Brief Review of our presentations & discussions (with help from workshop and session leads!)

One slide (key outcomes)

Workshop 1

Workshop 2

Workshop 4

Workshop 5

Workshop 6

Five Slides (composition, key messages, outcomes / next steps)

Session 1

Session 2

Session 3

Session 4

Session 5

Session 6

W1 – Application of Genetics to Small Pelagic Fish

Rita Castilho (Portugal), Anna Verissimo (Portugal), Jan McDowell (USA), Malika Chlaida (Morocco)

Outcomes

1 Provided a better understanding of different genetic/genomic approaches and their potential applications to fisheries science.

2 Fostered discussion on how to apply genetic methods to answer research questions and advance SPF fisheries management.

3 Recognized challenges in communication between population geneticists and fisheries managers and the need for a common technical language.

W2: The Devil's in the Details of Using Species Distribution Models to Inform Multispecies and Ecosystem Models

Outcomes

- 30 participants, w/co-conveners including Early Career Scientists Mariana Hill-Cruz, Pierre-Yves Hernvann, Robert Wildermuth

1 **Outlined** a manuscript on the state of the art and emerging solutions for coupling Species Distribution Models (SDMs) to more complex (multispecies, ecosystem) models.

2 **Identified common needs**, such as to understand the fundamental niche rather than realized niche, when intending SDMs for climate projection

3 **Identified case studies** from the California Current and Humboldt Current, but we invite more!

Goal: Manuscript targeted for MEPS theme issue

W4: Evaluating Inter-Sectoral Tradeoffs and Community-Level Response to Spatio-Temporal Changes in Forage Distribution and Abundance

Outcomes

- 29 participants, w/co-conveners including Early Career Scientists Felipe Quezada Escalona and Robert Wildermuth. Also 4 presentations.

Fleets and their responses to SPF distribution & abundance shifts discussed (Portugal, Bay of Biscay, Oman, Mauritania, Spain, Mexico, USA, Denmark, Peru, Italy, +freeze trawlers)

1 **Identified examples of fleet flexibility and adaptation** (which vessels shift portfolios, which fleets already mix target species seasonally or have shifted in recent years).

2 **Identified examples of how price, markets, + fish size/quality drive fleet dynamics & decisions**

3 **Identified challenges to industry from spatial closures and shifting transboundary stocks**

Goal: December workshop report, and then develop outline into peer-reviewed manuscript

WK5: Recent advances in the Daily Egg Production Method (DEPM): challenges and opportunities

Convenors: A. Uriarte (AZTI-SP), T. Ward (IMAS-AU), C. Nunes (Ipma-PT), L. Cubillos (Udec-CL), K. Ganias (AUT-GR)

- About 35 people attended the WK

The WK was structure in 3 topics, each followed by 30 min discussion

1
- Block 1: Estimating daily egg production and mortality; ongoing challenges and potential solutions (8 contributions)
- Block 2: Issues on Adult parameters and Spawning Biomass estimates: (4 contributions)
- Block 3: Problems and challenges on the application of the DEPM to scombrids (mackerel and horse mackerel) (3 contributions)

2 Submission of publications and initiative for 2023 review paper within WGSPF
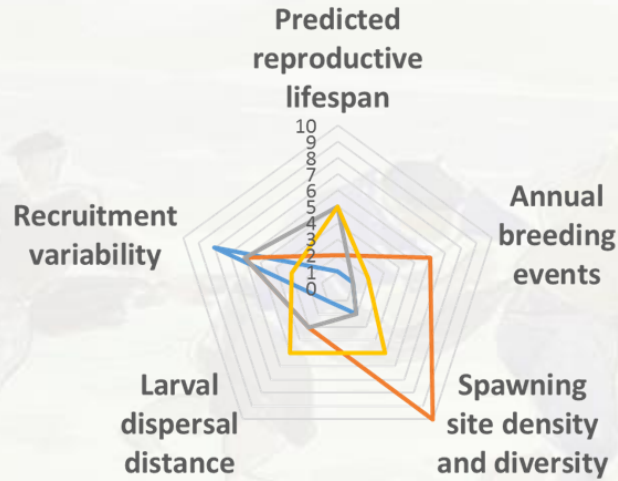
WK5: Recent advances in the Daily Egg Production Method (DEPM): challenges and opportunities

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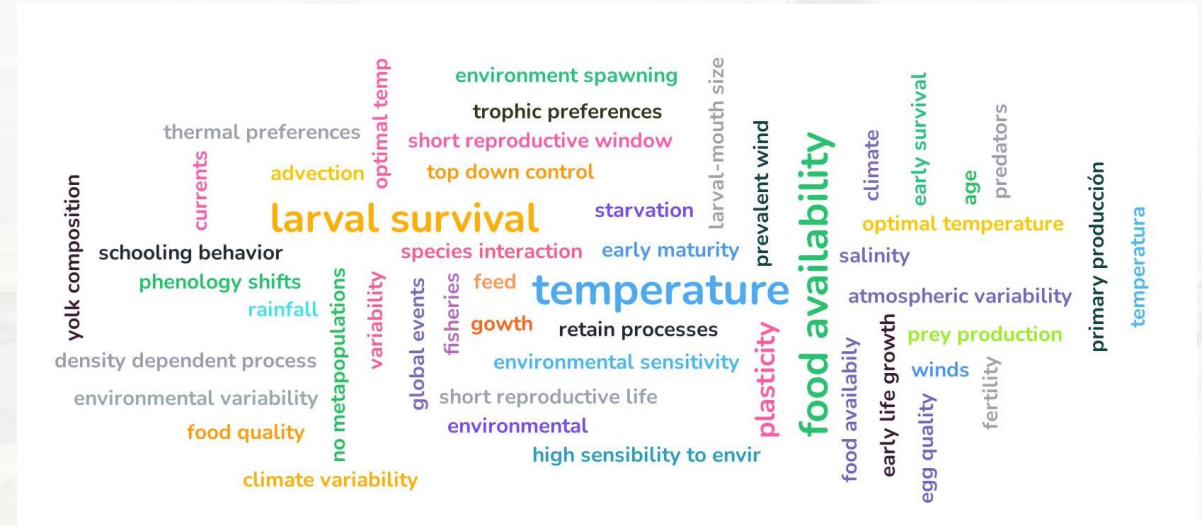
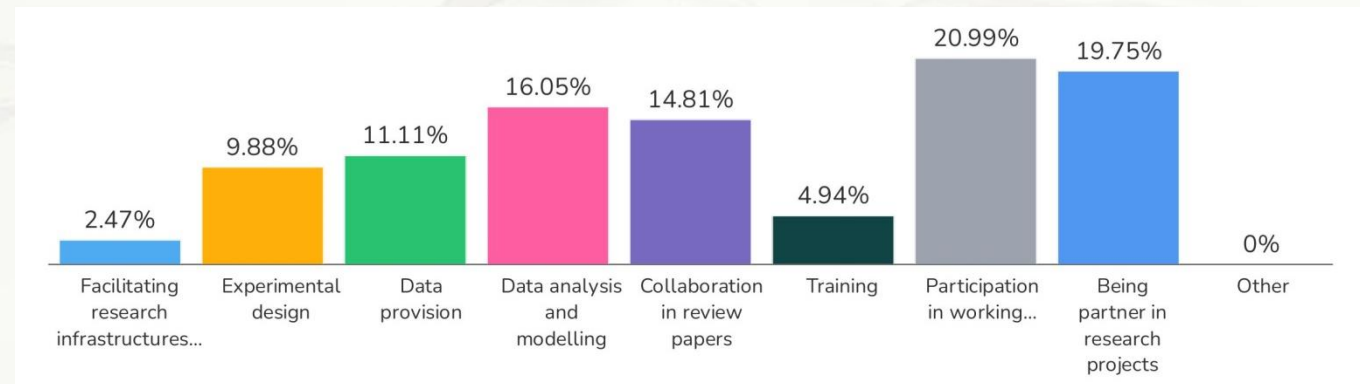# W6. SPF Reproductive Resilience (R. Domínguez-Petit, S. Lowerre-Barbieri, L. Castro, A. Takasuka)

