JOINT ICES-PICES WORKING GROUP ON SMALL PELAGIC FISH (WGSPF - OUTPUTS FROM 2023 MEETING)

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Contents

i Executive summary

The Working Group on Small Pelagic Fish (WGSPF) was established to review progress on understanding how environmental and anthropogenic factors influence Small Pelagic Fish (SPF) population dynamics across different ecosystems. The group's main aim is to foster international and multidisciplinary collaboration to establish comparative analyses and predictive capacities for SPF dynamics under varying ecosystem states.

This report addresses critical questions regarding the impact of various drivers on SPF populations, the establishment of networking environments for collaborative research, and the identification and prioritization of research needed to advance knowledge and predictive capabilities concerning SPF population dynamics.

The group achieved significant progress in reviewing the influence of environmental and anthropogenic drivers on SPF dynamics. Collaborative efforts led to the development of comparative analyses across different ecosystems. The findings underscore the complexity of SPF population dynamics and the critical role of environmental variability and human activities in shaping these dynamics. The work supports the need for ecosystem-based management strategies for SPF, integrating biophysical and socio-economic models to ensure sustainable fisheries management.

This report highlights the ongoing challenges in predicting SPF population dynamics due to the multifaceted nature of environmental and anthropogenic influences, emphasizing the need for continued research and data collection.

The 2022 SFP organized symposium stands out as a pivotal output, assembling international experts to share findings, methodologies, and future research directions on small pelagic fish. This event fostered significant advancements in understanding food web dynamics, the impact of environmental drivers on variability, and the development of models for forecasts and projections. The working group's efforts have been documented in numerous peer-reviewed publications and contributions to international symposia, showcasing the global collaborative nature of this research initiative.

WGSPF emphasizes the importance of continuing to refine predictive models for SPF populations, integrating new monitoring and modelling technologies, and addressing gaps in knowledge regarding SPF responses to environmental and anthropogenic changes. Future priorities include continuing the compilation of world-wide databases for comparative analyses, extending the focus of studies to forage species, including mesopelagic fishes, squid, euphausiids, and other species; and prioritizing also effects on, and from, forage fish predators and community-and ecosystem-level impacts.

ii Expert group information

Expert group name	ICES/PICES Working Group on Small Pelagic Fish (WGSPF)
Expert group cycle	Multiannual
Year cycle started	2020
Reporting year in cycle	4/4
Chairs	Myron Peck, The Netherlands (ICES)
	Ignacio Catalán (ICES)
	Akinori Takasuka, Japan (PICES)
	Ryan Rykaczewski, USA (PICES)
Meeting venues and dates	9-11 March 2020, Copenhagen, Denmark, ICES HQ (31 participants)[1]
	22-30 October 2020, Online Meeting (PICES AM; 12 participants)
	10, 13-14 September 2021, Online Meeting[2], ICES ASC. (35 participants)
	12-13 November 2022, Lisbon (60 participants)
	12-14 February 2024, La Paz, México (35 participants; WGSPF/WG43)

Note: many other subgroups meetings were held online in the frame of Task Forces and Activity Groups (see corresponding sections). Further, several PICES meetings (WG43, sibling group to WGSPF) were conducted[3].

[1] First meeting: Last accessed Feb 14, 2024. https://meetings.pices.int/publications/other/members/WG-43-SPF-kick-off-meeting-report-Sept2020.pdf.

[2] Agenda: last accessed Feb 14, 2024. https://meetings.pices.int/publications/other/members/WG-43-WGSPF-2021-ANNUAL-MEETING.pdf.

[3] PICES WG43. last accessed Feb 14, 2024. https://meetings.pices.int/members/working-groups/wg43

1 Background and motivation

Small pelagic fish (SPF) account for more than 30% by weight of the total landings of marine capture fisheries around the world. They also play an important role in the transfer of energy through mid-trophic levels in marine ecosystems and are key resources for the world's growing aquaculture industry, as well as for direct consumption fisheries. The oscillations in the populations of SPF are dramatic and cyclical in response to climate variability on multidecadal timescales. However, mechanisms linking climate variability to population dynamics are still unresolved. Hence, there are many challenges to sustainable use of SPF production. As the population dynamics of SPF display basin-scale teleconnections, synthetic and multidisciplinary studies at the regional-to-global scale are required to understand the processes and mechanisms to build predictive capacity.

International collaboration on SPF research was first spearheaded by the GLOBEC Regional Program on Small Pelagic Fish and Climate Change (SPACC), launched in 1994 with a workshop in La Paz, Mexico. The SPACC program aimed to understand and predict climate-induced population dynamics of SPF in relation to physical and biological processes and included several major themes: long-term changes in ecosystems, retrospective analyses, comparative population dynamics, reproductive habitat dynamics, and economic implications of climate variability. The SPACC program culminated in 2010 with the publication of a review book. Between 2010 and 2017, no international program specific to SPF has been launched, although SPACC-II visions have been discussed (e.g. Alheit (2010) and van der Lingen *et al*. (2010)). In the following decade, there has been substantial scientific progress made in several ecosystems: different hypotheses of mechanisms of population dynamics of SPF have been proposed, data from long-term monitoring and stock-assessment efforts have accumulated, numerical modelling approaches have progressed, and technologies such as genome analysis, acoustic monitoring, and machine-learning techniques, have rapidly developed. ICES/PICES co-sponsored a symposium on "Forage fish interactions: Creating the tools for ecosystem-based management of marine resources" (Nantes, France, November 12–14, 2012) leading to publication of twelve articles in the ICES Journal of Marine Science (Peck *et al*., 2014). The need for a platform to organize intensive international collaboration was re-confirmed during the PICES/ICES Symposium on "Drivers of dynamics of small pelagic fish resources" (Victoria, BC, Canada, March 6–11, 2017). This symposium led to special issues in Deep-Sea Research Part II (Alheit *et al*., 2019; 15 articles) and Marine Ecology Progress Series (Alheit and Peck, 2019; 22 articles).

The platform for international collaboration will allow the marine science community to more rapidly address challenging goals such as to: 1. Perform a synthesis of mechanisms linking climate variability to population dynamics of SPF among different ecosystems to reconcile multiple recruitment hypotheses; 2. Gain an holistic, ecosystem-level view of the causes and consequences of fluctuations in SPF populations such as how different factors (physical forcing, trophodynamics, and fishing pressure) interact to control the dynamics of populations; 3. Unite different fields (climate science, oceanography, plankton and fish ecology, quantitative fisheries stock assessment, sociology and economics) to build interdisciplinary approaches to examine SPF as part of social–ecological systems; 4. Incorporate new monitoring (e.g. environmental DNA) and modelling (e.g. end-to-end) technologies to better understand and manage pelagic ecosystems; 5. Provide projections of the effects of climate change on the distribution and productivity of SPF; 6. Propose strategies to safeguard marine ecosystem services stemming from SPF including conservation concerns related to SPF and their predators. Because small pelagic fish are highly valued by society and exhibit variability associated with changes in climate forcing, ecosystem structure, and fishing pressure, efforts to understand their dynamics require an integration of

knowledge across oceanographic disciplines. Human society cannot expect to prepare a plan for sustainable development of the oceans unless we can improve our understanding of the largest component of ocean fisheries—the small pelagic fish. Consideration of the dynamics of these species, their sensitivity to exploitation and climate change, and the implications of such changes for the human populations that they support is essential to promote ocean sustainability and guide adaptation.

Figure 1.1 Foundational ICES/PICES WGSPF meeting in March 2020, ICES HQ (with remote participants shown in background), only days before shutdowns due to the COVID pandemic.

2 Terms of reference and status summary

Below the Terms of Reference (ToRs), expected deliverables and their status is summarized. ToRs activities are summarized in detail in subsequent sections. The list of products can be found in section 7.

Table 2.1 Terms of references and deliverables

Terms of Reference (ToR)		Expected deliverables and status
a.	To review recent progress on understanding how various drivers (environmental and/or anthropogenic) impact the population dynamics of SPF in different ecosystems and whether and how potential drivers shift with changes in ecosystem state.	Review papers within peer-reviewed journals. Status: Several papers have been produced or are in progress. See descriptions in the results section and the Products section.
b.	Create a networking environment for international and multidisciplinary collaboration to foster the establishment of similar study frameworks and comparative analyses of SPF across different social–ecological systems, based on updated time-series datasets of climate indices, environmental factors and fisheries biology as well as ecophysiological information (feeding, growth and survival).	Meeting reports submitted to ICES/PICES, Perspective Paper(s) submitted to peer-reviewed journal(s). Status: Interim reports account for the progress of meetings. Currently, 117 active members are registered in the WGSPF. Several papers have been produced or are in progress. See descriptions in the results section and the Products section.
c.	Identify, prioritize and conduct research most needed to advance our knowledge and capacity to predict the population dynamics of SPF at both short (seasonal to interannual) and long (decadal to centennial) time-scales.	Meeting reports submitted to ICES/PICES, Perspective Paper(s) submitted to peer-reviewed journal(s). Status: Several meetings were produced, as reported in the interim reports. SCI papers were produced on this topic. See descriptions in the results section, and in the Products section.
d.	Recommend strategies of marine ecosystem monitoring and fisheries management of SPF which will contribute to sustainable ecosystem-based fisheries management, through biophysical, ecosystem and/or socio–economical models.	Meeting reports submitted to ICES/PICES, Perspective Paper(s) submitted to peer-reviewed journal(s) Status: Several meetings were produced, as reported in the interim reports. SCI papers were produced on this topic. See descriptions in the results section, and in the Products section.
e.	Propose topic sessions at PICES Annual Meetings and ICES Annual Science Conferences focused on advances in SPF science and to organize a joint ICES/PICES symposium on SPF at regular intervals (e.g. once every 4 years) leading to the publication of findings in special issues of primary journals.	Joint ICES-PICES theme sessions. An International ICES-PICES SPF symposium (follow-up to March 2017 Victoria meeting). Special issue(s) in peer-reviewed journal(s) Status: Several meetings were produced, as reported in the interim reports. The ICES-PICES SPF symposium was held in 2022 in Lisbon. See description in the symposium section and the Products section.

3 Task forces and activities

Due to the wide scope and ample participation of ICES and PICES community in the WG (over 117 people registered), it was decided to address the ToRs devoted to generating science and reviews by creating Task Forces, each with a few specific Activities. These were defined through a bottom–up process and detailed in the first meeting.

Three broad Tasks Forces (Table 3.1) were defined to address the range of ecological, management, and socio-economic questions concerning SPF stocks worldwide (ToRs a,c,d). ToR b is in the basis of the group generating all the other ToRs, including ToR e, which is the symposium and has its own section. For the three Task Forces, eleven activities and several associated research questions were identified through a bottom–up process based on a series of questions to the participants, to be developed during the lifetime of the WG. Within each activity, WG members have collaborated on a specific topic designed and lead by group members. It was expected that each topic used a comparative approach across systems and/or species (ToR b), although more regional approaches or specific research questions benefitting from group discussions were also encouraged.

