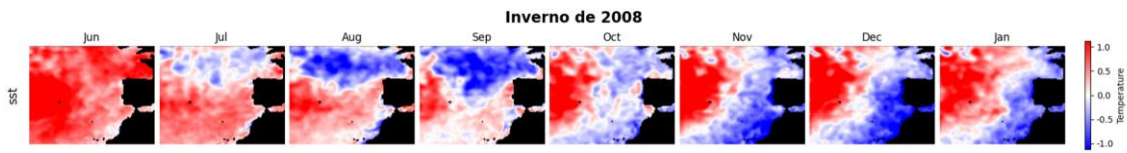
ELSEVIER

Science of the Total Environment

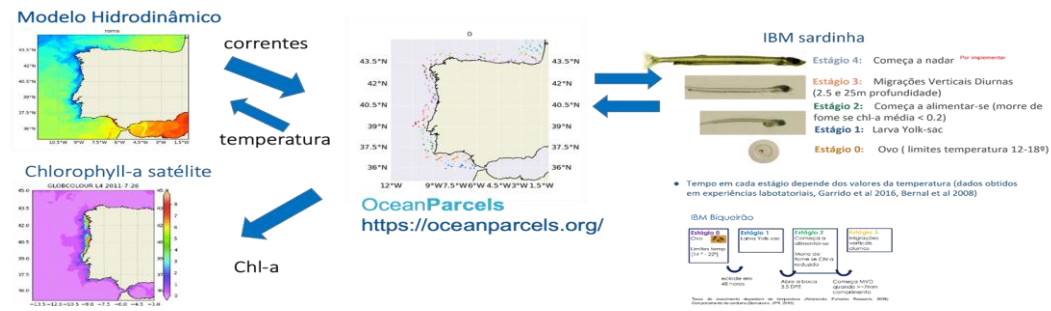
What drives the recruitment of European sardine in Atlanto-Iberian waters (SW Europe)? Insights from a 22-year analysis

Afonso Ferreira ^{a,*}, Susana Garrido ^{a,b}, José Lino Costa ^a, Ana Teles-Machado ^{b,c}, Vanda Brotas ^{a,d}, Ana C. Brito ^{a,d}

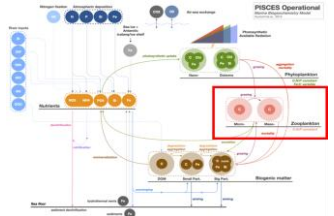
Check for updates



T2. Lagrangian simulations coupled with individual-based models of sardine and anchovy



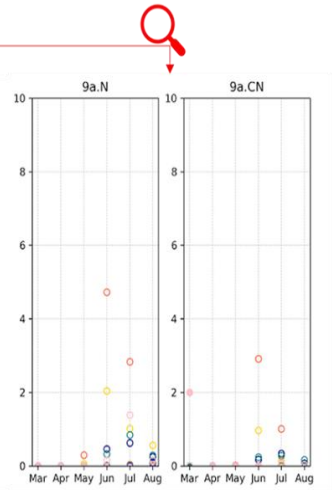
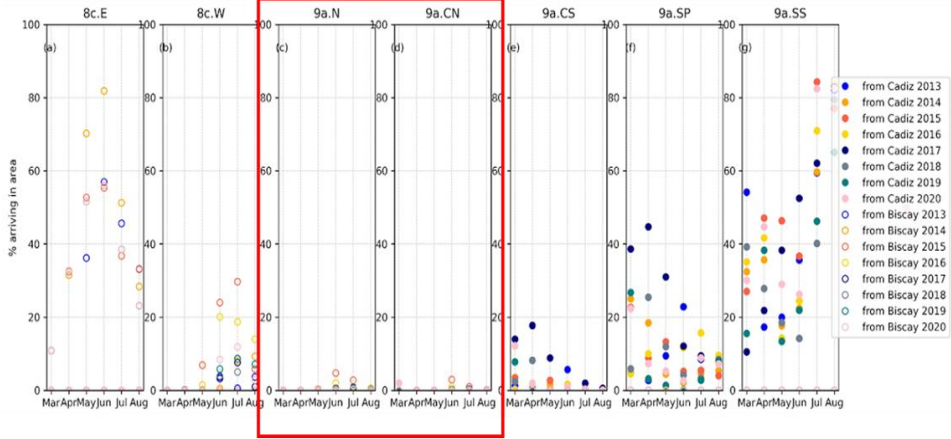
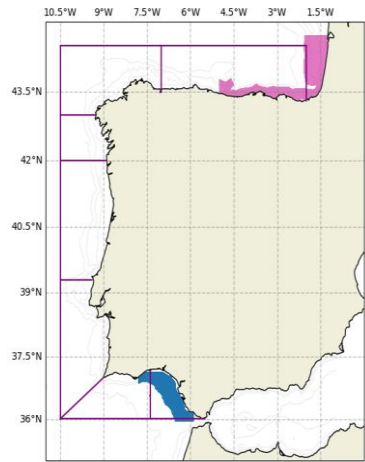
T3. Implement a biogeochemical model coupled with the CROCO regional ocean model for the Iberian coast



Activity 4 – Natural Mortality



T1. Investigate interannual variability in sardine and anchovy egg and larval mortality using IBMs



T2. Investigate the effects of anthropogenic pollutants on pelagic fish mortality