- 55 participants + 4 convenors
- Interactive virtual discussion

1. Multi-dimensional S-R system

2. Drivers of the boom/bust processes in SPF

3. Main SPF species analyzed

4. Potential collaboration

S1: Trophodynamic Processes

Susana Garrido (Portugal), Richard Brodeur (USA), Jana del Favero (Brazil), Francis Juanes (Canada), Tatsuya Sakamoto (Japan)

1) Impact(s) of environmental drivers on phenology, abundance and/or composition of key prey taxa, novel diet studies and/or processes impacting rates of feeding, competition, and predation;

2) Comparisons of trophic overlaps between SPF and other planktivorous species; especially, studies investigating climate-driven and/or density-dependent processes or the impacts of environmental drivers;

3) Studies exploring novel techniques in quantitative and qualitative analyses of SPF trophic ecology in marine and/or inland waters (from numerical modelling molecular or biochemical techniques (e.g., from genetic, eDNA, fatty acid, or stable isotopic analyses)

Categories of Talks & Posters

Species	Oral	Poster
Sardina pilchardus	10	8
E. encrasicolus	5	2
Sardinops sagax	5	1
E. mordax	5	1
E. ringens	6	0
Clupea harengus	5	2
Clupea pallasi	4	1
Strangomera bentincki	2	0
S. sprattus	4	0
Sprattus fuigensis	2	0
Scomber colias	0	1
Others (e.g., mesopelagic)	14 (1/3 mesopelagic)	3

Regions	Oral	Poster
Mediterranean Sea	3	3
Humboldt	3	0
Baltic Sea	1	0
NE Atlantic	5	6
Canary Current	1	0
Kuroshio	1	0
Alaska	1	1
SW Atlantic	1	1
North Sea	0	1
Atlantic Iberia	3	0
California Current	5	0
Bering Sea	0	1
Global	4	1

Multidisciplinary approaches for diet analysis

- Many approaches have been used together (stomach content analysis, stable isotopes, fatty acid, DNA metabarcoding, etc.)

- Compound-specific stable isotope analysis is especially powerful because we don't need baseline data

- Gelatinous zooplankton and highly digested organisms can be detected in SPF stomachs by DNA metabarcoding! Could we **quantify?**

- **But do not forget basic stomach content analysis**

Limited larval diet studies

- Data concentrated on adults

- Few experimental studies presented (3 posters) but have a lot of potential.

  Hybrid studies (field + experiments,

  e.g., mesocosm studies).

Limited studies of predation <u>ON</u> SPF

- Need to look at predatory impacts on individual SPF

- Predators can be used as a sampler to understand SPF ecology and distributions

- Fisheries are also predator and can compete with other apex predators.

S2: Life cycle Closure: Advances in process understanding

Ignacio Catalán (Spain), Noelle Bowlin (USA), Motomitsu Takahashi (Japan), Martin Huret (France)

Encouraged presentations on advancing process understanding of SPF life cycle closure, with emphasis on spatial ecology and life history strategies. Studies that focus particularly on processes affecting early life stages, from eggs to juveniles (growth, connectivity, density-dependence, recruitment), as well as research on adult stages (e.g., maturation, fecundity, migration).

Categories of Talks & Posters

1) Spatially-explicit research with relevance for management, including individual-based modelling, trait analysis as linked to spatial dynamics, etc. (11 orals, 7 posters)

2) Studies on species/population acclimation (plastic response) or genetic adaptation based either on molecular, rearing or modelling experiments (4 orals, 5 posters)

3) Comparisons of traits (growth, reproduction and survival) and mechanisms (extrinsic, intrinsic) explaining life cycle closure and habitat utilisation/connectivity at different scales in space and time, in particular across regions or under different climate regimes (9 orals, 5 posters)
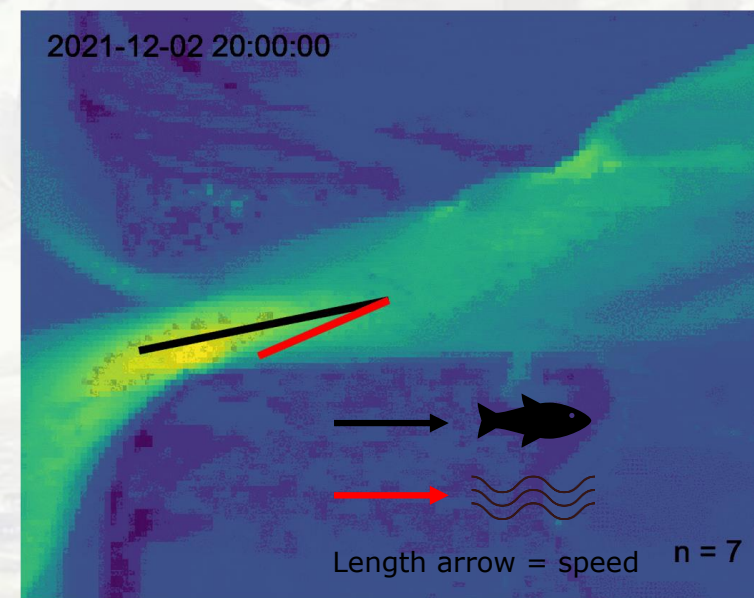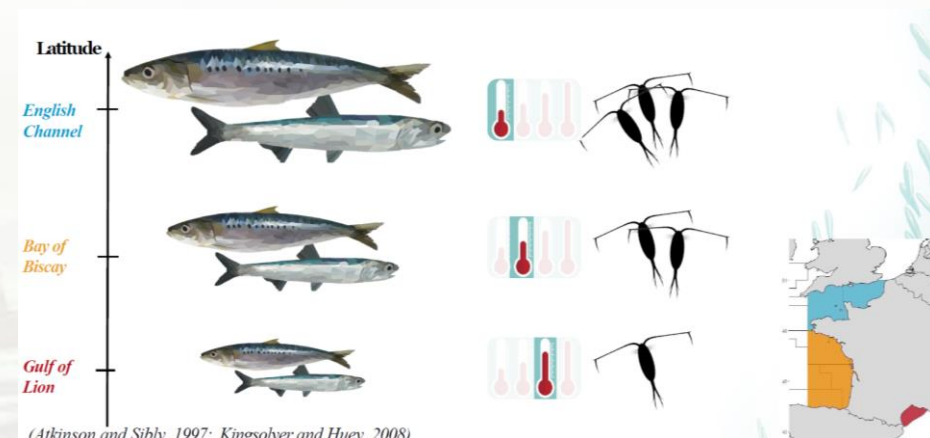
Key Message (s)

- Large **knowledge gaps** recognized in **understanding mechanisms responsible for life cycle closure through time and space.** Large differences in knowledge exist across large marine ecosystems & species. Particularly for key processes (migrations, nursery areas, stock mixing).