Table 3.1 Task forces and activities, including leadership.

Task force on ecological process knowledge (ToR a,b)		
Activity Group 1 (AG1)	Critical review, evaluation and testing of classic hypotheses	Akinori Takasuka (Japan), Myron Peck (the Netherlands)
Activity Group 2 (AG2)	Life cycle closures - bottlenecks and gaps in knowledge	Ignacio Catalan (Spain), Noelle Bolwin (US)
Activity Group 3 (AG3)	Drivers of spatial distribution and phenology	Rebecca Asch (USA), Marta Moyano (Norway)
Activity Group 4 (AG4)	Foodweb dynamics	Richard Brodeur (US), Susana Garrido (Portugal)
Activity Group 5 (AG5)	Internal and external drivers of growth, reproduction, and survival	Florian Berg (Norway), Martin Huret (France), Martin Lindegren (Denmark)
Task force on translating process knowledge (ToR c, b)		
Activity Group 6 (AG6)	Survey design and monitoring	Matthias Kloppmann (Germany), Chris Rooper (Canada)
Activity Group 7 (AG7)	Improving short term forecasts and/or long-term projections	Stefan Koenigstein (USA), Ryan Rykaczewski (US)
Activity Group 8 (AG8)	Improvements to management	Salvador Lluch-Cota (Mexico), Richard Nash (UK), Andrés Uriarte (Spain)
Task force on social-ecological approaches (ToR d, b)		
Activity Group 9 (AG9)	Networks, vulnerability, and opportunities of dependent human communities	Myron Peck (the Netherlands)
Activity Group 10 (AG10)	Quantifying trade-offs in goods and services	Cecilie Hansen (Norway), Isaac Kaplan (US)

Activity Group 11 (AG11)	Bioeconomic modelling	Myron Peck (the Netherlands)

4 Results from Task Forces and activities (ToRs a-d)

4.1 Task force 1: ECOLOGICAL PROCESS KNOWLEDGE

Activity Group 1 (AG1): Critical review, evaluation and testing of classic hypotheses

Leads: Akinori Takasuka (Japan), Myron A. Peck (the Netherlands)

The objectives of AG1 were to organize and conduct a critical review of hypotheses related to the biology, ecology, and management of SPF and to generate ideas of how specific hypotheses might be tested by other Activity Groups. Through discussion during the workshops, the literature review focused on any hypotheses related to mechanisms and processes behind population/recruitment dynamics of SPF and their roles in marine ecosystems.

First, we set up key questions. For example, what hypotheses have been proposed for mechanisms of population dynamics, recruitment, roles in ecosystems of SPF? What are the advantages/disadvantages of the existing hypotheses? What new hypotheses might be extracted from discussions at the 2020 ICES/PICES/FAO symposium in Lisbon? In total, > 40 ideas were collected from the members for further elaboration. These ideas were organized into classic hypotheses appearing in the early history of fisheries oceanography (e.g. focusing on feeding success during the early life stages), advanced hypotheses appearing during the last few decades (e.g. bottom–up, top–down, and wasp-waist controls) and detailed biological processes in relation to oceanographic processes. Some hypotheses extracted from the presentations at the symposium (Lisbon, 2022) focused on phenology, advection/retention, migration, interspecific interactions, trophic interactions, multiple environmental windows, density-dependent processes, habitat suitability, etc. For each hypothesis, the profile was summarized in seven categories: (1) General topic, (2) Name and (3) Definition of the hypothesis, (4) Description about related processes, relevant factors, relevant biological parameters, target developmental stages, and (5) Original source (original references, target regions and species in the original references, etc.). In addition, we discussed, (6) Advantages and disadvantages of the hypothesis, and (7) How the hypothesis could be tested (approach, data, regions, and method description).

Pursuing publication of a review paper was agreed during the previous workshops. Accordingly, the structure of the possible review paper was proposed based on the profile table of the collected hypotheses. The proposed structure constitutes sections of introduction, list of hypotheses, classic hypotheses, advanced hypotheses, synthetic/proposed hypotheses, and future recommendations, which may be modified at later stages. It was agreed by group members that other Activities would be started and, it is to be hoped completed. These Activities might generate new ideas or hypotheses that could be included here. The paper is expected to be drafted in 2024 by multiple co-authors. AG1 also contributed to the Symposium (see corresponding section), particularly through presentations in S2 and a keynote on this topic.

Activity Group 2 (AG2): Life cycle closures - bottlenecks and gaps in knowledge

Leads: Ignacio Catalan (Spain), Noelle Bowlin (US)

The goal of this activity was to work on one or several fronts (papers, databases, etc.) with the aim of comparing spatial processes related to the life cycle closure between regions (for one or several species). The wide field of individual-based models applied to Early Life Stages of Fish has its natural niche in this activity. The study of bottlenecks and gaps in knowledge were another goal of the activity. Activity 2 attracted 29 people from the PICES and ICES communities. In addition to the kickoff meeting in February 2020, the AG2 members met five times; two physically (12 November 2022, 15 people; 13 February 2024, 7 people) and three virtually (17 May 2020, 13 people; 17 December 2020, 15 people and 7 April 2021, 16 people), fulfilling the requirements of ToR b. The meetings were used to organize the collaborative papers and the Symposium session (S2) where most of the activity was presented.

From the outputs acknowledging the WG explicitly, there are several contributions to the special volumes of the SPF Symposium (ToR d). Some of these works dealt with ways to link species distribution models and genetics (Baltazar-Soares *et al*. 2023). Others analysed spatial displacements of some life cycle components (e.g. Van der Kooij *et al*., in press, MEPS), or projected future suitable habitats under climate change, at different resolutions, for adults (Lima *et al*., Sci Tot Env 2022) or spawning areas (Lima *et al*., Front Mar Sci, 2022). Several other research products on SPF have benefited from the WG discussions; although they do not explicitly acknowledge the WG, those research products were presented at the symposium and published in the special volumes.

Another main output is a finalized draft of a paper in which the majority of the activity members participated (ToR a, ToR c), entitled "Worldwide appraisal of knowledge gaps in the space usage of small pelagic fish: highlights across stock uncertainties and research priorities" (Figure. 4.1). This paper reviewed the knowledge gaps on spatial variability of 9 spatial components/processes (e.g. nursery areas, spawning areas, larval connectivity, feeding migrations, adult distribution, etc.) for 78 stocks of 17 species and 19 Large Marine Ecosystems. We reviewed > 3000 papers and 55 grey literature sources (e.g. assessments) and identified time-series length and continuity of the different components, as well as data continuity, data type, existing models, etc. We identified gaps in a comparative way and propose actions to increase data coverage or fill gaps from knowledge gained in other systems. It is expected that the manuscript will be submitted before summer 2024.

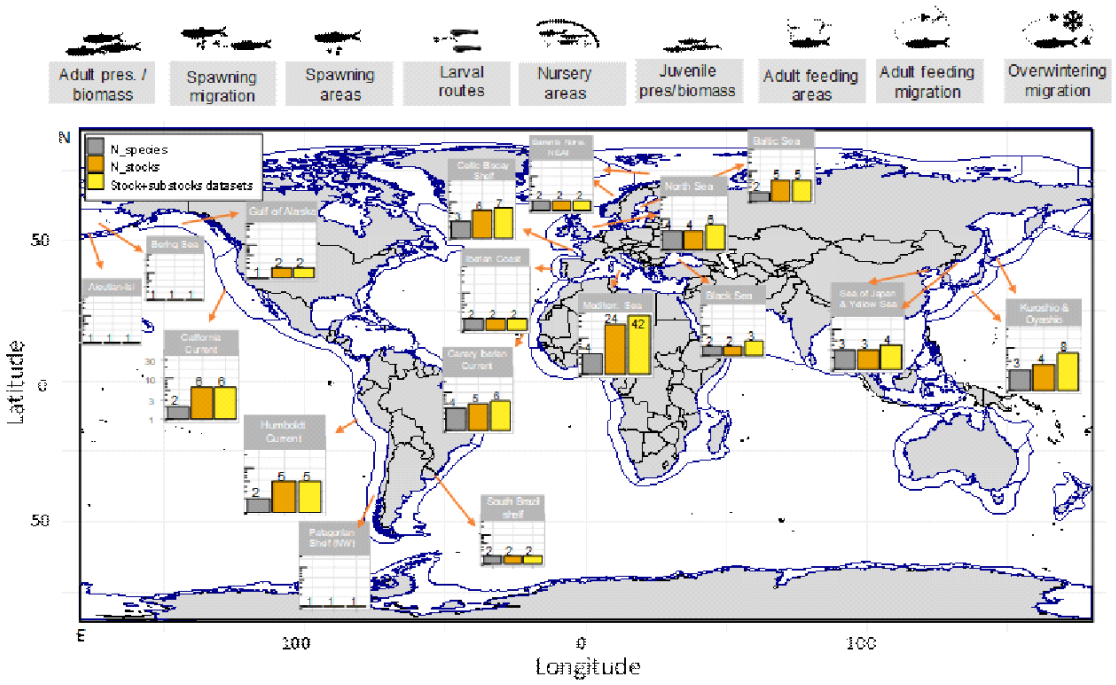

Figure 4.1 Key processes (top), and spatial coverage, number of stocks, species and datasets included in the review paper on knowledge gaps of spatial variability of SPF across life stages. Adapted from Catalán *et al.* (in prep).

The other crucial activity from AG2 was organizing the SPF symposium in Lisbon ToR e, supporting one specific session, S2 "Life cycle closure: advances in process understanding" that was proposed as a joint session between A2 and A5, with I. Catalán, N. Bowlin, M. Huret and M. Takahashi responsible for co-convening the session or presenting A2 activities. The S2 session attracted 24 oral presentations and 16 posters. Specific presentations can be found at the symposium webpage (see Symposium section).

Activity Group 3 (AG3): Drivers of spatial distribution and phenology

Leads: Rebecca Asch (US), Marta Moyano (Norway)

Changes in ocean climate, ecosystem productivity, population dynamics, and fishing pressure can lead to alterations in both the geographic area occupied by stocks of SPF and in the seasonal timing of key biological processes, such as spawning and feeding migrations. Activity Group 3 examines the drivers of spatio-temporal dynamics among SPF. The mailing list for the activity includes 49 member scientists representing 18 countries. A primary outcome of this activity has been the sponsorship of a symposium session on "Understanding Population- and Ecosystem-level Shifts: From Seasonal Timing to Tipping Points" at the 2022 ICES/PICES/FAO symposium. Forty-eight abstracts were submitted to this symposium session representing 18 countries, with nearly half of these abstracts from early career scientists. Two sub-activities related to WGSPF Activity 3 have emerged – one focused on spawning phenology and the other focused on using acoustic and trawl survey data to understand the fundamental and realized niches of SPF species. Preliminary results of these collaborative activities are summarized below.