LIMNOLOGY AND OCEANOGRAPHY
Letters

SPECIAL ISSUE-LETTER

Microplastic ingestion and diet composition of planktivorous fish

Clara Lopes ^{1,*}, Joana Raimundo ¹, Miguel Caetano ¹, Susana Garrido ^{1,2}

¹IPMA - Portuguese Institute of Sea and Atmosphere, Lisbon, Portugal
Centre, Faculdade de Ciências, Universidade de Lisboa Campo Gra

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doi: 10.1002/lno.1144

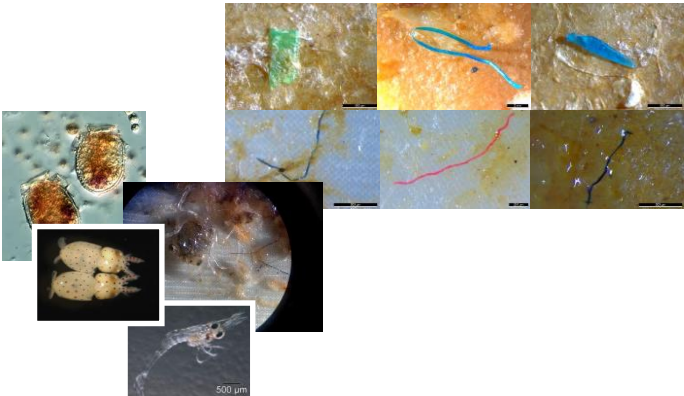
Science of the Total Environment 901 (2023) 166050

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journal homepage: www.elsevier.com/locate/scitotenv

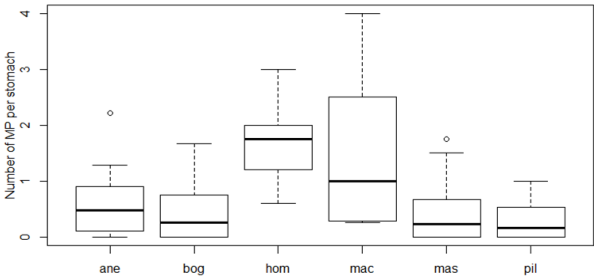
ELSEVIER

Microplastic distribution in different tissues of small pelagic fish of the Northeast Atlantic Ocean

Clara Lopes ^{a,b,c,*}, Ana C. Ambrosino ^a, Cátia Figueiredo ^b, Miguel Caetano ^{a,b}, Miguel M. Santos ^{b,c}, Susana Garrido ^{a,d}, Joana Raimundo ^{a,b}



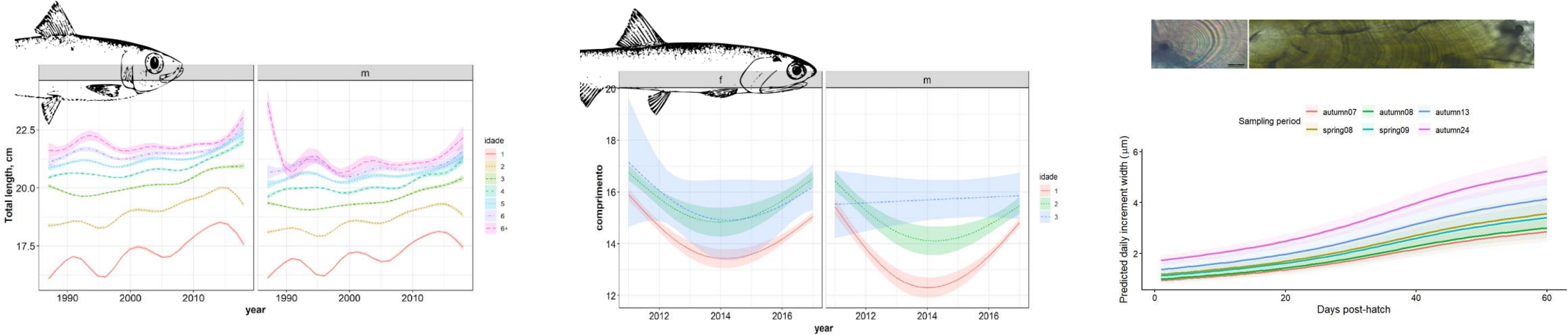
Microplastics



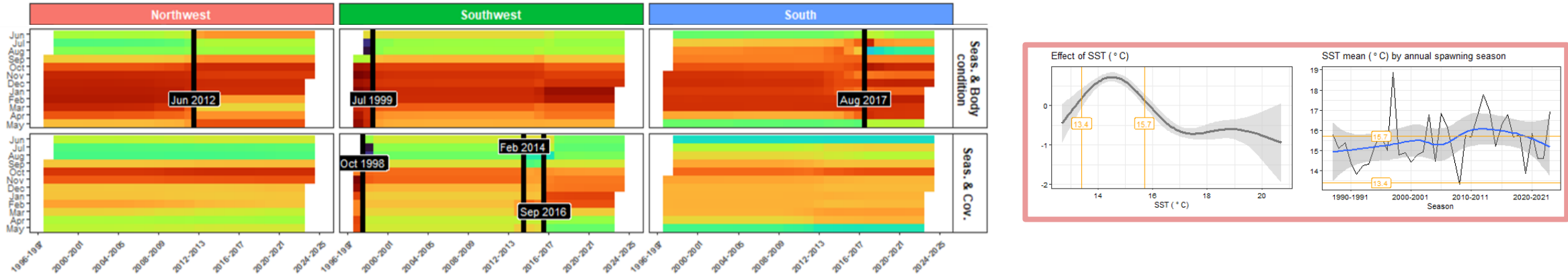
Activity 5 – Growth and Reproduction



T1. Investigate the effects of environmental variability on the growth and reproduction of pelagic fish