- Time-series have increased, allowing for analyses of trait variability. However there has not been a noticeable increase in cross-regional analyses/collaborations
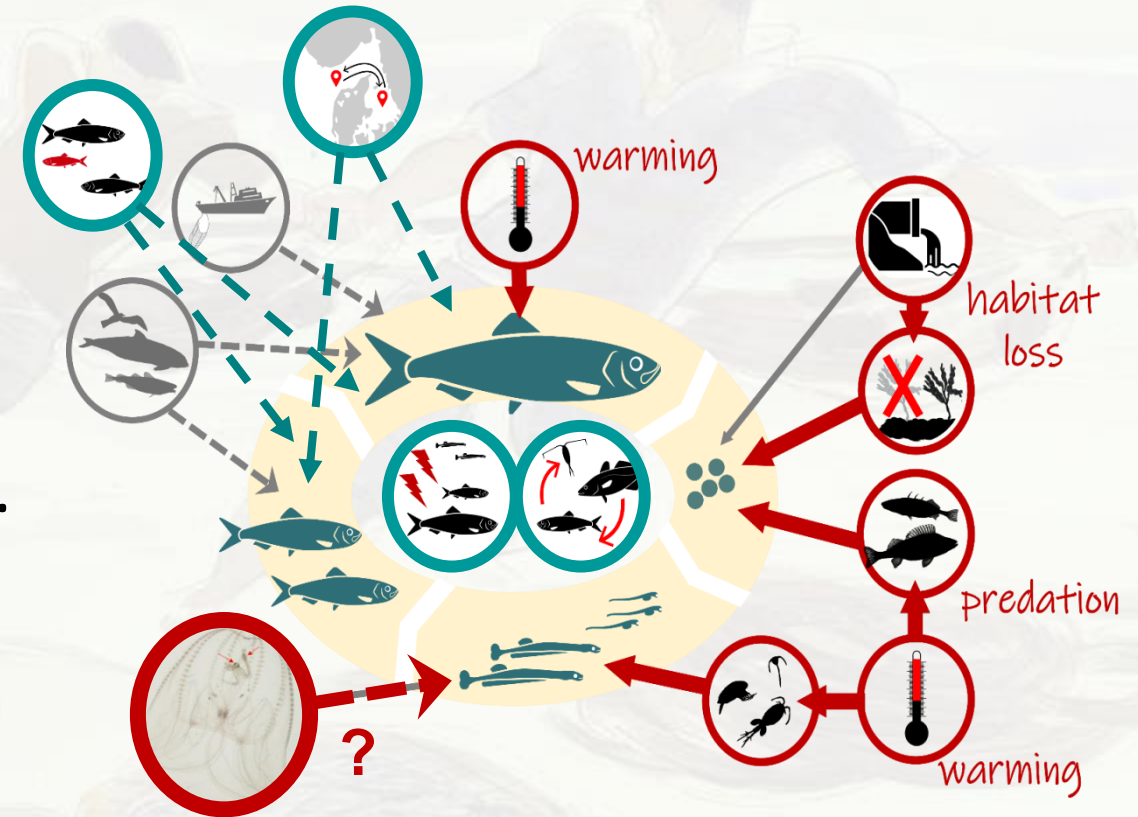
Moyano et al.

Key Message (s)

(Atkinson and Sibly, 1997; Kingsolver and Huey, 2008)

- **High potential for mechanistic** (e.g. bioenergetics) models to **test hypotheses at the individual to population levels (scenario-based approach)**; There are lots of (underutilized) data for validation to increase predictive capacity.

- **New technologies** show great potential, if combined, to monitor key life stages and processes with higher precision and lower cost (**genetics, isotopes, passive acoustics**).
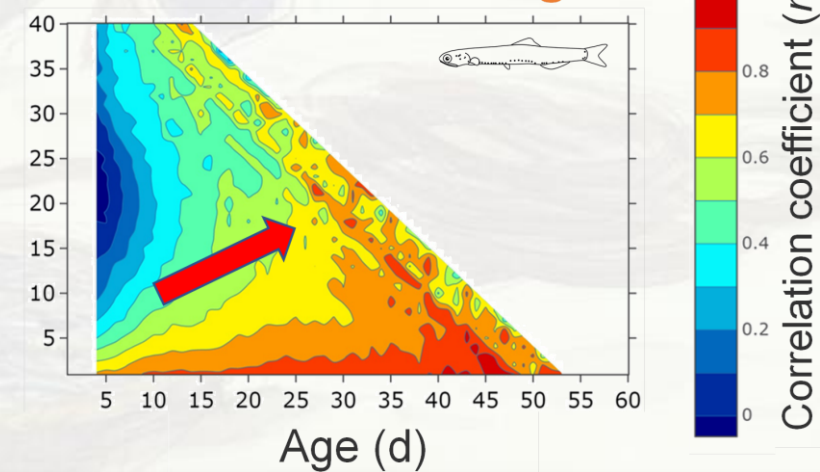

2021-12-02 20:00:00

Length arrow = speed   n = 7

Maathuis et al.

Key Message (s)

- Hypothesis testing through data reanalysis of long time series **challenge old paradigms** (e.g., SSB proportional to recruitment)

- **Field-based results vs lab experiments**; need **collaboration** with modellers, experimental biologists (rearing), and field monitoring

- Some (but not many) studies on **adaptation and acclimation**.

$y = 0.412 - 0.008x$
$n = 151$ $R^2 = 0.739$

Volume (mm³)

SST (°C)
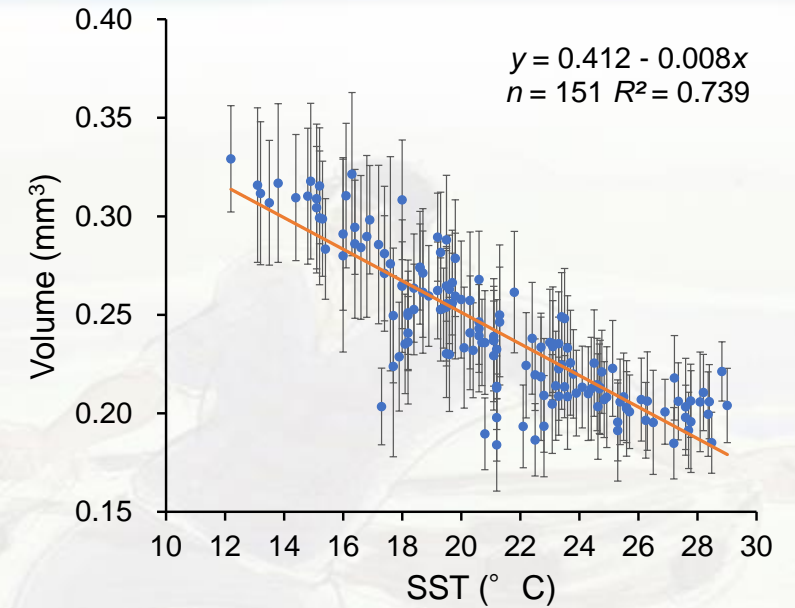
Anchovy
increased with age

Age (d)

Correlation coefficient (r)

Key Open Questions & Recommendations for Future Collaboration

- High potential to **extract data** to fill in gaps on key life stages and processes from existing surveys (e.g. acoustics).

- Need for more **transnational** collaboration and cooperation to tackle large-scale, spatially-explicit life cycles processes.