The first sub-activity aims to: (1) Quantify interannual variability and long-term trends in spawning phenology, with the goal of assessing the observed signal-to-noise ratio in time-series; (2) Determine if regions with more rapid temperature changes are associated with faster shifts in spawning phenology, and; (3) Compare results across regions, species, and latitudinal gradients. During the first phase of this ICES/PICES working group, participants identified 35 datasets

representing 57 time-series for which long-term trends and/or interannual variability of SPF reproductive phenology can be assessed. These time-series document spawning phenology of 24 species through: surveys of eggs, larvae, and adult spawning migrations; maturity stages and the gonado-somatic index; otolith-based estimates of SPF hatch dates, and; historical documentation of peak spawning times recorded in newspaper articles. Since participants in some countries were unable to share raw data, we developed a series of code templates for analysing phenological datasets with weekly, monthly, and annual resolutions so that each activity member can analyse their data in a consistent and reproducible manner to allow for inter-ocean basin comparisons. A trial analysis has been completed using these templates focusing on 13 phenology time-series from North America. Initial results show: (1) spring-and fall-spawning fishes generally react to warming by advancing or delaying their spawning time, respectively; (2) climate change trends are larger than interannual variability of phenology among over two-thirds of the stocks analysed. This is noteworthy given the prevalence of interannual-to-decadal variability of SPF population dynamics; (3) areas with the most rapid rates of warming contain species that appear to exhibit a lower phenological sensitivity to changing temperatures than other regions. We plan to continue work in this arena in the next phase of this international collaboration.

The second sub-activity aims to: (1) Define the environmental niche for several environmental variables (e.g. temperature, salinity, oxygen, chlorophyll), and; (2) Identify whether direct vs. indirect environmental influences differ in their temporal stability along time-series. Several datasets covering northern and southern hemisphere were identified on the first phase of the working group. Due to challenges in data formatting, consistency, access and inter-comparability across geographical basins and Large Marine Ecosystems (LMEs), a first data analysis was conducted in the North Atlantic (led by Martin Lindegren), focusing on Atlantic herring, European anchovy, sardine, and sprat. Species distribution models were fitted using presence/absence data from trawl and acoustic surveys and environmental variables (temperature, salinity, depth, phytoplankton biomass) as predictors. Models were fitted with and without ecoregion to represent the overall vs. region-specific responses for these four species. Preliminary results suggest that 1) temperature was the most important environmental driver of SPF distribution, followed by salinity and depth; 2) the predicted responses to environmental drivers differed among and within species (e.g. across ecoregions), suggesting that SPF populations likely differ in their adaptation and tolerance to environmental conditions. We envision that this compiled dataset and approach will offer significant opportunities for further collaboration and global comparative global studies in the realm of forage fish. Data compilations in other regions are continuing.

Activity Group 4 (AG4): Foodweb dynamics

Leads: Richard Brodeur (US), Susana Garrido (Portugal)

Activity 4 aimed to advance our understanding on SPF foodweb dynamics, the impact of environmental drivers on the variability of trophic interactions and promote studies exploring novel techniques in the analyses of SPF trophic ecology.

In the first meeting of the WGSPF in 2020, members defined five topics related to SPF trophodynamics as top priorities for study:

Topic 1 - Compile and analyse information on temporal and spatial variability of predation pressure, which can contribute to the estimation of natural mortality of SPF; Topic 2- Study SPF through predators' diets, namely abundances and distribution patterns based on consumption; Topic 3 - Examine how changes in zooplankton affect SPF, particularly changes in species biomass composition and size distributions, and focusing particularly on the larval stage; Topic 4 - Examine changes in the flow of energy and organic matter (i.e. trophic transfer efficiencies)

through SPF-dominated foodwebs, using models and biochemical tracers (stable isotopes, fatty acids). Topic 5 – Consider whether intraguild predation and competition are significant factors in SPF population dynamics and investigate the spatial scale of these interactions by examining the spatial and temporal overlap between predators and prey.

After defining the topics considered important gaps in our understanding of the trophodynamics of SPF, researchers interested in these topics and available databases were identified.

AG 4 sponsored Session 1 of the International Symposium on Small Pelagic Fish which included 27 oral communications and 16 posters on the trophodynamic processes involving SPF. Trophodynamic studies from 13 geographic regions were discussed, including areas in the North Atlantic (NE Atlantic, Baltic Sea, North Sea, Iberian Atlantic waters, Canary Current, and Mediterranean), South Atlantic (Patagonia shelf), North Pacific (California Current, Gulf of Alaska, Bering Sea, Kuroshio Current) and South Pacific (Humboldt Current). Six studies involving global scale comparisons were initiated as a result of AG 4 of the WGSPF and presented at the symposium; using stable isotopes or foodweb models to compare the structure of the pelagic foodwebs, studying predator–prey size relationships in SPF, and reviews on larval feeding ecology and the accumulation and diversity of contaminants and trophic parasites in SPF. The number of contributions on SPF as predators was higher than those studying SPF as prey, and those focusing on the trophic ecology of adults were higher than for larvae. Larval feeding ecology of SPF was recognized as an important gap in our knowledge. The combination of traditional stomach analysis and new techniques has allowed increased specificity of SPF diet, namely for easily digested organisms, such as gelatinous zooplankton and teleost eggs, now being detected in stomachs by DNA metabarcoding. Techniques to study the feeding intensity of SPF have also shown potential to identify spatial and temporal trends in feeding dynamics. As a result, next steps of activity 4 will include increasing knowledge of topics such as SPF as prey and SPF larval feeding ecology by promoting comparative studies benefiting from the global community of experts involved in this WG activity.

Diet studies on SPF and their predators remain particularly relevant and timely to document long-term trends related to climate change and as necessary inputs to ecosystem models. Many techniques are now being combined to understand the trophodynamics of SPF such as stomach content, stable isotopes and fatty acid analyses as well as DNA metabarcoding. A goal of the WG is to standardize and bring together these diverse datasets into an open database for use in cross-regional comparative studies and ecosystem models in future. Future changes in predator–prey interactions depend on a complex array of individual factors affecting physiological rates and the strengths of associations between species. Although aspects of the trophodynamics of SPF have been studied for decades, gaps in knowledge still exist on important aspects of SPF diets, including prey quality requirements for the growth and survival of early life stages, ontogenetic diet shifts, and feedback between the changes in prey field dynamics and reproduction.

Figure 4.2 Figure credit: Original artwork by João Bruno Leal Sousa, student in the Degree of Communication Design in ESAD, Portugal, and one of the 10 winners of the 2021 edition of the contest "SARDINHAS DE LISBOA" promoted by EGEAC, Portugal. Modified by S. Garrido.

This activity produced several scientific outputs (see corresponding section), including five papers stemming directly from the WG (Fonseca *et al*., 2024; Garrido *et al*., 2024; Jacobson *et al*., 2024; Ruzicka *et al*., 2024; Veríssimo *et al*., 2024), and 15 papers produced from the corresponding

session convened at the symposium (Fonseca *et al*., 2024; Gaichas *et al*., 2024; Giménez *et al*., 2024; Garrido *et al*., 2024; Gleiber *et al*., 2024a,b; Gunther *et al*., 2024; Hardy *et al*., 2024; Jacobson *et al*., 2024; Moyano *et al*., 2023; Ouled-Cheikh *et al*., 2024; Ruzicka *et al*., 2024; Thorvaldsen *et al*., 2024; Veríssimo *et al*., 2024; Wells *et al*., 2024).

Activity Group 5 (AG5): Internal and external drivers of growth, reproduction, and survival

Leads: Florian Berg (Norway), Martin Huret (France), Martin Lindegren (Denmark)

The aim of AG5 was to describe species and cross-regional variability of the life history traits of SPF, and to analyse the drivers causing this variability of including both internal (intrinsic) and external factors. We have focused on growth in response to density-dependent and environmental drivers.

Two datasets were compiled: 1) Growth rates from experiments and their metadata, and 2) Field data (survey or assessment) on variables such as size-, weight- and abundance-at-age and their associated environment. The experimental dataset consists of growth-rate data from 40 different experiments on six species (Figure 4.3). The field dataset gathered information on 31 stocks of European, Japanese and Californian sardine and anchovy, as well as European herring (Figure 4.4). Environmental data corresponding spatially to the different stocks were extracted from available dataset. SEAPODYM was the most consistent dataset, being global so available for most of the stocks, and providing both temperature and food as zooplankton biomass.

The growth data were explored by either statistical meta-analysis or bioenergetics modelling. For the experimental data, preliminary results based on GAMs highlight the effect of temperature on the growth rate, but also some density-dependent effects, which should be avoided when conducting experiments. Density-dependence was also highlighted when applying GAMs to the field dataset and across stocks, with a significant negative, non-linear effect of total abundance on growth. There was also a dome-shaped response to temperature, and saturating effect of the zooplankton concentration. Finally, a Dynamic Energy Budget (DEB) model applied to European anchovy and sardine, and forced by the environment, revealed that regional food and temperature explained part of the observed positive latitudinal gradient in growth in the Atlantic, and of the positive east to west gradient in the Mediterranean Sea.

The next step is the preparation of a publication that will attempt to integrate the analysis from our different approaches (experimental, statistical, mechanistic) and focus on their respective and complementary contributions in the improved understanding of the drivers of growth in SPF.

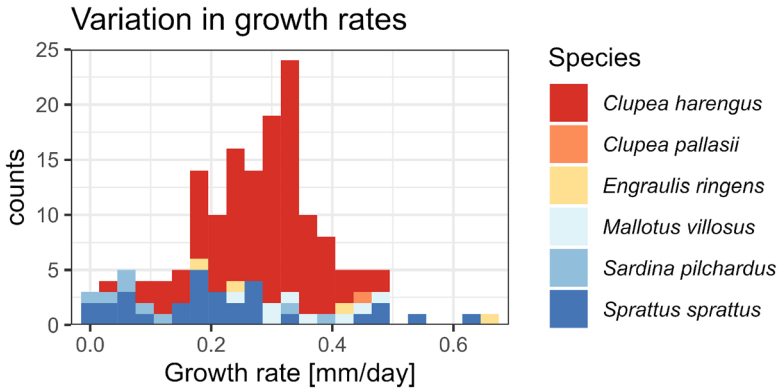

Figure 4.3 Distribution of growth rates from experiments across 6 species.