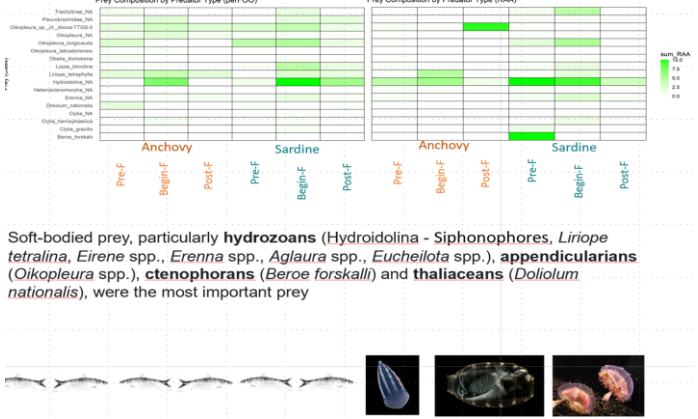
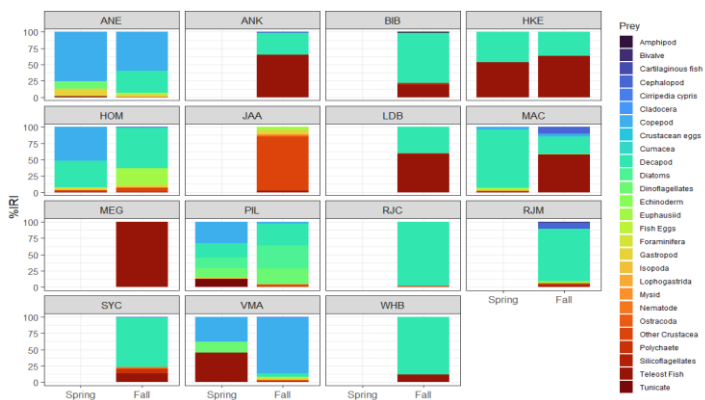
T2. Investigate the impacts of environmental change on sardine reproductive phenology



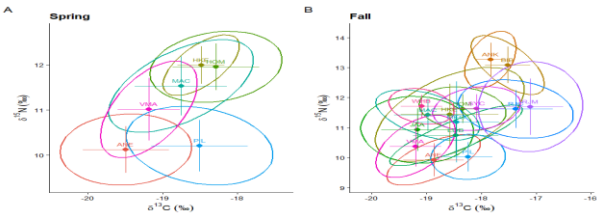
Activity 6 – Trophic Ecology



T1. Investigate trophic interactions among organisms in the marine ecosystem off Portugal, assessing their distribution, trophic overlap, intraguild predation, and competition



T2. Characterise seasonal, spatial, and interannual variability in the pelagic food web, from plankton to top predators, using stable isotope analysis.



T3. Expand the database by integrating all available data on trophic relationships in the pelagic ecosystem off mainland Portugal

HORSE MACKEREL



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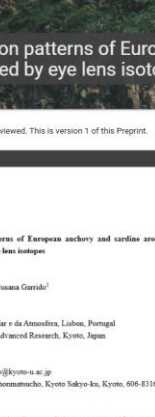
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Different migration patterns of European anchovy and sardine around Iberian Peninsula revealed by eye lens isotopes

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Authors

Tatsuya Sakamoto, Susana Garrido

1 Different migration patterns of European anchovy and sardine around Iberian

2 Peninsula revealed by eye lens isotopes

3

4 Authors

5 Tatsuya Sakamoto^{1,2*} and Susana Garrido¹

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15 Keywords

16 Eye lens, stable isotope, migration, population structure, anchovy, sardine, fishery

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Advance View https://doi.org/10.3354/meps14594	MARINE ECOLOGY PROGRESS SERIES Mar Ecol Prog Ser	June 20, 2024
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Contribution to the Theme Section 'Small pelagic fish: new research frontiers'



Anchovy on the rise: Investigating environmental drivers of recruitment strength in the northern Canary Current

Afonso Ferreira^{1,*}, Ana C. Brito^{1,2}, José Lino Costa¹, Vanda Brotas^{1,2},
Ana Teles-Machado^{3,4}, Susana Garrido^{1,3}

Activity 8 – Abundance and Distribution



T1. Relate oceanographic factors to the horizontal and vertical distribution of sardine and anchovy schools

Spatial modelling using machine learning (Horizontal distribution)

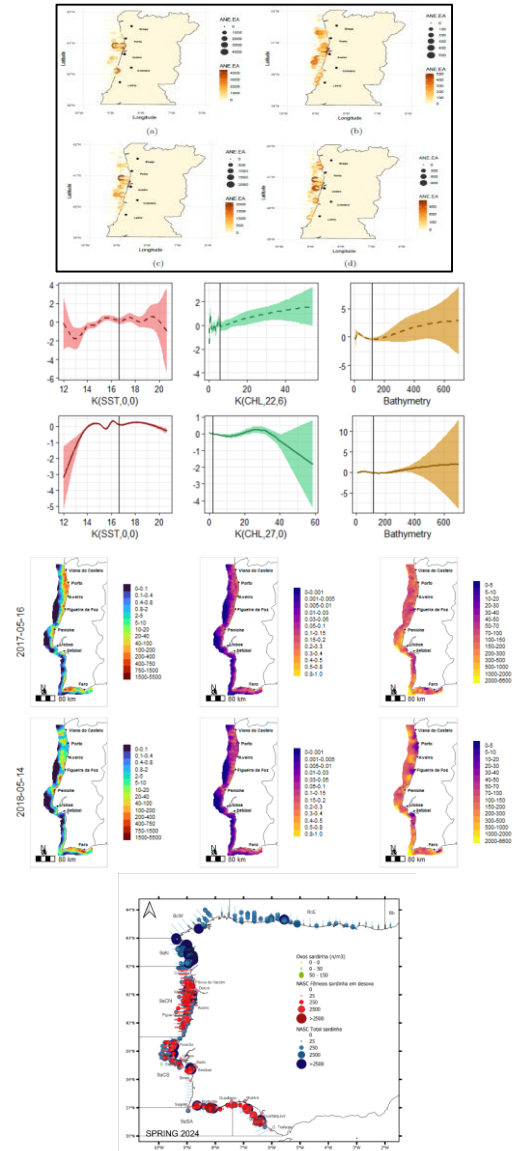
Influence of environmental conditions** (SST, chlorophyll, bathymetry, ocean currents) on distribution and abundance.