- Need to **integrate complementary approaches** (hydrodynamic models, bioenergetics, genetics, isotopes, acoustics) to solve long-lasting problems-> **multidisciplinary collaboration**

S3: Understanding Population- and Ecosystem-Level Shifts: From Seasonal Timing to Tipping Points

Rebecca Asch (USA), Matthew Baker (USA), Jennifer Boldt (Canada), Patrick Polte (Germany)

1) Re-analyses or short-term forecasts of phenological shifts in key aspects of life cycles, such as spawning or migration

2) Novel strategies to evaluate shifts in phenology, including assessment of the oceanographic, biogeochemical, or ecological drivers

3) Relationship between SPF and ecosystem-level tipping points

4) Perspectives on ways to define, evaluate, monitor, and promote stock and fishery resilience in the context of stock movement and boom-and-bust dynamics and in the context of the resilience of ecological functions

Categories of Talks & Posters

Phenology (6)

- Joel Durant
- Sofia Ferreira
- Michelle Staudinger
- Rebecca Asch
- Anna Neuheimer
- Lina Livadne

Spatial population dynamics (9)

- Chris Rooper
- Mathieu Doray
- Matthew Baker
- Ruben Rodriguez-Sanchez
- Jeroen van der Kooij
- Pierre Petitgas
- Sebastian Vasquez
- Antonio Palermino
- Marta Moyano

### Tipping points, abrupt shifts, & population dynamics (10)

- Mary Hunsicker
- Muhamad Naimullah
- Juan Pablo Zwolinski
- Jennifer Boldt (2)
- Haruka Nishikawa
- Bocar Sabaly Balde
- Brenda Temperoni
- Marcos Arteaga
- Ana Moura
- Elena Fernandez Corredor

***Some overlap & integration across categories

Key Message (s)

Phenology

- Match-mismatch Hypothesis has been around for a long time but can now be better evaluated at a population scale

- However, survey design can make trend detection challenging in some cases

- Mismatches can explain ~20-25% of recruitment variability

- Need to think about multi-trophic level mismatches (phytoplankton → zooplankton → SPF → top predators)
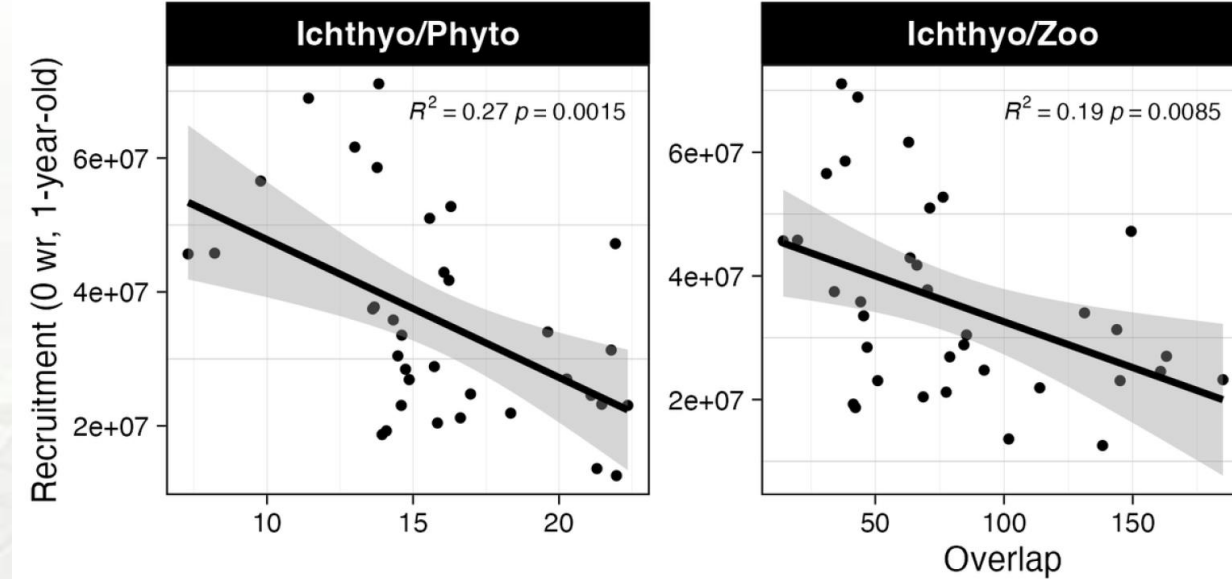

From S. Ferreira

Key Message (s)

Spatial population dynamics
- Range expansions and reproductive potential can be driven by climate or variations in population density

- Habitat suitability modeling can point to future local extinctions, especially when there are distribution barriers

From S. Vasquez

- Regional, downscaled climate models are allowing for testing of new hypotheses related to larval advection, dispersal, survival, and meta-population connectivity
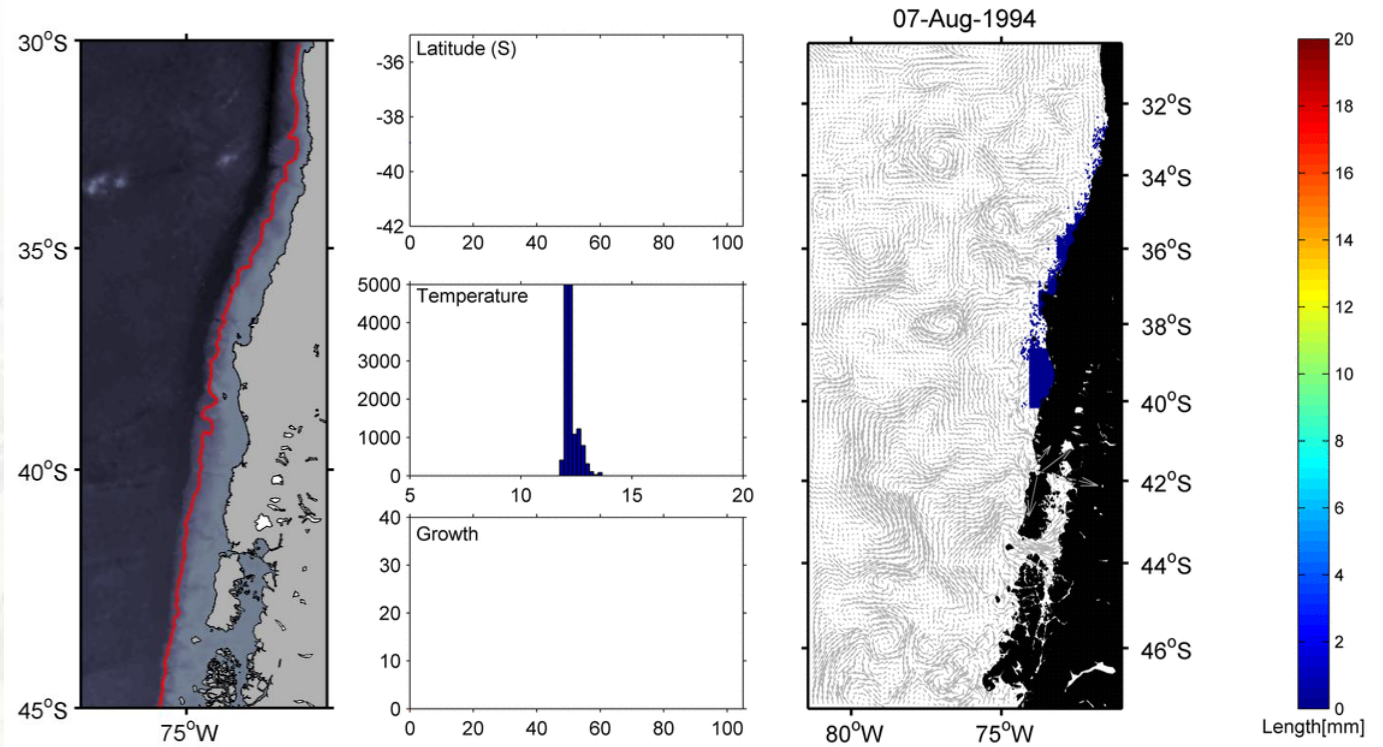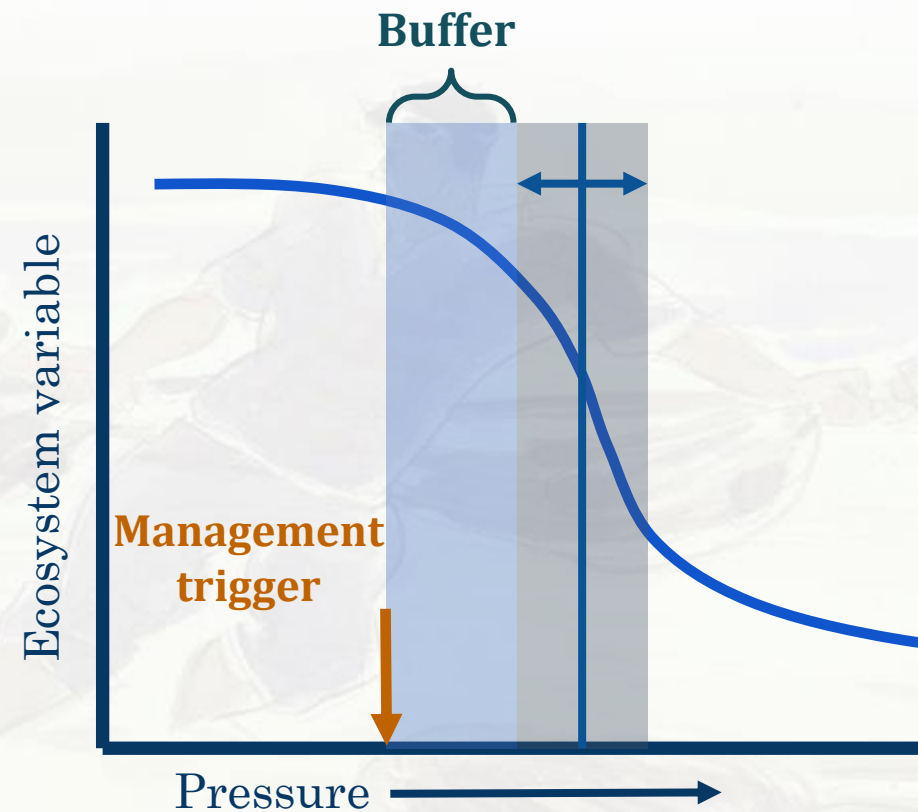
Key Message (s)