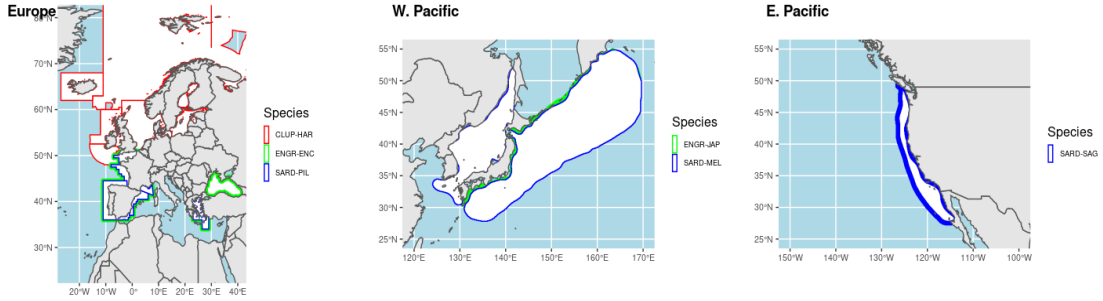

Figure 4.4 The 31 stocks of European anchovy, sardine and herring, Japanese anchovy and sardine, and Californian sardine for which a trait database was built.

The products generated in AG 5 included: 1) A dataset on growth experiments on selected species, 2) A dataset based on field data of growth and reproductive traits, 3) Collaboration with Activity Group 2 in the convening of Session 2 of the 2022 SPF Symposium in Lisbon: 'Life cycle closure: advances in life cycle closure' by Motomitsu Takahashi, Noelle Bowlin, Martin Huret and Ignacio Catalan, 4) Poster in session 2 of the SPF Symposium: Martin Lindegren *et al.* 'A cross system comparison of internal and external forcing regulating growth of Small Pelagic Fish throughout ontogeny', 5) Poster in session 2 of the SPF Symposium: Florian Berg *et al.* 'Understanding the underlying mechanisms affecting growth of small pelagic fish. An experimental meta-analytical approach'.

4.2 TASK FORCE 2: TRANSLATING PROCESS KNOWLEDGE

Activity Group 6 (AG6): Survey design and monitoring

Leads: Matthias Kloppmann (Germany), Chris Rooper (Canada)

The primary goal of AG6 was to organize a community of scientists who were active in conducting surveys to assess small pelagic fish abundance and distribution from different regions across the globe. This goal was realized by addressing two actionable objectives; 1) review and compile metadata and descriptions of existing monitoring surveys for SPF, and 2) examine current methodologies and potential advances in monitoring SPF through a topic session and a workshop during the 2022 Small Pelagic Fishes Symposium held in Lisbon, Portugal.

To date, metadata has been generated for 77 monitoring surveys across the globe. The majority of surveys identified to date has been from the northern hemisphere (Figure 4.5). The majority

of surveys target sprat (genus *Sprattus*), herring (genus *Clupea*), anchovy (genus *Engraulis*) and sardine (genus *Sardina*). Surveys of adult and juvenile stages of SPF used primarily some combination of fisheries acoustics and capture technology (e.g. fisheries acoustics combined with seine catches for target verification for Pacific herring in Alaska, Figure 4.6). Early life history stages are generally surveyed using plankton nets (e.g. sardine egg surveys in Australia). Mostly, these monitoring surveys have focused on commercially important species and areas with high-value fisheries.

During the ICES/PICES/FAO Symposium held 11-14 November 2022 there was a workshop titled "Recent Advances in the Daily Egg Production Method (DEPM): Challenges and Opportunities" and a topic session titled "Progress in Pelagic Surveys: From Biomass Estimates to Monitoring Ecosystems" led by members of Activity Group. In the workshop there were 15 oral presentations and a wide ranging discussion of global use of DEPM to estimate SPF spawning biomass. At the topic session there were 27 oral presentations and 21 poster presentations (17 by early career scientists). The topics covered a range of monitoring programs and research (Figure 4.7). Of particular note were a number of presentations that advanced monitoring using commercial fisheries vessel acoustics and the advances in analyses techniques that allow better estimation of SPF abundance. Two manuscripts arising out of the workshop and topic session were published in a Special Collection of the Canadian Journal of Fisheries and Aquatic Sciences (Gaichas *et al*. 2023, Citores et al. 2024) (See Products list).

This activity has spawned a number of ongoing collaborations that are expected to continue after the expiration of the activities official term. Members are currently working to draft a review manuscript that synthesizes some of the lessons learned and potential future research avenues regarding small pelagic fish surveys. Some of the topics that may be addressed by this manuscript would be the timing of surveys relative to phenology of things like spawning and feeding migrations, net selectivity, non-stationarity of fish distribution, modelling approaches and new and emerging technologies (e.g. eDNA and sail drones). In 2024 at the PICES annual meeting there will be a topic session "Advances in observational, analytical, and modelling tools that lead to better observations and improved understanding of small pelagic fish" that was inspired by collaboration among members of this group. In future we also hope to organize a workshop that looks at ways to incorporate or use acoustic data collected on commercial fishing vessels to assess small pelagic fishes. These ongoing and planned activities highlight the importance of the initial engagement and community building undertaken by Activity Group 6 to bring together researchers interested in surveying and monitoring small pelagic fishes.

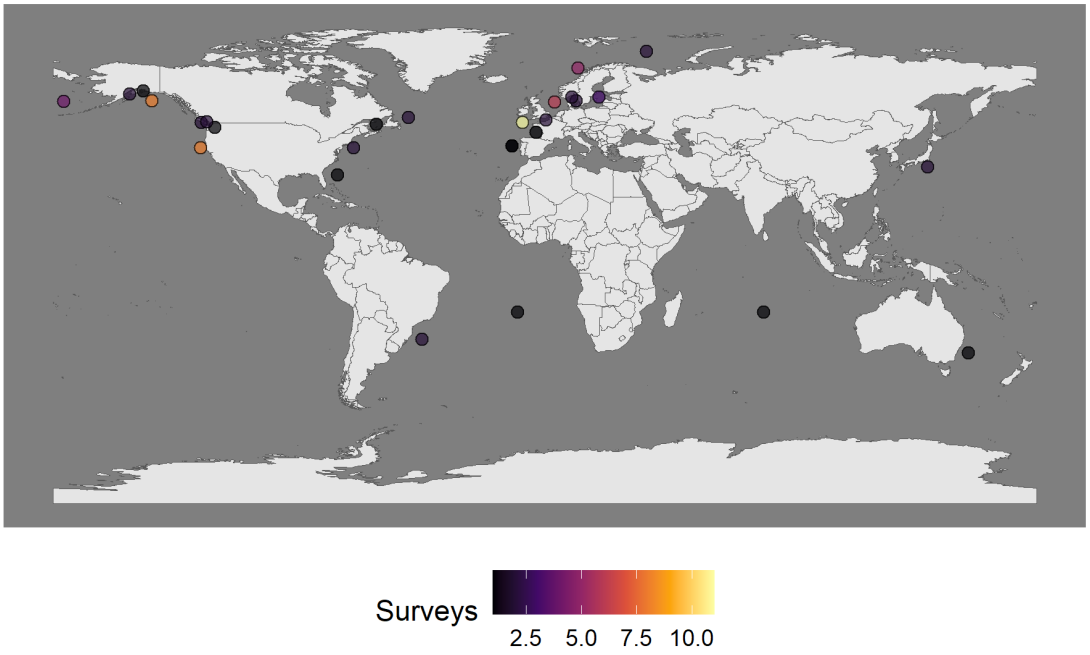

Figure 4.5 Location of small pelagic fish surveys and monitoring programs (n = 77) included in the metadatabase compiled by Task Force 2, Activity 6.

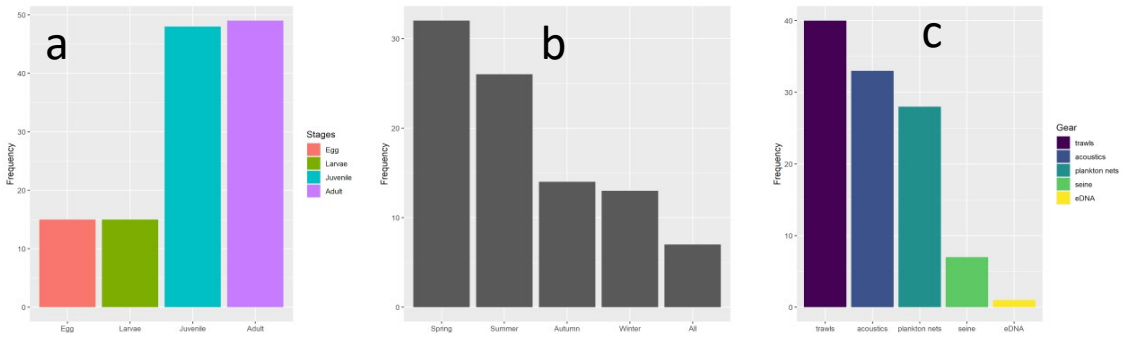

Figure 4.6 Frequency of surveys and monitoring programs addressing egg, larval, juvenile and adult life history stages (a), frequency of surveys and monitoring programs conducted by season (b) and predominant gear types used to survey small pelagic fishes. Data are compiled from the Task Force 2, Activity Group 6 survey and monitoring program metadatabase.

Figure 4.7 Word cloud that represents topics from presentation and poster abstracts in Topic Session 5 of the 2022 Small Pelagic Fishes Symposium in Lisbon, Portugal.

Activity Group 7 (AG7): Improving short term forecasts and/or long-term projections

Leads: Stefan Koenigstein (USA), Ryan Rykaczewski (US)

Discussion of efforts to apply oceanographic or ecological models to make forecasts of SPF population characteristics and their response to climate change motivated formation of Activity 7 within Task Force 2. This group of scientists familiar with ocean circulation and ecosystem models censused the efforts to forecast SPF populations in different marine ecosystems with the objective of better understanding the various mechanisms that may confer predictability of SPF populations, advancements in these efforts, and challenges to improving these models. Comparing the approaches applied and the challenges faced by those working on similar issues around the globe will help the community improve forecasts of SPF populations and their response to climate change and variability.

To support these objectives, WGSPF organized a number of sessions at meetings. At the 2022 symposium in Lisbon, the leads of Activity Group 7 were co-conveners of Session 4 titled "Responses to Climate Variability and Change at Decadal to Centennial Time-scales." The session attracted 29 presentations (both oral and poster). In addition, Activity Group 7 leads co-convened Workshop 2 on modelling approaches, titled "The Devil's in the Details of Using Species Distribution Models to Inform Multispecies and Ecosystem Models" that had four oral presentations and a poster. These two events at the symposium stimulated rich conversation about different approaches to investigate the links among climate processes and the SPF populations (both their population size, connectivity among stocks and subpopulations, spatial distribution, and competition among species). The working group meeting that followed the symposium allowed members to continue the discussion and inspired a manuscript currently in development (mentioned below).