Assessment of vessel catchability** using vessel characteristics (size, activity time, engine power).

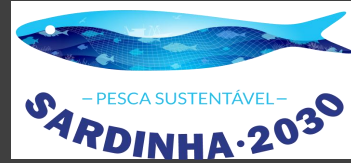
Analysis of the spatial behaviour of fishing activity and its relationship with species distribution and environmental conditions (wind speed, wave height).

T2. Investigate the influence of environmental factors on the spatial distribution of sardine and anchovy and identify preferred spawning habitats

T3. Assess spatial interactions between sardine and marine megafauna (cetaceans and seabirds)



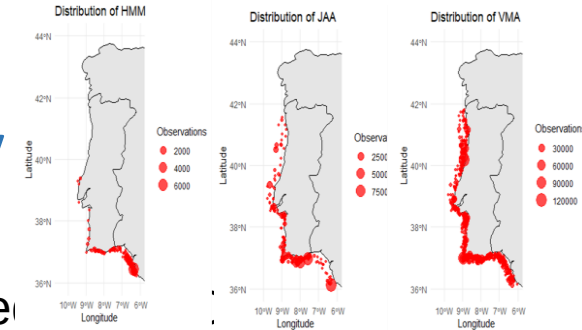
Activity 9 - Population dynamics and stock assessment



T1. Estimate the abundance and exploitation status of data-limited species caught by purse-seine fisheries

Develop population assessment models for the most relevant species selected based on certification requirements

Assess the impact of purse-seine fisheries on secondary species within the MSC Standard (Principle 2) and provide input data for the EwE ecosystem model (Action 10).



T3. Develop a horse mackerel recruitment index using data from acoustic surveys, beach-seine fisheries, and purse-seine fisheries

T4. Implement alternative sardine stock assessment approaches for comparison with the model currently used within ICES

T6. Develop a spatial bioeconomic model to optimise sardine harvest control rules and compare it with the Management Strategy Evaluation (MSE) approach used to develop the current harvest control rule

Activity 10 – Ecosystem modelling



T1. Update the Ecopath model

- Update diets
- New initial year: 1996
- Balance the model

T2. Update the Ecosim model

- Extend the model through 2024
- Compile and prepare the time series
- Calibrate the model

Test the impact of model structure on the classification of sardine as a key low-trophic-level species.



Activity 11 - Impact of fishing on the ecosystem

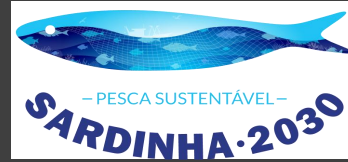
T1. Map areas and periods of juvenile aggregation for the main purse-seine target species and identify measures to avoid their capture.

T2. Estimate bycatch and discards in purse-seine fisheries and identify best mitigation practices.

T3. Characterise incidental catches of PET species and recommend best practices for monitoring and mitigation.

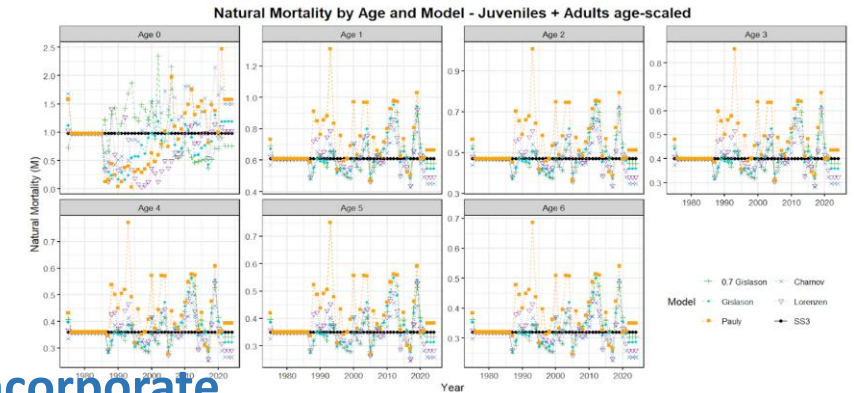
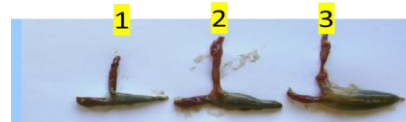


Activity 12 - Management Indicators and Strategies



T1. Identify ecosystem indicators to improve single-species assessments of the main purse-seine target species (e.g., predation mortality, time-varying natural mortality).