Tipping points, abrupt shifts, & population dynamics

- Tipping points and non-linear dynamics are ubiquitous

- They can lead to multiple alternative stable states where recovery may not be possible in the near term

- Bayesian DFA – new tool for detecting tipping points at ecosystem level for rapid detection and 1-year forecasts
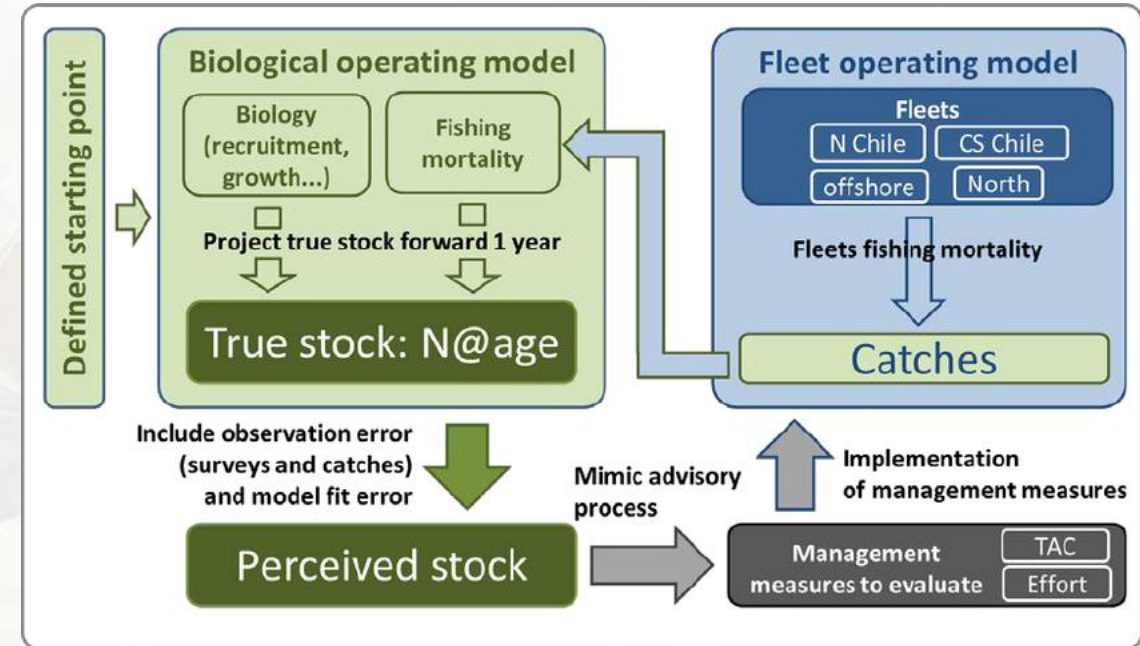

From M. Hunsicker

Key Open Questions & Recommendations for Future Collaboration

- Fewer talks on tipping point detection

- How often do phenological mismatches lead to tipping points? Can rapid natural selection "solve" mismatches?

- We need to better connect population and ecosystem level changes with advice to promote resilient fisheries → Integration with Session 6

MSE Illustration

S4. Responses to Climate Variability and Change at Decadal to Centennial Time Scales

Ryan Rykaczewski (USA), Dimitri Gutierrez (Peru), Haruka Nishikawa (Japan), Renato Salvatteci (Germany)

1. Use information from multi-disciplinary approaches to better resolve the responses of SPF species to climate variability during paleo, observational, and future time periods;

2. Highlight divergent perspectives & propose hypotheses that might reconcile differing views;

3. Recognize that relationships among SPF populations and environmental conditions may be non-stationary across periods or when viewed at different spatio-temporal scales;

4. Discuss how insight offered by paleo and observational records can be applied to make better projections of SPF population responses to future anthropogenic climate change.

Categories of Talks & Posters

- 2 Posters
- 18 Talks (incl. KN+invited). Topics: Paleo, observational (incl archived material), modelling
- 9 talks from Early Career Scientists
- Broad range of approches and techniques for **observations and archives- new techniques applied to old records** (vertebrae from archaeological sites, otoliths, sediment records)
- **Several modelling approaches** (IBM, DEB, trophic models) to explain and explore climate variability and population fluctuations / underlying mechanisms

Key Message (s)

- Paleo-: Several presentations from multiple sites (**Peru, Japan, coastal areas in the Baltic Sea**) showing records that expand our knowledge beyond the observational record.

- Innovative techniques are being applied (e.g. DNA).
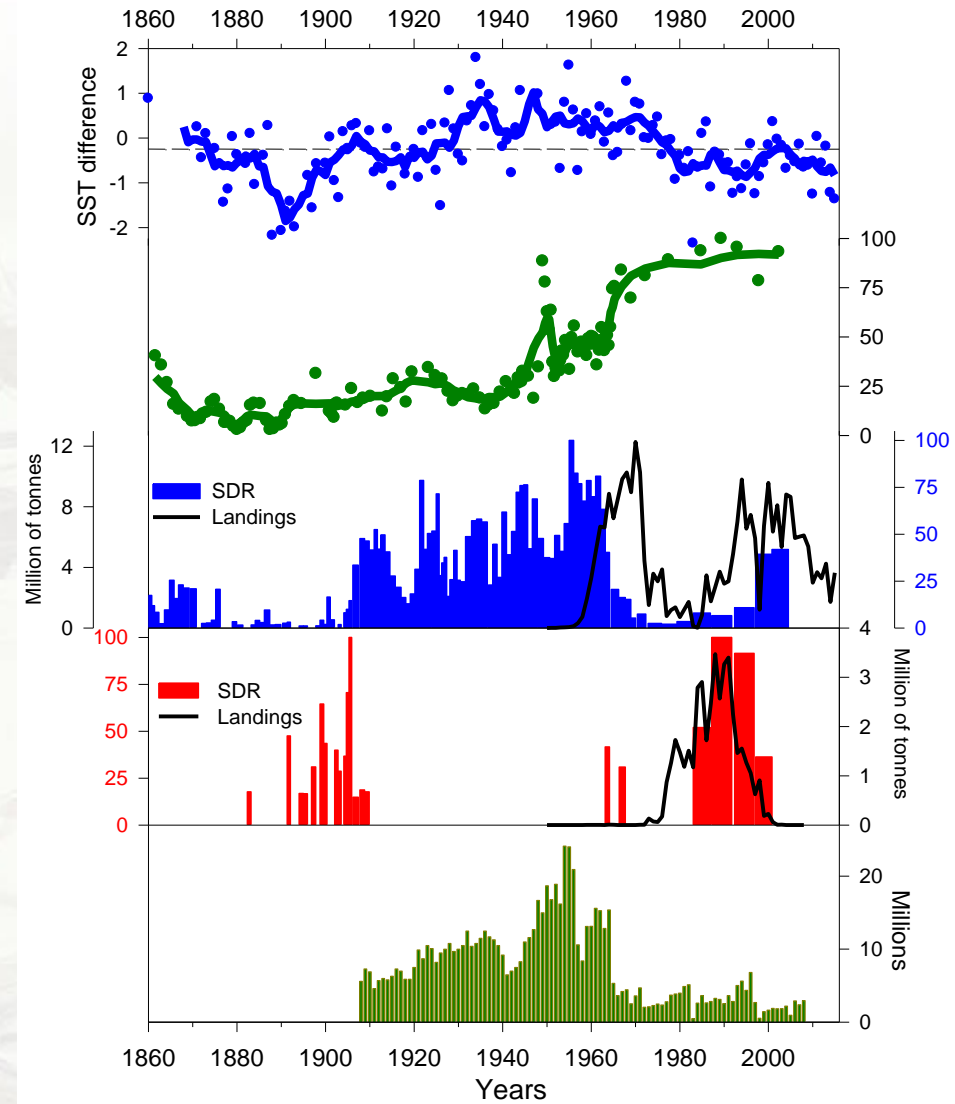
Key Message (s)