AG7 co-leads and members also co-convened Session 3 at the 2023 PICES Annual Meeting in Seattle. The session was titled "Responses of small pelagic fish to extreme events in Pacific ecosystems." This session was co-convened with members of PICES WG49 on Climate Extremes and Coastal Impacts in the Pacific, and the session attracted 10 presentations from around the ocean basin.

Building on the discussions at the Lisbon symposium, Activity Group 7 members have continued to develop a manuscript that highlights the advances and challenges to apply oceanographic or ecological models to make predictions (shorter term) or projections (longer term) of SPF characteristics. In addition to the potential to offer useful forecasts, use of numerical ocean models allows integration multidisciplinary data in a quantitative fashion and helps to identify observational and experimental data needs (by highlighting processes that are either poorly constrained or highly influential). This manuscript will make use of case studies contributed from around the globe to illustrate the following advantages of modelling approaches:

- ability to quantify environmental links of recruitment and other population processes;
- potential to improve understanding of population regulation, density-dependence, and reasons for SPF boom and bust (each contributing to non-linearities and threshold responses in populations);
- ability to better quantify links between plankton dynamics and food availability for SPF;
- developing better understanding of foodweb links to competitors and predator stocks; and

- improved prediction of spatial distributions (i.e. range shifts, variations in phenology) that consider the influence of population abundance/biomass and connectivity among substocks.

In addition to this manuscript in preparation that is a direct result of WGSPF discussions, there are articles contributed to the Theme Section "Small pelagic fish: new research frontiers" in *Marine Ecology Progress Series.* Currently, one article is In Press (Takahashi M, Higuchi T, Shirai K, Ito Si, Yoda M. 2024. Interdecadal variabilities in growth and temperature trajectories of *Trachurus japonicus* juveniles: 1960s–1970svs.2000s–2010s) and a second article is under review (See Products section)

Activity Group 8 (AG8): Improvements to management

Leads: Salvador Lluch-Cota (Mexico), Richard Nash (UK), Andrés Uriarte (Spain), Isaak Kaplan (US)

Activity Group 8 has involved the participation of scientists from different regions, mostly ICES and PICES Member Countries. A first phase of work started in July 2020 and ended with the November 2022 ICES/PICES/FAO symposium in Lisbon. During that conference, AG8 leaders supported a Workshop on economics and fleet responses to stock variability (29 participants, 4 presentations), and another on coupling species distribution models to complex ecosystem models (30 participants, 4 presentations). Manuscripts related to these two workshops are in progress. Also, 16 participants of AG8 met during the conference to revise the work plan. Attendees included Pierre-Hernvann, Martin Pastoors, Cecilie Hansen, Laura Wise, Carryn de Moor, Margarita Rincon, Maria José Zuñiga, Toshi Kitaka, Alfonso Perez, Mariano Sergio Gutierrez Torero, and the four coordinators, Richard Nash, Isaac Kaplan, Andrés Uriarte, and Salvador E. Lluch-Cota.

Since the Lisbon conference, the AG8 work is organized around two main (complementary) topics: 1) which is the best strategy to manage the highly variable and productive populations of small pelagic fish, and 2) how can climate variability and change be integrated into the Management Strategy Evaluation (MSE).

The first part of the strategy has been identifying, documenting, and discussing management schemes for small pelagic fish, and the metrics and candidate models that can be used to compare their performance. Management schemes of interest include in-season reactions, threshold harvest control rules, empirical harvest control rules, trend-based indicators, rules for management across stock and jurisdictional boundaries, and several ideas from the ICES Workshop on Data Limited Stocks of Short Lived Species (WKDLSSLS). Models that are being used in the analyses include FLBEIA, Atlantis models for the California Current and Nordic and Barents Seas, and single-species MSEs for South Africa. These span the range of MSE options including full MSEs and those that assume 'shortcut' perfect assessments, as well as those that apply empirical harvest rules (relying on observations rather than statistical stock assessments).

For the second topic, on how can climate change and environmental variability be integrated into the MSE, the goal has been to compare the value of simple vs. complex models, including variability driven by physical and biological factors (e.g. trophic interactions), and ways to deal with recruitment variability within the MSE.

During 2023, main activities were carried out on an institutional and regional basis. Some of this research, submitted to publication in scientific journals, reports on rules that adjust reference points to stock productivity and their performance, simulated recruitment regimes as related to environmental indices, and multispecies and ecosystem considerations that are increasingly

being considered within harvest control rules (HCRs). Some of these papers are included in the CJFAS Special volumes stemming from the Lisbon symposium (see Products list), including Wildermuth et al. (2023), Quezada *et al.* (2023), de Moor *et al*. (2023)., Schiano *et al*., (2023). Other products included: a) Ibaibarriaga, L. Citores, D. Garcia, L. Wise, I. Riveiro, S. Sánchez-Maroño, A. Silva and A. Uriarte: Regime-shifts for Iberian sardine: a multi-model approach. Oral presentation to the ICES ASC 2023, Theme Session P, 11-14 September, Bilbao (Spain). Manuscript in preparation., b) Andrés Uriarte, Leire Citores, Leire Ibaibarriaga, Isabel Riveiro, Sonia Sánchez-Maroño, Laura Wise, Alexandra Silva. 2023. Dynamic harvest control rules based on recruitment levels to manage stocks of uncertain productivity: application to Iberian sardine. Oral presentation to the ICES ASC 2023, Theme session O "A region to be managed: The case of the Bay of Biscay and the Iberian Coast under environmental and socio-economic stressors".

Some of the AG8 members (C. Hansen, R. Nash and A. Uriarte) have acted as editors of the special volume of the Canadian Journal of Fisheries and Aquatic Science compiling contributions related to this Activity (the special issue entitled "Small Pelagic Fishes: New Frontiers in Science for Sustainable Management"), and I. Kaplan acted as editor for the special volume of the Marine Ecology Progress Series, entitled "Small pelagic fish: new research frontiers."

4.3 TASK FORCE 3: SOCIAL-ECOLOGICAL APPROACHES

This Task Force had fewer activities than either Task Force 1 and Task Force 2. It was challenging to recruit members with social-economic expertise from both the PICES and, to a lesser extent, ICES areas. The membership of Activity Groups in Task Force 3 has been enhanced after the ICES-PICES-FAO symposium in Lisbon and it is envisioned that work will increase in the planned second phase of this joint ICES-PICES working group. The topics addressed by activities in Task Force 3 are considered to be extremely important by WGSPF members and some activities can be reported.

Activity Group 9 (AG9): Networks, vulnerability, and opportunities of dependent human communities

Lead: Myron Peck (The Netherlands)

AG9 organized a session at the ICES-PICES-FAO symposium in Lisbon (S7) to discuss advancements in socio-ecological analyses and sustainable policies for dependent human communities. That session had presentations on the reliance of coastal communities on SPF for nutrition, food security, and employment and how to advance the management and governance arrangements impacting access to SPF resources. Discussions highlighted recent trends in processing, marketing and use of SPF (e.g. reduction for feed, changes in value chains, economic tipping points) and reported on climate vulnerability assessments and adaptation measures. The seven oral presentations and a poster presentation highlighted contrasting perspectives of fishers and fisheries managers in the effectiveness of regulations and in addressing changes in SPF stocks due to climate variability. The adaptiveness of fishing communities after changes in SPF productivity was also discussed with an example from the Bay of Biscay and for the Pacific coast of the United States (e.g. Quezada et al. In Press CJFAS). A take home message from S9 was the need for more "well-worked" examples of SPF management that take into account vulnerability in human communities. Taking a holistic, "food systems approach" including all types of SPF fisheries is needed to understand the role of SPF in social-ecological systems. The session ended with a plea to increase the number of members in WGSPF with a social science background.

A half-day workshop was also organized that addressed the equitable distribution and nutritional benefits of SPF. That session included a presentation on the recent FAO technical report on SPF food systems (Bavinck *et al.*, 2023). The workshop focused on topics such as how SPF are embedded in diets and cultures of local communities (and related socio-economic benefits) and the high demand of SPF for fishmeal production and what is needed to ensure the equitable distribution of the livelihood and nutritional benefits of these species. This workshop summarized the impacts of unsustainable / non-equitable harvest strategies of SPF on vulnerable consumer groups emphasis on SPF supply chains in African communities.

Activity Group 10 and 11 (AG10, AG11): Quantifying trade-offs in goods and services; Bioeconomic modelling

Leads: Cecilie Hansen (Norway), Isaac Kaplan (US), Myron Peck (Netherlands)

Small pelagic fish are challenging to manage and to model, due to the large fluctuations in their abundance and distribution. While the complexity and processes in ecosystem models may be sufficient for simulations of the small pelagic fish behaviour, the economic modules associated with these models usually lack the details needed for economic analysis. Similar, bioeconomic models tend to lack the sufficient resolution of the ecosystem. To be able to estimate the consequences of the high variability and management suggestions on the whole system, including society, a connection between these model systems is needed.

A potential solution to bride large complex ecosystem and bioeconomic models, is put forward by Ni *et al*. (2023), where an end-to-end ecosystem model (NoBa Atlantis) is used to train a neural network to represent ecosystem dynamics necessary for the bioeconomic analyses. The harvest levels resulting from the training was fed back into Atlantis, opening for the possibility of exploring ecosystem effects on components not used in the training of the network.

Although the proposed solution is a step forward, there are many knowledge needs. Recruitment cycles, overlap and interaction with predator and prey species, responses to climate change (adaptability, avoidance, severity of response) and to other anthropogenic impact (e.g. fisheries, pollution, noise), are among these.

AG10 organized a session (S6) at the ICES-PICES-FAO symposium on reconciling the ecological roles and harvest goals by developing and testing management strategies to enhance marine ecosystem services. It is critical that management of SPF consider ecological, economic, as well as social roles of these resources. Natural, environmentally driven fluctuations pose an additional challenge, and S6 focused on management approaches that ensure (or attempt to balance) harvest, forage provision, and other ecosystem services. The main tool was ecosystem modelling and management strategy evaluation (as discussed by Lujánet *al.*, 2023) to test spatial management, improved monitoring and recruitment forecasts, or alternative harvest strategies. The aim was to identify success stories from particular regions (e.g. deMoor *et al*. 2023), with careful consideration about how that success can be replicated in other regions. Several publications on these topics resulted this session (see section 7).

5 The Small Pelagic Fish Symposium (ToR e)

Figure 5.1 Symposium banner ad (PICES press 31 (1), 2023).

The completion of ToR e involved the organization of an international symposium on small pelagic fish, which took place on 7–11 November 2022 in Lisbon and was entitled "Small pelagic Fish. New Frontiers in Science and Sustainable Management". The symposium details and abstracts can be found in this link[4]. Furthermore, a comprehensive review of the symposium can be found in the PICES press[5]. We here offer a summary of the key facts from the symposium.