T2 . Estimate feeding intensity indicators for pelagic fish and other species

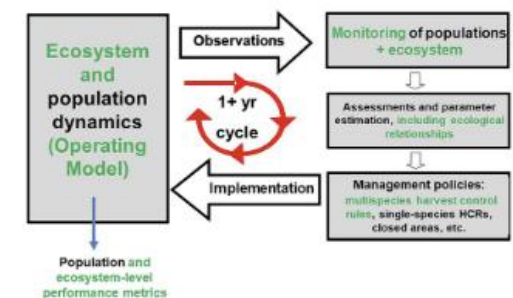


T3. Estimate biological reference points for sardine management that incorporate ecosystem information

T4. Test fishing strategies to assess the ecosystem impacts of harvesting sardine and other low-trophic-level species.

T5. Incorporate ecosystem information into the evaluation of harvest control rules for sardine.

T6. Develop a spatial bioeconomic model to optimise sardine harvest control rules and compare it with the Management Strategy Evaluation (MSE) approach used to develop the current harvest control rule.





Joint PICES/ICES Working Group on Sustainable Pelagic Forage Communities

Co-chairs: Rebecca Asch, Susana Garrido,
Motomitsu Takahashi, Chris Rooper



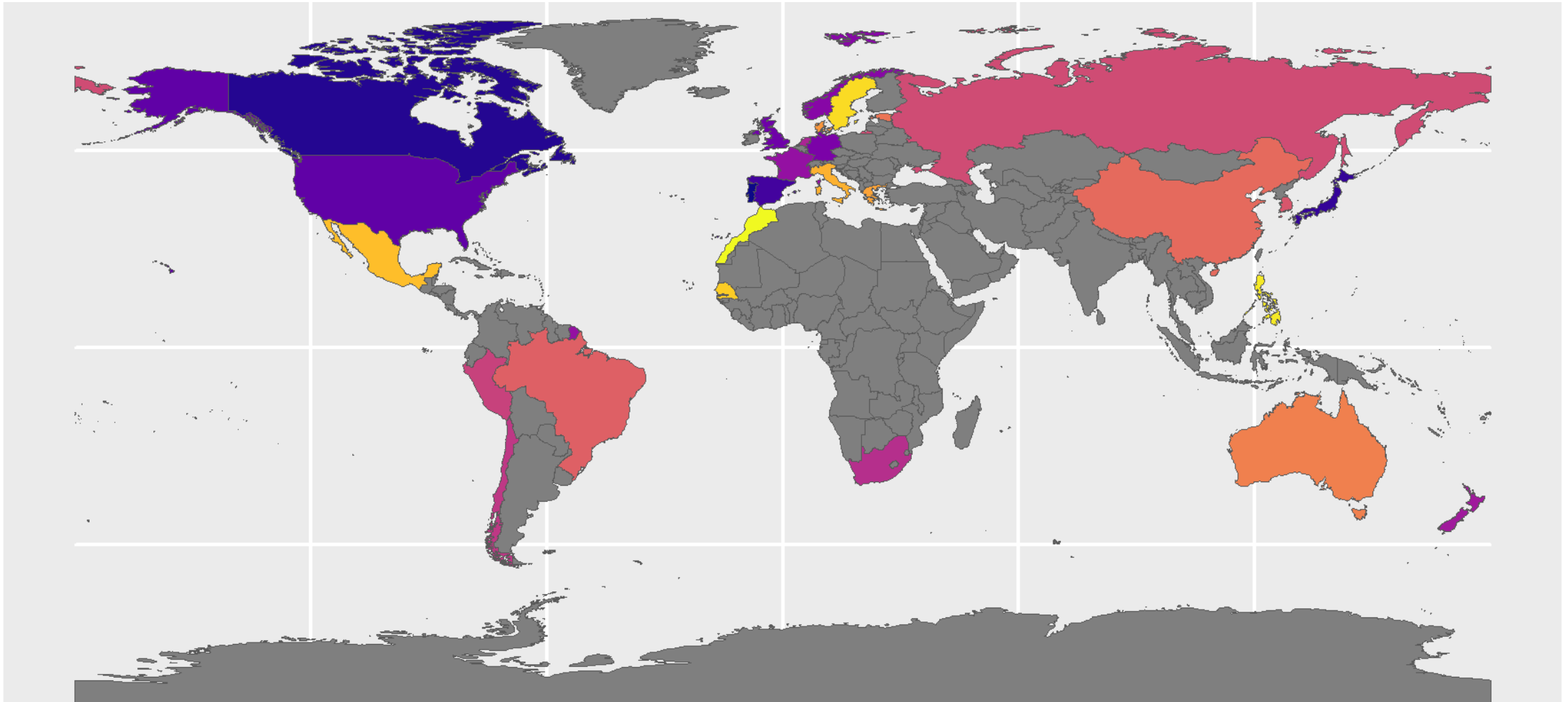
Terms of Reference – WG53/WGSPF

- Foster international and interdisciplinary collaboration to establish similar study frameworks and comparative analyses of forage species, their ecology, and fisheries.
- Assess recent progress on understanding fluctuations of forage species (abundance, distribution, diversity, and characteristics) and their impacts on the structure and function of ecosystems, particularly upper trophic levels including marine birds and mammals.
- Identify, prioritize, and recommend research most needed to advance our knowledge and capacity to forecast ecosystem responses to changes in forage species.
- Recommend strategies for studying and monitoring socio-ecological systems to improve ecosystem-based management for the sustainable harvest of forage species.
- Describe how climate change and other anthropogenic factors impact forage species and examine how these factors will affect economies, nutrition of human communities, aquaculture, fishery portfolios, and/or transboundary management among countries with different levels of development in fisheries, and recommend options for adaptation.
- Organize a joint ICES/PICES/FAO symposium on Small Pelagic Fishes tentatively scheduled for April 2026 (La Paz, Mexico)