- Observational period: Improved mechanism-oriented approaches in contrast to purely correlational studies

- Several reports on changes (trends and projections) of habitat suitability (+ or -) among different species.

- Physiological traits are incorporated to explain basic mechanisms underlying and spatial and temporal patterns.

Key Message (s)

- Modelling: habitat mapping and mechanistic modelling approaches were presented.

- Application of mechanistic models (IBM, DEB + earth system models) give valuable insights on factors controlling climate impacts relative to ontogenia/behaviour, density-dependence and fishing pressure.

Key Open Questions & Recommendations for Future Collaboration

- More interaction among the modelling, stock assessment/population dynamics and paleo community will be beneficial to improve our understanding of small pelagic fish fluctuations.

- Paleo vs historical periods: moving from disagreement to reconciliation. Some recent events (e.g. anchovy boom in California Current System) challenging previous paradigms foster discussions among disciplines.

S5: Progress in Pelagic Surveys

Maria Manuel Angélico (Portugal), Chris Rooper (Canada), Jeroen van der Kooij (UK), Tim Ward (Australia)

1) New technologies, approaches (e.g., survey design, data processing, autonomous vehicles) and products;

2) Biomass estimation – improving accuracy and precision, alternative indicators of stock status, use in stock assessments;

3) Climate change-induced challenges to survey design and products;

4) Incorporation of industry data to supplement traditional survey data;

5) Spatial patterns in survey and fisheries data

6) Ecosystem-based approaches, integrated monitoring, modelling, survey products for ecosystem assessment.

Categories of Talks & Posters

All continents except Antarctica, Sardines, Anchovies, Herring, etc....

Daily Egg Production to estimate abundance	Early Career	Mid-late career	Subtopics
Daily Egg Production Method for estimating abundance		2	Methods to estimate parameters, simulation studies, time series
Improving acoustic methodology & analyses	3	4	Simulation approaches, technical approaches, applying new technologies or analyses
Fisheries dependent data streams	1	2	Optimizing data collection and analysis
Alternative methods for estimating presence & abundance of hard to assess fishes	1	2	Using diet data, using eDNA, tagging
Ecosystem effects	3	3	Regional ocean modeling, spatial analyses with covariates, predator-prey dynamics
Using fisheries data	3	4	Acoustics, fleet observing systems

Observations can come from many different types of platforms

- Technological advances have enabled us to do more with less
  - Ecosystem data, approaches
  - ROBOTS ARE COMING!!!!!
  - ? Even robot fish

- How to mix different types of monitoring data is important
  - Some are difficult to interpret
  - Different scales (transect v. point)
  - Fleet technology is often as good as science
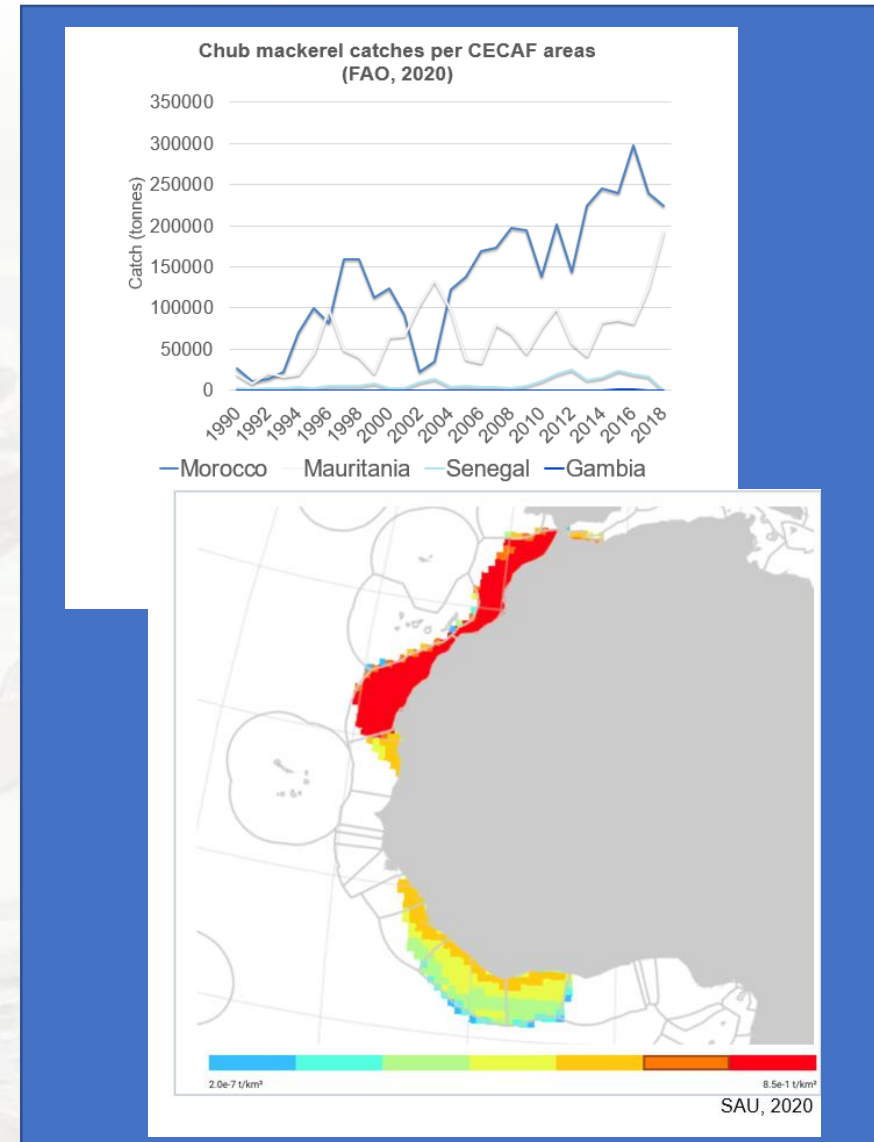

Project Results: Sample of recorded data

Fisheries research

Control

Photo from: Breivik, M., Sand, G., 2009. Jens Glad Balchen: A Norwegian Pioneer in Engineering Cybernetics. MIC 30, 101–125.
https://doi.org/10.4173/mic.2009.3.2

Capturing spatial patterns is almost as important as capturing time trends

- Smaller and larger scales
- Interactions w/ environment, competitors, etc.
- Fleet technology and attaching science sensors to fishers can help with this!