The symposium, and its derived products in form of special volumes (see corresponding section), was one of the main outcomes of the WGSPF. The symposium gathered a large community of scientists and managers who aimed to improve the ecological understanding, management, and future status of these keystone populations. This scientific community had last met in 2017, in Victoria, Canada. The 2022 symposium was a perfect opportunity to advance that theme of international collaboration. Lisbon was an extraordinary setting for this meeting, as the interests of the symposium's participants were matched by the prominence of SPF, particularly sardine, in the culture of Portugal. The artwork, cuisine, and history of the region served as persistent reminders of the significant role that SPF can play in ecological and socio-economic communities.

The symposium was hosted by the Portuguese institute for Sea and Atmosphere (IPMA), and it received a substantial amount of co-sponsorship, including 20 companies or organizations, with the primary international organizations being PICES, ICES and FAO. The event was co-convened by M. Peck (ICES), A. Takasuka (PICES), I. Catalán (ICES), R. Rykaczewski (PICES) and S. Garrido (ICES). The latter was the local host from IPMA (Figure 5.2).

Briefly, the symposium attracted 288 participants from 39 countries and 4 international organizations (PICES, ICES, FAO and NPFC). Scientists came from six continents: Australia – 5, Africa – 18, Europe – 168, Asia – 36, North America – 47, and South America – 15, with 47 participants being from developing countries. Participation of experts in climate, physical oceanography, zooplankton, fisheries biology and socio-economic clearly indicated the interdisciplinary nature of research on SPF. The group was nearly gender-balanced (47% female, 53% male), with a substantial portion of the attendees identifying as early career scientists (44%).

[4] PICES, Symposium webpage, last accessed 14 February 2024. https://meetings.pices.int/meetings/international/2022

[5] PICES Press 31 (1), 2023. Last accessed 14 February 2024. https://meetings.pices.int/publications/pices-press/PICES-Press-2023-Vol31No1.pdf

Figure 5.2 The co-convener of the symposium; From left to right, A. Takasuka, R. Rykaczewski, S. Garrido, I. Catalán and M. A. Peck.

The symposium was organized around seven sessions for oral presentations revolving around bottom–up created topics by the international community, and mediated through WGSP meetings, six workshops that took place prior to the symposium official start, and a poster session (Table 5.1). Morning plenary sessions on November 8–10 provided overarching keynote presentations and introduced topics for the concurrent sessions that were convened that day. Note that most of the Sessions correspond to one or more activities in which the ToRs were organized, thus providing a good match between the WGSPF scientific goals and the Symposium goals.

In total, there were 278 presentations at the symposium, including 14 plenary talks, 7 invited and 173 contributed talks, and 84 posters, which were discussed thoroughly during an evening poster-viewing session.

Table 5.1 Scientific structure of the Symposium, including conveners. For the sessions, cross-reference to the Activities (AG1-AG6) from the WGSPF is highlighted.

Type of session	Topic	Conveners
	Sessions	
Session 1 (AG4)	Trophodynamic processes	Susana Garrido, Richard Brodeur, Jana del Favero, Francis Juanes, Tatsuya Sakamoto
Session 2 (AG2-AG5-AG1)	Life Cycle Closure: Advances in Process Understanding	Ignacio A. Catalán, Noelle Bowlin, Martin Huret, Motomitsu Takahashi.
Session 3 (AG3)	Understanding Population- and Ecosystem-level Shifts: From Seasonal Timing to Tipping Points	Rebecca Asch, Matthew Baker, Jennifer Boldt, Patrick Polte
Session 4 (AG7)	Responses to Climate Variability and Change at Decadal to Centennial Scales	Ryan Rykaczewski, Dimitri Gutierrez, Hakura Nishikawa, Renato Salvatteci
Session 5 (AG6)	Progress in Pelagic Surveys: From Biomass Estimates to Monitoring Ecosystems.	M. Manuel Angelico, Chris Rooper, Jeroen van der Kooji, Tim Ward
Session 6 (AG10)	Reconciling Ecological Rules and Harvest Goals: Development and Testing Management Strategies to Enhance Marine Ecosystem Services.	Sarah Gaichas, Cecilie Hansen, Isaac Kaplan, Richard Nash

Session 7 (AG9, AG11)	Advancing Social-ecological Analyses and Sustainable Policies for Human Communities Dependent on SPF.	Tarûb Bahri, Maria Gasalla, Mitsutaku Makino, Myron A. Peck
Poster Session		
Poster session	It included contributions from all sessions	Common venue and discussion
Workshops		
Worshop 1	Application of Genetics to Small Pelagic Fish	Ana Veríssimo, Malika Chlaida, Jan McDowell and Rita Castilho
Workshop 2 (AG7, AG8)	The Devil's in the Details of Using Species Distribution Models to Inform Multispecies and Ecosystem Models	Isaac Kaplan, Elliott Hazen, Robert Wildermuth, Stefan Koenigstein, Mariana Hill-Cruz, Pierre-Yves Hernvann and Barbara Muhling
Workshop 3	Small Pelagics for Whom? Challenges and Opportunities for the Equitable Distribution of Nutritional Benefits.	Molly Ahern, Maarten Bavinck, Marian Kjellevold and Jeppe Kolding
Workshop 4 (AG8)	Evaluating Inter-Sectoral Trade-offs and Community-Level Response to Spatio-Temporal Changes in Forage Distribution and Abundance.	Desiree Tommasi, Felipe Quezada Escalona, Isaac Kaplan, Dorleta Garcia and Robert Wildermuth
Workshop 5 (AG6)	Recent Advances in the Daily Egg Production Method (DEPM): Challenges and Opportunities.	Andrés Uriarte, Tim Ward, Cristina Nunes, Luis Cubillos and Kostas Ganias
Workshop 6 (AG2,AG1)	Small Pelagic Fish Reproductive Resilience.	Rosario Dominguez-Petit, Susan Lowerre-Barbieri, Leonardo Castro and Akinori Takasuka

A Symposium resolution has been sent to ICES seeking for support for the 2026 SPF symposium that will take place in La Paz, Mexico. ICES has already endorsed the symposium, and PICES has approved a resolution supporting it and committing funds.

6 Special volumes and perspective paper

The Symposium produced two special volumes, one in Marine Ecology Progress Series (MEPS) and one in Canadian Journal of Fisheries and Aquatic Sciences (CJFAS). The details of these special volumes are provided below, and the publications are listed in the Products list section.

Marine Ecology Progress Series (MEPS), Theme Section "Small pelagic fish: new research frontiers"

This Theme Section includes contributions from the 2022 international (ICES, PICES, FAO) symposium on "Small Pelagic Fish: New Frontiers in Science for Sustainable Management".

Editors: Myron A. Peck, Ignacio Catalán, Susana Garrido, Ryan Rykaczewski, Rebecca Asch, Jan McDowell, Elliott Hazen, Isaak Kaplan.

Metrics as of 14 February 2024:

Number of submissions: 24. Accepted papers 14; Rejected, 4; Withdrawn, 2; In review (several stages) 4; Available online 7 (https://www.int-res.com/journals/meps/theme-sections/spf2).

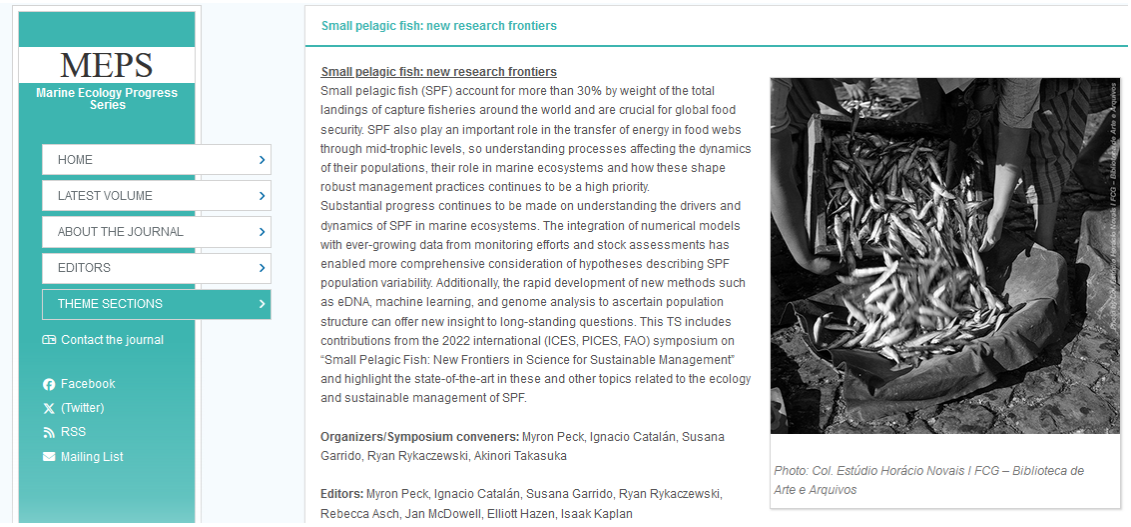

Figure 6.1 MEPS special volume on the symposium, in process.

Canadian Journal of Fisheries and Aquatic Sciences (CJFAS), Special Issue

This Special Issue includes contributions from the 2022 international (ICES, PICES, FAO symposium on "Small Pelagic Fish: New Frontiers in Science for Sustainable Management")

Figure 6.2 CJFAS special volume on the symposium, in process.

Editors: Chris Rooper, Jennifer Boldt, Sarah Gaichas, Cecile Hansen, Richard Nash, Andrés Uriarte, Tim Ward.

Metrics as of 23 February 2024:

Number of submissions: 17 Accepted papers; 7 Available online.

Currently, a perspective paper on the advances on small pelagic fish research derived from the WGSPF is being produced. The initial draft was finalized in La Paz, Mexico, on February 15. It is expected that it will be submitted before May 2024. Further, two introductory papers to both special volumes (MEPS, CJFAS), coauthored by the Guest Editors are being finalized.

7 Products list

This section lists peer-reviewed papers acknowledging the WG (*), and those published in the special volumes from the symposium but not acknowledging the WG (**). It also includes subsections on press notes and other publications.