WG53/WGSPF Membership

n = 31 countries (+ 4 international organizations)

n = 166 individuals



WGSPF Meetings (July 2024 – July 2028)

Past

La Paz – February 2024 (transitional meeting)

Honolulu – October 2024 (PICES Annual Meeting)

Lisbon – February 2025

Yokohama – November 2025 (PICES Annual Meeting)

La Paz – May 2026

Future

Nanaimo – October 2026 (PICES Annual Meeting – requested)

TBD (ICES Region?) – February-ish 2027

Activities

<i>Activity 1: Spatiotemporal processes affecting life history</i>	R. Asch, D. Silva,B. Erisman
<i>Activity 2: Food-web Dynamics</i>	S. Garrido, B. Hunt
<i>Activity 3: Drivers of growth, reproduction, and survival</i>	M. Huret, M. Lindegren, F. Berg, M. Takahashi
<i>Activity 4: Distribution, migration and connectivity</i>	T. Sakamoto
<i>Activity 5: Non-climatic and non-fisheries anthropogenic impacts</i>	P. Polte, R. Asch, F. Juanes
<i>Activity 6: Forage beyond boundary currents</i>	R. Rykaczewski, C. Rooper
<i>Activity 7: Advanced technologies and methodologies</i>	M.M. Angélico, C. Rooper, D. McGowan
<i>Activity 8: Short-term forecasts and long-term projections</i>	S. Koenigstein, R. Wildermuth
<i>Activity 9: Improving management with actionable science</i>	K. Jacobson, P. Sun, R. Wildermuth
<i>Activity 10: Social-ecological analysis</i>	M. Gasalla, N. Heck, I. Kaplan, P. Sun
<i>Activity 11: Future in 2050</i>	M. Peck, S.-I. Ito, C. Rooper

Activity 1: Spatiotemporal Processes Affecting Life History

Activity leaders: Rebecca Ash (USA), Brad Erisman (USA) & Daniela Silva (Portugal)



What is this activity doing?

Topics of research underway:

1. Trends in the **reproductive phenology** & thermal sensitivity of small pelagic fishes (Rebecca Asch)
2. Environmental sensitivity in **spatial distribution** (Marta Moyano and Martin Lindegren)
3. Stock characterization in relation to **life history traits** and population structure (Brad Erisman)
4. **Joint modelling** using fisheries-dependent and independent datasets (Daniela Silva)
5. Using **maturity status and GSI** data to look at phenology (Susana Garrido)



Activity 2: Food-web dynamics of small pelagic fish

Activity leaders: Susana Garrido (Portugal) and Brian Hunt (Canada)



What is this activity doing?

- Compile metadata on top predator diet databases from different regions. Lead: S. Garrido, B. Hunt
- Review paper on SPF nutrition (e.g., energy density, fatty acids, lipid content, essential vitamins) as it related to top predator health. Lead: B. Hunt, H. Pethybridge
- Review of predator-prey allometric relationships of SPF. Lead: F. Juanes
- Modification of ecosystem models to divide species into stanzas (life history stages of larger fish species that overlap with SPF during early life history) and compare outputs. Leads: J. Ruzicka, S. Garrido, D. Szalaj
- Application of semi-quantitative stomach fullness categories (from empty to full; categories 1–4) to examine, seasonal, spatial, and diel variations in feeding. Lead: S. Garrido
- Review best practice in evaluating larval fish diets using molecular methods. Lead: S Garrido
- Paper on a global stable isotope-based trophic level comparison of SPF and connecting with CLIOTOP project on mesopelagic micronekton stable isotope. Leads: R. Brodeur, H. Pethybridge, B. Hunt
- Assessment and characterization of SPF functional traits across freshwater, coast to offshore habitats. Leads: R. Brodeur, B. Hunt

Activity 3: Interval & external drivers of growth, reproduction & survival



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Activity leaders: Florian Berg (Norway), Martin Lindegren (Denmark), Martin Huret (France), Motomitsu Takahashi (Japan)

1) **Experimental** (Florian Berg)

Review and analysis of available data on traits and associated experimental conditions



2) **Statistical modelling** (Martin Lindegren)

Meta-analysis on the variability of the traits across many different stocks



3) **Mechanistic modelling** (Martin Huret)

Bioenergetics model to explore the variability in growth across stocks and responses to regional external factors



4) **Analysis of recruitment variability** (Moto Takahashi) :

Effect of internal and external drivers on recruitment variability



Activity 4: Distribution, Migration, and Connectivity

Activity leader: Tatsuya Sakamoto (Japan)



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- Identifying Japanese sardine's pathway across the Pacific onto the U.S. west coast
- Studies of European sardine on recent colonization event associated to genome rearrangement
- Assess SPF range shifts, colonization events, and the driving mechanisms via comparative analyses
- Review techniques for studying population structure and connectivity – Examining current methods used to study population structure and connectivity, their global applications, and contributions to stock assessment



Activity 5: Non-climatic and non-fisheries anthropogenic impacts

Activity leaders: Rebecca Asch (USA), Francis Juanes (Canada), Marta Moyano (Norway), Patrick Polte (Germany)



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This activity aims to collect information across species and oceans on cases of seascape modification effects and provide a comprehensive review on the cause-and-effect chains to provide informed answers. This activity will also point out research gaps. A trait-based approach will be used to characterize existing impacts documented in the scientific literature so as to better understand what impacts may be generalizable across organisms with similar life history, ecological, and physiological traits.