Chub mackerel catches per CECAF areas (FAO, 2020)

— Morocco   Mauritania   — Senegal   — Gambia

SAU, 2020

Analysis techniques are improving rapidly

- Simulation can be used to answer questions that can then be applied to field

- Modeling techniques are constantly being developed for solving tricky problems (spatial autocorrelation)

- Multispecies monitoring needs to understand species and size selectivity

Conditional Geostatistical Simulations - Acoustics
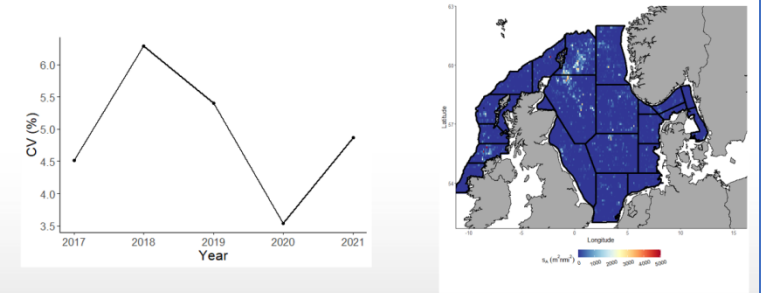
5 / 14
10 November 2022

Sven Gastauer
Evaluation of the uncertainty of the Herring Acoustic-Trawl Survey

THÜNEN

Presence/absence modelling:

$$logit(\pi_{sti}) = \alpha_1 + \sum_{j=1}^{p'} \mathbf{f}(K(X'_{jsti}, c, l)) + \gamma'_t + kW_{st}$$

1. If the biomass **is only affected by chlorophyll on the same day**, then
   $K(CHL_{sti}, 0, 0) = CHL_{sti}$
2. If the biomass **is affected by chlorophyll 14 days ago**, then
   $K(CHL_{sti}, 14, 0) = CHL_{st(i-14)}$
3. If the biomass **is affected by chlorophyll 14 days earlier and 2 days before and after**, then
   $K(CHL_{sti}, 14, 2) = w_{16}CHL_{st(i-16)} + w_{15}CHL_{st(i-15)} + w_{14}CHL_{st(i-14)} + w_{13}CHL_{st(i-13)} + w_{12}CHL_{st(i-12)}$

13/25   Daniela Silva   CMAT, University of Minho

Key Open Questions & Recommendations for Future Collaboration

- Question - How can we continue, enhance and expand monitoring in the face of budget constraints?

- Question - How can we make improvements in collaboration across regions?

- Need – Survey planning tools for acoustic surveys that are tested on simulated data/stocks

- Need – Energy savings on surveys!

- Gap/Opportunity – Industry funding for SPF surveys

- Opportunity – Unmanned vehicles and coordinating/integrating monitoring across methods

- Opportunity - Take advantage of non-directed data streams to assess SPF and fisheries

Aggregating predators: diet similarity to bluefish

S6: RECONCILING ECOLOGICAL ROLES AND HARVEST GOALS: DEVELOPMENT AND TESTING MANAGEMENT STRATEGIES TO ENHANCE MARINE ECOSYSTEM SERVICES

Sarah Gaichas (USA), Cecilile Hansen (Norway), Isaac Kaplan (USA), Richard Nash (UK)

- Management of small pelagic fish (SPF) must **reconcile their ecological, economic, and social roles**
- **Natural, environmentally driven fluctuations** pose an additional challenge
- We focus on **management approaches that ensure harvest, forage provision, and other ecosystem services**
- **Ecosystem modelling and management strategy evaluation** to test spatial management, improved monitoring and recruitment forecasts, or alternative harvest strategies.
- **Identify success stories from particular regions**, with careful consideration about how that success can be replicated.

Categories of Talks & Posters

- 8 presentations and posters from Early Career Scientists
- Plenary speaker: Carryn de Moor, *Ecosystem objectives in MSE in South Africa*
- Invited speaker: Amy Schueller, *Ecological reference points for menhaden*
- Talks on the theme of **reconciling the ecological, economic, and social roles of small pelagic fish**
  - Testing management strategies and harvest control rules
  - Bioeconomics
  - Industry-led sampling and monitoring
  - Tradeoffs for dependent predators
  - Spatial dynamics of small pelagics, fleets, and predators
  - Impacts of recruitment variability, oceanography, and climate change

Key Messages

- Multispecies and ecosystem considerations are increasingly used within stock assessments and harvest control rules (HCRs)
- HCRs based on 'simple' biological rules might turn out to be more successful and give a better fit for the system
- Let's start thinking about HCRs and MSEs now. Don't wait till the stock crashes!
- Fishers give valuable input, data coverage, and commitment
- Indicators of stock shifts can be an early warning signal for managers and fishers

Key Messages

- Multiple models used together are most successful
- Single-species assessments are necessary, but ecosystem/MICE models important to get the full picture
- Prediction of short-lived, extremely variable SPFs is both difficult and necessary. Using pre-fishery survey info might improve the assessment or management.
- Shared stocks are a concern in light of climate change (due to shifts in distributions and other effects)

Points for ongoing discussion and work

- Ecosystem models struggle to replicate the boom & bust behaviour of SPFs. What is the best approach for handling this in future projections (even 1-2 years ahead)?
- When to use spatial versus nonspatial foodweb models? Or feed both into the management process?
- Should more stressors be added to the ecosystem models, apart from climate and fisheries? Noise, litter, disturbance, contaminants?
- When can ecosystem models help develop reasonable ecosystem-based Harvest Control Rules?

Key Open Questions & Recommendations for Future Collaboration

- **Collaboration to continue via PICES ICES Working Group (WGSPF/ WG43)**
- **Task Force 2, Activity 8: Improvements to management**
- **Leaders: Richard Nash, Andres Uriarte, Isaac Kaplan, Salvador Lluch-Cota**
- **Three questions (focus) within the activity:**
  1. Best strategy to manage highly productive and variable small pelagics
  2. How can climate change and environmental variability be integrated into Management Strategy Evaluation?
  3. How can we objectively and over inter-annual scales define dynamic indicators to help management on: a) the attribution or partition biomass reductions to the influence of climate versus overfishing, and b) the relative trophic importance of small pelagics?
- **You are welcome to join tomorrow, 9am, at the Jupiter Hotel – or email the leaders**

S7: Advancing socio-ecological analyses and sustainable policies for dependent human populations

Maria Gasalla (Brazil), Myron Peck (Netherlands), Mitsutaku Makino (Japan), Tarûb Bahri (FAO)

Discuss the reliance of coastal communities on SPF for nutrition, food security, and employment and advance the management and governance arrangements impacting access to SPF resources.