7.1 Peer-reviewed papers

7.1.1 Papers in the Special Volume of MEPS:

* Acknowledge WGSPF, **WGSPF not acknowledged but authored by WG members

Accepted (available online)

1. Rooper CN, Boldt JL, Cleary J, Peña M, Thompson M, Grinnell M. Evaluating factors affecting the distribution and timing of Pacific herring Clupea pallasii spawn in British Columbia. MEPS SPF2: AV1 | Full text in pdf format (*)
2. Wells BK, Santora JA, Bizzarro JJ, Billings A, Brodeur RD, Daly EA, Field JC, Richerson KE, Thorson JT. Trophoscapes of predatory fish reveal biogeographic structuring of spatial dietary overlap and inform fisheries bycatch patterns. MEPS SPF2: AV2 | Full text in pdf format (**)
3. Gunther KM, Baker MR, Aydin KY. Using predator diets to infer forage fish distribution and assess responses to climate variability of the eastern Bering Sea. MEPS SPF2: AV3 | Full text in pdf format (**)
4. Maathuis MAM, Couperus B, van der Molen J, Poos JJ, Tulp I, Sakinan S. Resolving the variability of habitat use by juvenile small pelagic fish in a major tidal system by continuous echosounder measurements. MEPS SPF2: AV4 | Full text in pdf format (*)
5. Thorvaldsen KG, Neuenfeldt S, Mariani P, Nielsen JR. Hiding in plain sight: predator avoidance behaviour of mesopelagic Maurolicus muelleri during foraging. MEPS SPF2: AV5 | Full text in pdf format
6. Fonseca P, Barata M, Castanho S, Pousão-Ferreira P, Garrido S. Effect of diet composition and temperature on the gastric evacuation rate of European sardine: implication for egg predation estimates. MEPS SPF2: AV6 | Full text in pdf format (*)
7. Luján C, Oliveros-Ramos R, Barrier N, Leadley P, Shin YJ. Key species and indicators revealed by an uncertainty analysis of the marine ecosystem model OSMOSE. MEPS SPF2: AV7 | Full text in pdf format

Papers Accepted but not yet available online.

8. Veríssimo A, Fonseca P, Garrido S. Molecular barcoding reveals patterns of egg predation in small pelagic fish. Prepress abstract | Small pelagic fish: new research frontiers (*)
9. Ruzicka J, Chiaverano L, Coll M, Garrido S, Tam J, Murase H, Robinson K, Romagnoni G, Shannon L, Silva A, Szalaj D, Watari S. The role of small pelagic fish in diverse ecosystems: knowledge gleaned from foodweb models. Prepress abstract | Small pelagic fish: new research frontiers (*)
10. Berg F, Seljestad G, Folkvord A. Growth of spring- and autumn-spawned larvae of Atlantic herring (Clupea harengus); results from a long-term experiment mimicking seasonal light conditions. Prepress abstract | Small pelagic fish: new research frontiers (*)
11. Jacobson KC, Marcogliese DJ, MacKenzie K. Parasites of small pelagics reflect their role in marine ecosystems. Prepress abstract | Small pelagic fish: new research frontiers

12. Garrido S, Albo-Puigserver M, Moyano M. Larval trophic ecology of small pelagic fishes: a review of recent advances and pathways to fill remaining knowledge gaps. Prepress abstract | Small pelagic fish: new research frontiers (*)
13. Takahashi M, Higuchi T, Shirai K, Ito Si, Yoda M. Interdecadal variabilities in growth and temperature trajectories of Trachurus japonicus juveniles: 1960s–1970svs.2000s–2010s. Prepress abstract | Small pelagic fish: new research frontiers (**)

Four additional manuscripts are still in review (decision pending).

7.1.2 Papers in Canadian Journal of Fisheries and Aquatic Sciences (CJFAS), Special Issue

14. Mäkinen, K., Rajasilta, M., Ruuskanen, S., Karpela, T., Lauerma, A.O. and Sahlstén, J. 2023. Effects of incubation temperature and maternal phenotype on Baltic herring (Clupea harengus membras) eggs and larvae: An experimental study. (https://doi.org/10.1139/cjfas-2023-0032)
15. Gaichas, S.K., Gartland, J., Smith, B.E., Wood, A., Ng, E., Celestino, M., Drew, K., Tyrel A.S. and Thorson, J.T. 2023. Assessing small pelagic fish trends in space and time using piscivore stomach contents. Canadian Journal of Fisheries and Aquatic Sciences (https://doi.org/10.1139/cjfas-2023-0093) (**)
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7.3 Events

- 2022 Symposium: "Small Pelagic Fish: New Frontiers in Science and Sustainable management" November 7-11, 2022[6].
- 2023 PICES Annual Meeting in Seattle; Session 3 "Responses of Small Pelagic Fish to Extreme Events in Pacific Ecosystems.", chaired by A7 co-leads[7].

7.4 Databases

- Global Database on small pelagic fish surveys (in SharePoint, not publicly available yet, contact C. Rooper). Last accessed February 17.
- Dataset on growth experiments on selected species (in progress, contact F. Berg)
- Dataset based on field data of growth and reproductive traits (in progress, contact M. Huret)
- Dataset on phenology changes of several traits for 24 species (in progress, contact R. Asch)

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Annex 1: List of participants

Name	Institute	Country (of institute)
Akinori Takasuka	University of Tokyo	Japan
Alba Serrat Llinas	University of Girona	Spain
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Ana Sabatés	ICM-CSIC	Spain
Andre Lima	ISPA	Portugal
Andrés Ospina-Álvarez	CSIC-IMEDEA	Spain
Andrés Uriarte	AZTI	Spain
Angela Muench	Cefas	UK
Anna Akimova	Thünen-Institut	Germany
Annegret Finke	Thünen-Institut	Germany
Arild Folkvord	UiB	Norway
Arnaud Bertrand	IRD	France
Benoit Berges	WUR	The Netherlands
Carl van der Lingen	Retired	South Africa
Carryn de Moor	University Cape Town	South Africa
Cecilie Hansen	IMR	Norway
Cesar Villanoy	University of Sydney	Australia
Chris Rooper	DFO-MPO	Canada
Christian M. Canales Ramirez	PUC Valparaiso	Chile
Cristina Nunes	IPMA	Portugal
Daniel Grados	IMARPE	Peru
Dimitri Gutuerrez-Aguillar	IMARPE	Peru
Dohoon Kim	Pukyong University	South Corea
Dominique Robert	UQAR	Canada
Douglas Gherardi	INPE	France
Elena Ojea	University of Vigo	Spain

Erich Diaz	IMARPE	Peru
Ernesto Jardim	MSC	Belgium
Fabien Moullec	NIOZ	The Netherlands
Fabienne Daures	Ifremer	France
Fei Chai	SIO	China
Fernando Ramos	IEO-CSIC	Spain
Florian Berg	IMR	Norway
Francis Juanes	University of Victoria	Canada
Giannina Passuni	University of Hamburg	Germany
Goncalo Silva	ISPA	Portugal
Guillem Chust	AZTI	Spain
Hannah Murphy	DFO	Canada
Hans Sloterdijk	University Kiel	Germany
Haruka Nishikawa	JAMSTEC	Japan
Henn Ojaveer	ICES	Denmark
Hui Zhang	IOCAS	China
Iain Suthers	UNSW	Australia
Ignacio Catalan	CSIC-IMEDEA	Spain
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Isaac Kaplan	NOAA	USA
Isabel Riveiro	CSIC-IEO	Spain
James Ruzicka	NOAA	USA
Jana Menegassi del Favero	Freelance	Brazil
Jason Everett	UNSW	Australia
Jennifer Beckensteiner	University Brest	France
Jennifer Boldt	DFO	Canada
Jeroen van der Kooij	Cefas	UK
Joel K. Llopiz	WHOI	USA
Jorge Tam	IMARPE	Peru
José Bellido	CSIC-IEO	Spain

June Ferraz-Dias	University Sao Paulo	Brazil
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Laure Pecquerie	IRD	France
Leire Ibaibarriaga	AZTI	Spain
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Maria Manuel Angélico	IPMA	Portugal
Marianna Giannoulaki	HCMR	Grece
Mario Katsuragawa	University Sao Paulo	Brazil
Mark Payne	DTU	Denmark
Marta Albo	CSIC-IEO	Spain
Marta Coll	CSIC-ICM	Spain
Marta Moyano	NIVA	Norway
Martin Huret	Ifremer	France
Martin Lindegren	DTU	Denmark
Mary Gasalla	University of Sao Paulo	Brazil
Mathieu Doray	Ifremer	France
Matthew Baker	North Pacific Res Brd	USA
Matthias Kloppmann	Retired	Germany
Miguel Bernal	FAO	Rome
Minling Pan	NOAA	USA
Motomitsu Takahashi	FRA	Japan
Myron Peck	NIOZ	The Netherlands
Nadine Heck	ECU	USA
Nis Sand Jacobsen	DTU	Denmark
Noelle Bowlin	NOAA	USA
Olivier Thebaud	Ifremer	France
Patricia Ayón-Dejo	IMARPE	Peru

Patrick Polte	Thünen-Institut	Germany
Pierre Pepin	DFO	Canada
Raul Laiz	CSIC-IEO	Spain
Rebecca Asch	ECU	USA
Renato Nunes Rosa	University of Algarve	Portugal
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Sachihiko Itoh	University of Tokyo	Japan
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Shinichiro Nakayama	FRA	Japan
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Sukyung Kang	NFRDI	Korea
Sun Peng	Ocean University of China	China
Susana Garrido	IPMA	Portugal
Tarub Bahri	FAO	Rome
Tim Ward	University of Tasmania	Australia
Timothee Brochier	IRD	France
Toshihide Kitakado	Tokio University of Marine Sciences	Japan
Valerio Bartolino	Swedish University of Agricultural Sciences	Sweeden
Wilfredo Campos	University Philippines Vasayas	Philippines
Xabier Irigoien	AZTI	Spain
Xianshi Jin	Yellow Sea Fisheries Research Institute	China
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Yu Haiqing	OUC	China

Annex 2: Resolutions

Joint ICES-PICES Working Group on Small Pelagic Fish (WGSPF)

2019/FT/EPDSG05 A Joint **ICES-PICES Working Group on Small Pelagic Fish** (WGSPF), chaired by Myron Peck, Germany (ICES), Ignacio Catalan, Spain (ICES), Ryan Rykaczewski, USA (PICES), and Akinori Takasuka, Japan (PICES) will work on ToRs and generate deliverables as listed in the Table below.