FAO, 2016

Activity 6: Forage Communities Beyond Boundary Currents

Activity leaders: Ryan Rykaczewski (USA), Chris Rooper (Canada)



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- Use existing datasets to conduct comparative analyses of forage communities in open ocean systems, examining spatial and temporal variability and underlying drivers where data permit
- Synthesize insights from established mesopelagic research communities to understand current knowledge of sensitivity to oceanographic conditions, while contributing SPF expertise to develop testable hypotheses regarding temporal variability and climate responses
- Identify observational and modeling studies necessary to improve understanding of interannual to multi-decadal scale variability in forage communities, with focus on resolving responses to climate change and anthropogenic impacts including deep-sea mining



Activity 7: Advanced technologies and methodologies for assessing small pelagic communities



Activity leaders: Maria Manuel Angélico (Portugal), Dave McGowan (USA), Chris Rooper (Canada)

- Review methods for improving, measuring or correcting existing sampling methods for potential gear selectivity and sampling bias
- Review applications of new technologies to complement traditional/ existing surveys to provide more efficient, wider or better integrated abundance indices; additionally, review applications of new technologies to better characterize the pelagic ecosystem or habitat
- Review novel data processing and data analysis methods
- Data analysis using new statistical approaches



Activity 8: Short-term forecasts and long-term projections

Activity leaders: Stefan Koenigstein (Germany), Matt Baker (USA), Robert Wildermuth (USA)



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Working manuscript title: Channeling advances in ecological modelling of SPF into climate-adaptive & EBFM (CA in EM of SPF into CA & EB FM)

- Pathways for integrating modeling advances into decision-making
- Short-term forecasting and early warning systems
- Spatial management and assessment
- Climate change projections and adaptation planning
- Simulation testing, performance evaluation, and risk evaluation
- Key challenges and barriers to implementation
- Emerging directions and opportunities



Activity 9: Improving management with actionable science

Activity leaders: Kym Jacobson (USA), Peng Sun (China), Robert Wildermuth (USA)



Brief description of work (e.g., databases, ongoing papers)

- Szalaj et al. – review of EBFM progress in SPF fisheries
- Co-sponsor of paper on “Channeling Advances in Ecological Modelling of Small Pelagic Fish into Climate-Adaptive Fisheries Management”
- 1st workshop paper: “Best Practices for Improving Assessment of Small Pelagic Fishes Using Environmental Indicators”
- 2nd workshop paper: Led by Matt Baker/Susana Garrido. Working title: “Identifying Industry and Management Priorities to Inform Research in Fisheries”



Activity 10: Socio-ecological analyses

Activity leaders: Isaac Kaplan (USA), Sun Peng (China), Jaclyn Cleary (Canada), Nadine Heck (USA), and Mary Gasalla (Brazil)



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Theme 1: Human dimensions, communities, and wellbeing, especially related to Small Pelagic Fish (SPF).

- Foci: 1) Food security/availability, 2) Adaptation of small-scale pelagic fisheries to multiple stressors, 3) Indigenous/traditional knowledge and objectives

Theme 2: Transboundary management issues and game theory

- Conduct a review paper of modeling methods that can be used to “stress test” international management of shifting transboundary small pelagic fish stocks



Identifying management- and industry-informed research priorities for small pelagic fishes

Matthew Baker¹, Susana Garrido², Niels Hintzen³, Minje Choi⁴, and Asami Takahashi⁵

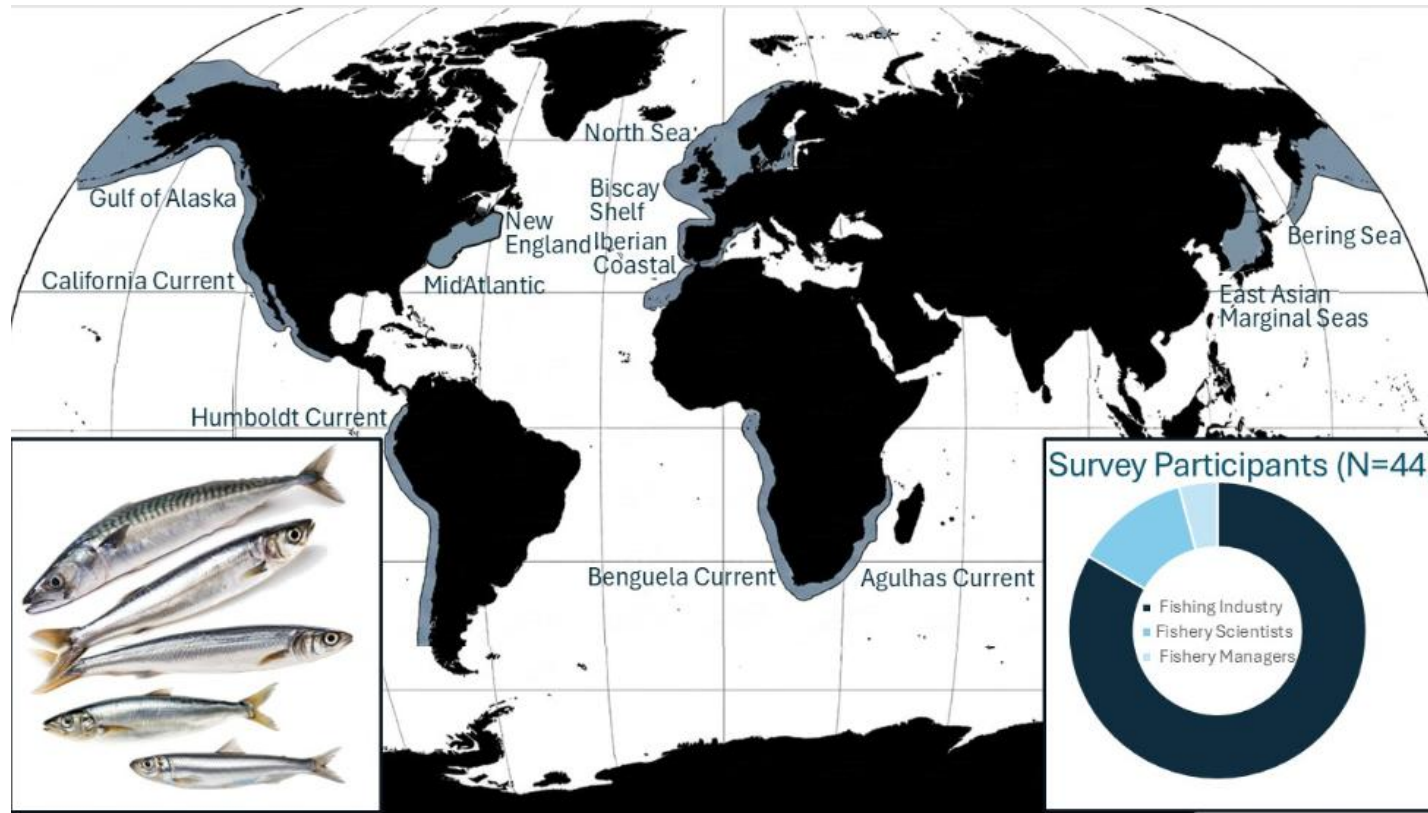
¹ North Pacific Research Board, Anchorage, USA; Matthew.Baker@nprb.org