Highlight recent trends in processing, marketing and use of SPF (e.g. reduction for feed, changes in value chains, economic tipping points) and report on climate vulnerability assessments, adaptation measures.
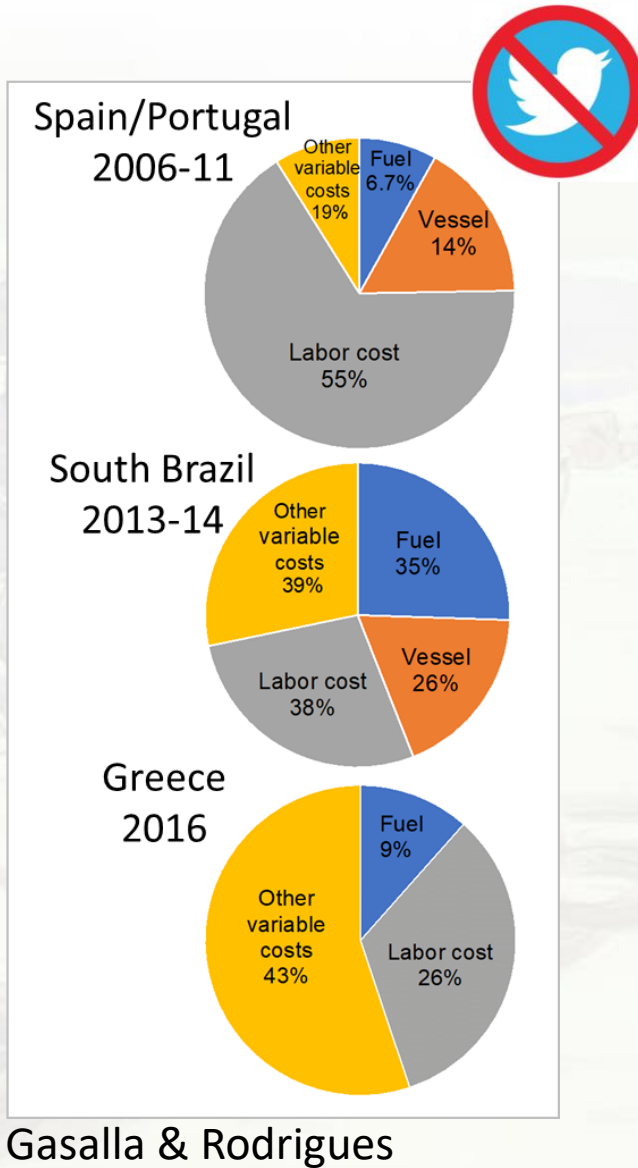
Categories of Talks & Posters

1) Harvesting lower (SPF) versus higher (e.g. TL 4 -5) trophic levels for food security and nutrition of dependent human communities   (1 oral)

2) Contrasting perspectives of fishers and fisheries managers (e.g. effectiveness of regulations, aspects of climate vulnerability) (2 oral)

3) Adapting to resource change by fishing communities / downstream sectors (e.g. response to fishery closure & Covid) (2 oral, 1 poster)

4) Comparative economic analyses of profitability of fishing fletes / purse seiners (1 oral)

5) Review of changes in the Peruvian anchoveta stock, its fisheries and management (1 oral)
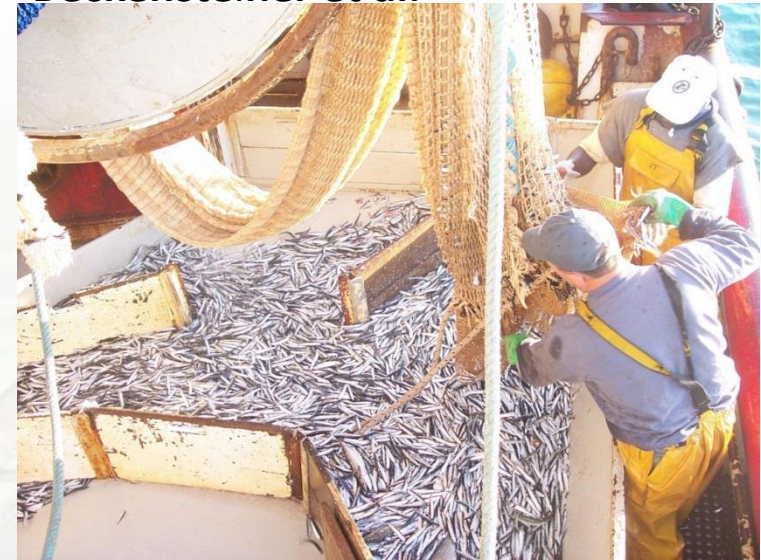
Key Message (s)

- Collecting information from dependent human communities (e.g. individuals / sectors involved in fisheries) takes time (years) and trust. Continuous process / dialog / feedback

- Various methods employed depending on the situation / context. Often diverse groups of stakeholders required. How you ask questions really matters!

Spain/Portugal 2006-11

Other variable costs 19%
Fuel 6.7%
Vessel 14%
Labor cost 55%

South Brazil 2013-14

Other variable costs 39%
Fuel 35%
Vessel 26%
Labor cost 38%

Greece 2016

Fuel 9%
Other variable costs 43%
Labor cost 26%

Gasalla & Rodrigues

Farisal Bagsit et al.

Key Message (s)

Beckensteiner et al.

- In many locations, there are **serious issues with equity in the provisioning of SPF** for protein security of local communities versus exporting.

- Incentives are often economic (industrial use) and **institutions reinforce current situations / policies** (also remember talk of Modesta Medard).
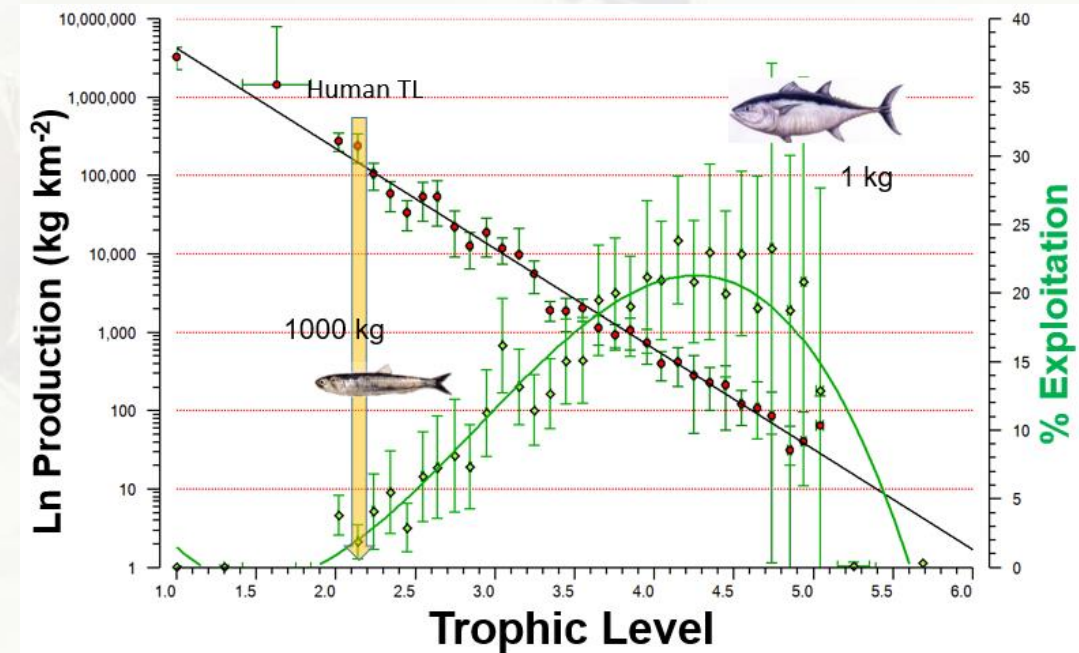
Kolding et al.

Key Message (s)

- Debated more intense harvesting of small pelagic fish due to their higher productivity, lower trophic level status, nutritional content. Some presentations identified how SPF stocks can be over-exploited and rebuilt. Harvest control rules are critical (implementation / enforcement depend on local context.

Kolding et al.

- Climate and fishing can act in synergy to collapse SPF stocks. Continue debate and reach consensus on the importance of these two (endogenous versus exogenous) pressures.

Key Open Questions & Recommendations for Future Collaboration

- The best possible ecology and social science should be integrated for holistic analyses (taking a food-systems approach) of not only small-scale fisheries but all types (e.g. industrialized) SPF fisheries.

- We need more "well-worked" case studies from different communities (at different scales) around the world.

- Social scientists are strongly encouraged to join WGSPF for the next four years of its activities.