	Meeting dates	Venue	Reporting details	Comments (change in Chair, etc.)
Year 2020	9-12 March	Copenhagen, Denmark	Final report by TBD	Intersessional meeting, funding mechanisms being explored. Location dependent on success of funding raising efforts.
Year 2020	22-30 October	Online meeting		(PICES AM)
Year 2021	10, 13-14 September	Online meeting		(ICES ASC)
Year 2021	18-29 October	Online meeting		(PICES AM)
Year 2022	Spring	TBA		Synthesis writing workshop planned (depending on successful funding applications)
Year 2022	September	TBA		(ICES ASC)
Year 2022	October	TBA		(PICES AM)

ToR descriptors

ToR	Description	Background	Science plan codes	Duration	Expected Deliverables
a	To review recent progress on understanding how various drivers (environmental and/or anthropogenic) impact the population dynamics of SPF in different ecosystems and whether and how potential drivers shift with changes in ecosystem state.	a) Science Requirements	1.2, 1.3, 2.2	4 years	Review paper(s) within peer-reviewed journal
b	Create a networking environment for international and multidisciplinary collaboration to foster the establishment of similar study frameworks and comparative analyses of SPF across different social–ecological systems, based on updated time-series datasets of climate indices, environmental factors and fisheries biology as well as	a) Science Requirements	1.9, 5.2	4 years	Meeting reports submitted to ICES/PICES, Perspective Paper(s) submitted to peer-reviewed journal(s)

	ecophysiological information (feeding, growth and survival).				
c	Identify, prioritize and conduct research most needed to advance our knowledge and capacity to predict the population dynamics of SPF at both short (seasonal to interannual) and long (decadal to centennial) time-scales.	a) Science Requirements	1.3, 7.6	4 years	Meeting reports submitted to ICES/PICES, Perspective Paper(s) submitted to peer-reviewed journal(s)
d	Recommend strategies of marine ecosystem monitoring and fisheries management of SPF which will contribute to sustainable ecosystem-based fisheries management, through biophysical, ecosystem and/or socio–economical models.	a) Science Requirements	2.5, 3.1, 4.1	4 years	Meeting reports submitted to ICES/PICES, Perspective Paper(s) submitted to peer-reviewed journal(s)
e	Propose topic sessions at PICES Annual Meetings and ICES Annual Science Conferences focused on advances in SPF science and to organize a joint ICES/PICES symposium on SPF at regular intervals (e.g. once every 4 years) leading to the publication of findings in special issues of primary journals.	a) Science Requirements	NA	4 years	Joint ICES-PICES theme sessions. An International ICES-PICES SPF symposium (follow-up to March 2017 Victoria meeting) Special issue(s) in peer-reviewed journal(s)

Summary of the Work Plan

Year 1	Initial meeting will take place in Spring 2020 of members from both ICES and PICES communities including a broader array of scientists from non-ICES and PICES regions (e.g. Humboldt EBUS, Mediterranean Sea). The ToRs will be discussed. Emphasis will be on summarizing ongoing work in various regions and scoping of joint research activities such as comparative analyses to be conducted by participants. A resolution for an international symposium on small pelagic fish will be submitted to ICES prior to the kick-off meeting. Two additional meetings will take place at the ICES ASC and PICES AM.
Year 2	An international Symposium will be convened (tentatively in late November / early December in Barcelona, Spain) immediately followed by a writing workshop to start producing synthesis articles stemming from activities in Year 1 and outcomes of the SPF symposium. The group will also meet at the ICES ASC and PICES AM.
Year 3	Meetings will take place at the ICES ASC and PICES AM. Final reporting of this first, 3-year phase of this group will be prepared. It is anticipated that a resolution will be submitted to extend the lifetime of this joint group beyond this first, three-year phase. The final symposium called “Small Pelagic Fish: new Frontiers in Sustainable Management” was successfully held in Lisbon in November 2022. https://meetings.pices.int/meetings/international/2022/pelagic/history

Year 4	Preparation of manuscripts has been the main activity during this year, as well as the compilation of the special volumes in Marine Ecology Progress Series and Canadian journal of Fisheries and Aquatic Sciences. Both volumes stem from the November 2022 SPF symposium held in Lisbon. Plans exist for the extention of the international group, but a formal meeting for that had to be extended to February 2024. This meeting will take place in la Paz, México. Where the 2026 SPF symposium is planned.

Supporting information

Priority	Small pelagic fish (SPF) account for more than 30% by weight of the total landings of marine capture fisheries around the world. They also play an important role in the transfer of energy through mid-trophic levels in marine ecosystems and are key resources for the world's growing aquaculture industry. The oscillations in the populations of SPF are dramatic and cyclical in response to climate variability on multidecadal time-scales. However, mechanisms linking climate variability to population dynamics are still unresolved. Hence, there are many challenges to sustainable use of SPF production. As the population dynamics of SPF display basin-scale teleconnections, synthetic and multidisciplinary studies are required to understand the processes and mechanisms to build predictive capacity. International collaboration on SPF research was spearheaded by the GLOBEC Regional Program on Small Pelagic Fish and Climate Change (SPACC), launched in 1994 with a workshop in La Paz, Mexico. The SPACC program aimed to understand and predict climate-induced population dynamics of SPF in relation to physical and biological processes and included several major themes: long-term changes in ecosystems, retrospective analyses, comparative population dynamics, reproductive habitat dynamics, and economic implications of climate variability. The SPACC program culminated in 2010 with the publication of its review book. Since then, no international program specific to SPF has been launched, although SPACC-II visions have been discussed (e.g. Alheit (2010) and van der Lingen et al. (2010)). In the following decade, there has been substantial scientific progress made in several ecosystems: different hypotheses of mechanisms of population dynamics of SPF have been proposed, data from long-term monitoring and stock-assessment efforts have accumulated, numerical modelling approaches have progressed, and technologies such as genome analysis have rapidly developed. ICES/PICES co-sponsored a symposium on "Forage fish interactions: Creating the tools for ecosystem-based management of marine resources" (Nantes, France, November 12–14, 2012) leading to publication of 12 articles in the ICES Journal of Marine Science (Peck et al., 2014). The need for a platform to organize intensive international collaboration was re-confirmed during the PICES/ICES Symposium on "Drivers of dynamics of small pelagic fish resources" (Victoria, BC, Canada, March 6–11, 2017). This symposium led to special issues in Deep-Sea Research Part II (Alheit et al., 2019; 15 articles) and Marine Ecology Progress Series (Alheit and Peck, 2019; 22 articles). The platform for international collaboration will allow the marine science community to more rapidly address challenging goals such as to: 1. Perform a synthesis of mechanisms linking climate variability to population dynamics of SPF among different ecosystems to reconcile various recruitment hypotheses; 2. Gain an holistic, ecosystem-level view of the causes and consequences of fluctuations in SPF populations such as how different factors (physical forcing, trophodynamics, and fishing pressure) interact to control the dynamics of populations; 3. Unite various fields (climate science, oceanography, plankton and fish ecology, quantitative fisheries stock assessment, sociology and economics) to build interdisciplinary approaches to examine SPF in social–ecological systems; 4. Incorporate new monitoring (e.g. environmental DNA) and modelling (e.g. end-to-end) technologies to better understand and manage pelagic ecosystems;

	5. Provide projections of the effects of climate change on the distribution and productivity of SPF; 6. Propose strategies to safeguard marine ecosystem services stemming from SPF including conservation concerns related to SPF and their predators. Because small pelagic fish (SPF) are highly valued by society and exhibit variability associated with changes in climate forcing, ecosystem structure, and fishing pressure, efforts to understand their dynamics require an integration of knowledge across oceanographic disciplines. Human society cannot expect to prepare a plan for sustainable development of the oceans unless we can improve our understanding of the largest component of ocean fisheries—the small pelagic fish. Consideration of the dynamics of these species, their sensitivity to exploitation and climate change, and the implications of such changes for the human populations that they support is essential to promote ocean sustainability and guide adaptation. The activities of the proposed joint working group will contribute primarily to the first three of the six goals identified in the PICES Strategic Plan (https://meetings.pices.int/About/PICES-Strategic-Plan-Oct-2016.pdf): (1) Foster collaboration among scientists within PICES and with other multinational organizations; (2) Understand the status and trends, vulnerability, and resilience of marine ecosystems; and (3) Understand and quantify how marine ecosystems respond to natural forcing and human activities (Goals 2 and 3 are similar to the two research themes in the PICES integrative scientific program on Forecasting and Understanding, Trends, Uncertainty and Responses of North Pacific Marine Ecosystems (FUTURE)). The activities of the joint working group also align with at least five of the seven ICES science priorities set in the ICES Strategic Plan (https://issuu.com/icesdk/docs/ices_stategic_plan_2019_web), including: (1) Ecosystem science, (2) Impacts of human activities, (3) Observation and exploration, (4) Seafood production and (5) Conservation and management science. The activitiesof this joint WG are considered to have a very high priority for both ICES and PICES. References: Alheit, J. (2010) SPACC continues under ICES wings. GLOBEC International Newsletter, 16(1): 24. van der Lingen, C.D., Lluch-Cota, S., Checkley, D., Bernal, M., Herzka, S., and Takasuka, A. (2010) SPACC II Planning Meeting 24-26 February 2010, La Paz, Mexico. GLOBEC International Newsletter, 16(1): 25–26. Alheit, J., Rykaczewski, R.R., Sundby, S., and Di Lorenzo, E. (2019) Drivers of dynamics of small pelagic fish resources: environmental control of long-term changes. Deep Sea Research II (special issue), 159: 1–3 Alheit, J. and Peck M.A. (2019) Drivers of dynamics of small pelagic fish resources: biology, management and human factors. Marine Ecology Progress Series (special issue), 617/618: 1–6. Peck, M.A., Neuenfeldt, S., Essington, T.E., Trenkel, V.M., Takasuka, A., Gislason, H., Dickey-Collas, M., Andersen, K.H., Ravn-Jonsen, L., Vestergaard, N., Kvamsdal, S.F., Gårdmark, A., Link, J., and Rice, J.C. (2014) Forage Fish Interactions: A symposium on "Creating the tools for ecosystem-based management of marine resources". ICES Journal of Marine Science (special issue), 71: 1–4.
Resource requirements	Some resources to support travel of key group members to PICES Annual Science Conferences will be requested (see below).
Participants	The group is expected to attract between 25 to 35 members and guests with broad coverage of ecosystems within and outside ICES and PICES regions.
Secretariat facilities	The group will request meeting rooms / times associated with the ICES ASC. This will require some assistance from members of the secretariat organizing those events. Similar requests will be made of the PICES secretariat.
Financial	Funds will be requested to support travel of key participants to the PICES ASC.

Linkages to ACOM and groups under ACOM	The group will identify how environmental drivers influence the productivity of SPF within ICES areas. This information will be useful to ACOM.
Linkages to other committees or groups	It is anticipated that very close working relationships will be created with other groups within the Ecosystems, Processes and Dynamics Steering Group such as those working on predators (e.g. JWGBIRD) and prey (WGZE) of SPF. Similarly, the work conducted will be useful to foodweb modelling (e.g. WKEWIEA) and to state-of-the-art biophysical modelling (e.g. WGIPEM) within SG Integrated Ecosystem Assessments.
Linkages to other organizations	Joint partnership between ICES and PICES: the proposal is simultaneously submitted to PICES; FAO General Fisheries Commission for the Mediterranean (GFCM; http://www.fao.org/gfcm): Working Group on Stock Assessment of Small Pelagic Species; North Pacific Fisheries Commission (NPFC; https://www.npfc.int/): Technical Working Group on Pacific Saury Stock Assessment (TWG PSSA) and Technical Working Group on Chub Mackerel Stock Assessment (TWG CMSA); UN Decade of the Oceans: The mandate of this joint ICES/PICES activity is relevant to the objectives of the UN Decade of Ocean Science for Sustainable Development and UN Strategic Development Goals (*e.g.* SDG 14, Life Below Water).