² Portuguese Institute for Sea and Atmosphere, Lisbon, Portugal

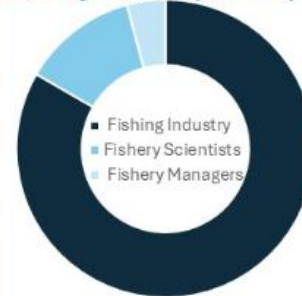
³ Pelagic Freezer Trawler Association, Zoetermeer, Netherlands

⁴ Marine Stewardship Council, Busan, Korea

⁵ Marine Stewardship Council, Tokyo, Japan



Survey Participants (N=44)



1. Co-defining research priorities

Engaging scientists, managers and industry, identifying shared needs and information gaps, translating industry objectives and knowledge into research questions, aligning research with management and operational needs

2. Co-producing knowledge and data

Combining scientific expertise with fishers' knowledge, industry-supported sampling and data collection, fleet-based observations and technologies, collaborative modelling and interpretation of environmental and fisheries data

3. Building long-term partnerships for management

Establishing sustained dialogue between science, industry and managers, creating mechanisms for industry input, strengthening trust and two-way communication, moving towards co-production of actionable science

Activity 11: Small Pelagic Fish in 2050 (Synthesis of WG53/WGSPG 10 activities)



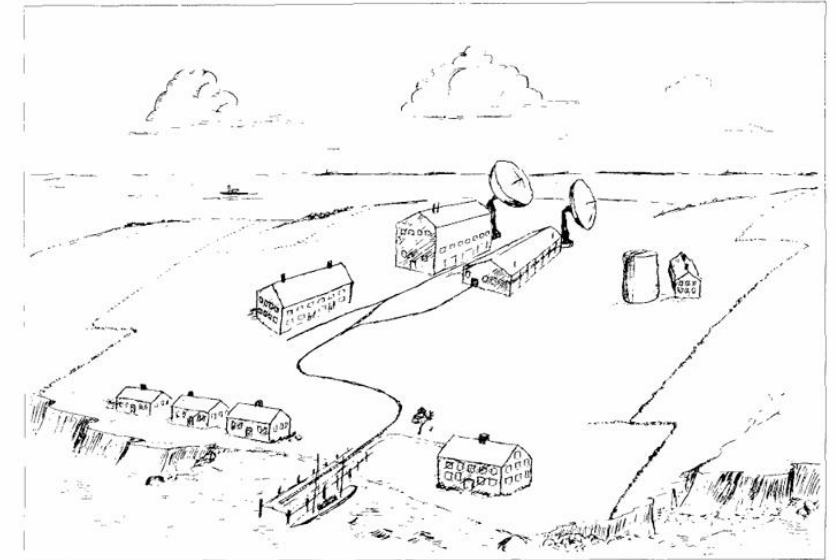
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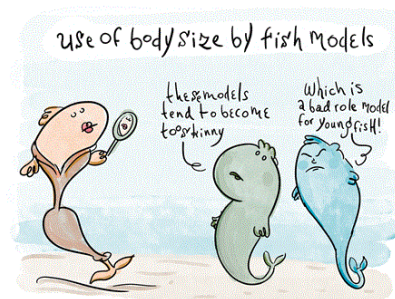
Activity leaders: Myron Peck (Netherlands), Chris Rooper (Canada), Shin-ichi Ito (Japan)

A potential publication: Science fiction “SPF science in 2050 and beyond”

Package of dreams for science regarding SPF which are expected to be realized in 2050 and beyond



Stommel (1989) The Slocum mission.
Oceanography, 2, 22-25



Link et al. (2019) A graphic novel from the 4th International Symposium on the Effects of Climate Change on the World's Oceans. ICES J. Mar. Sci.