Considerations when modelling productivity and environment

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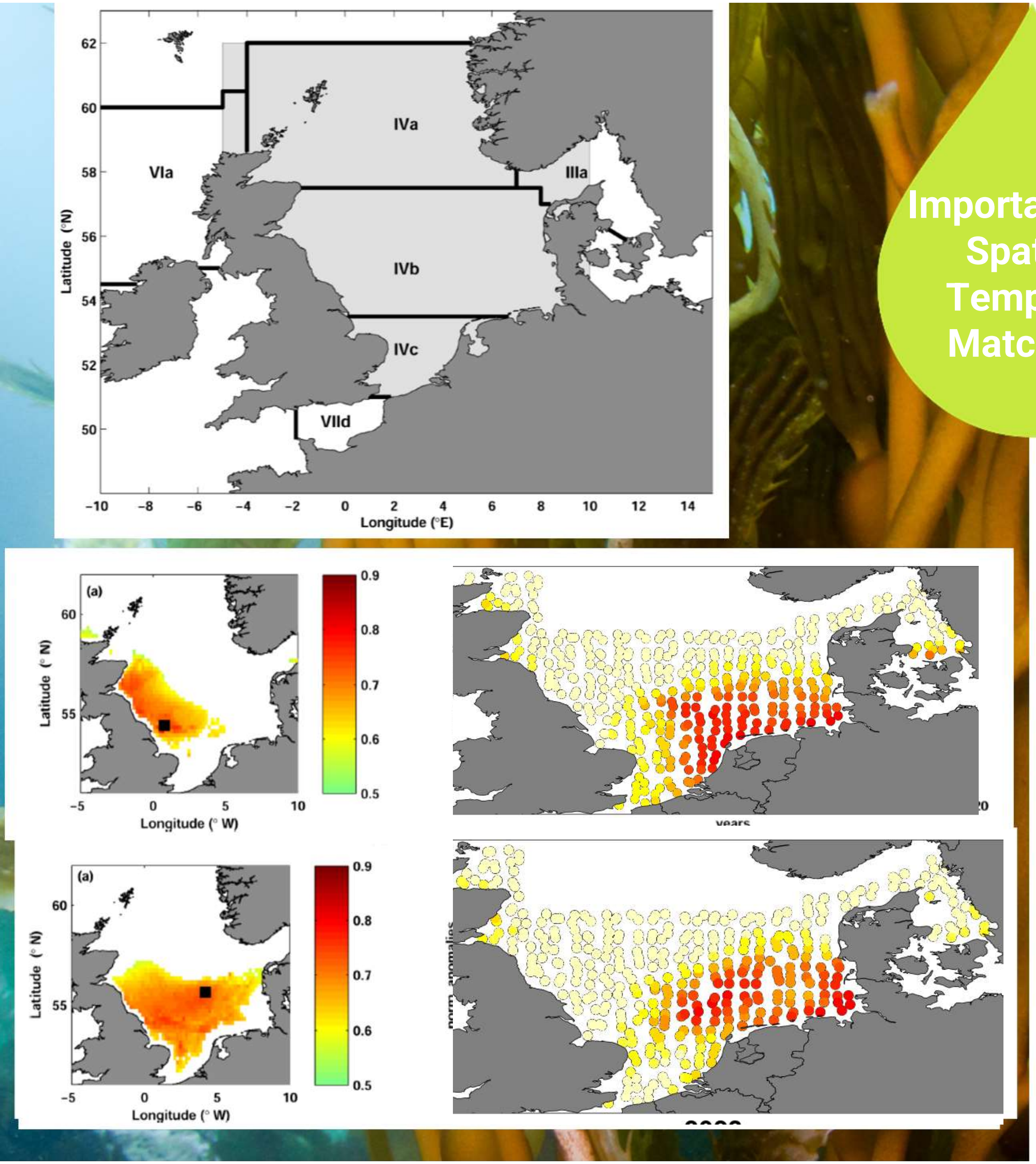
Importance of Spatio-Temporal Matching

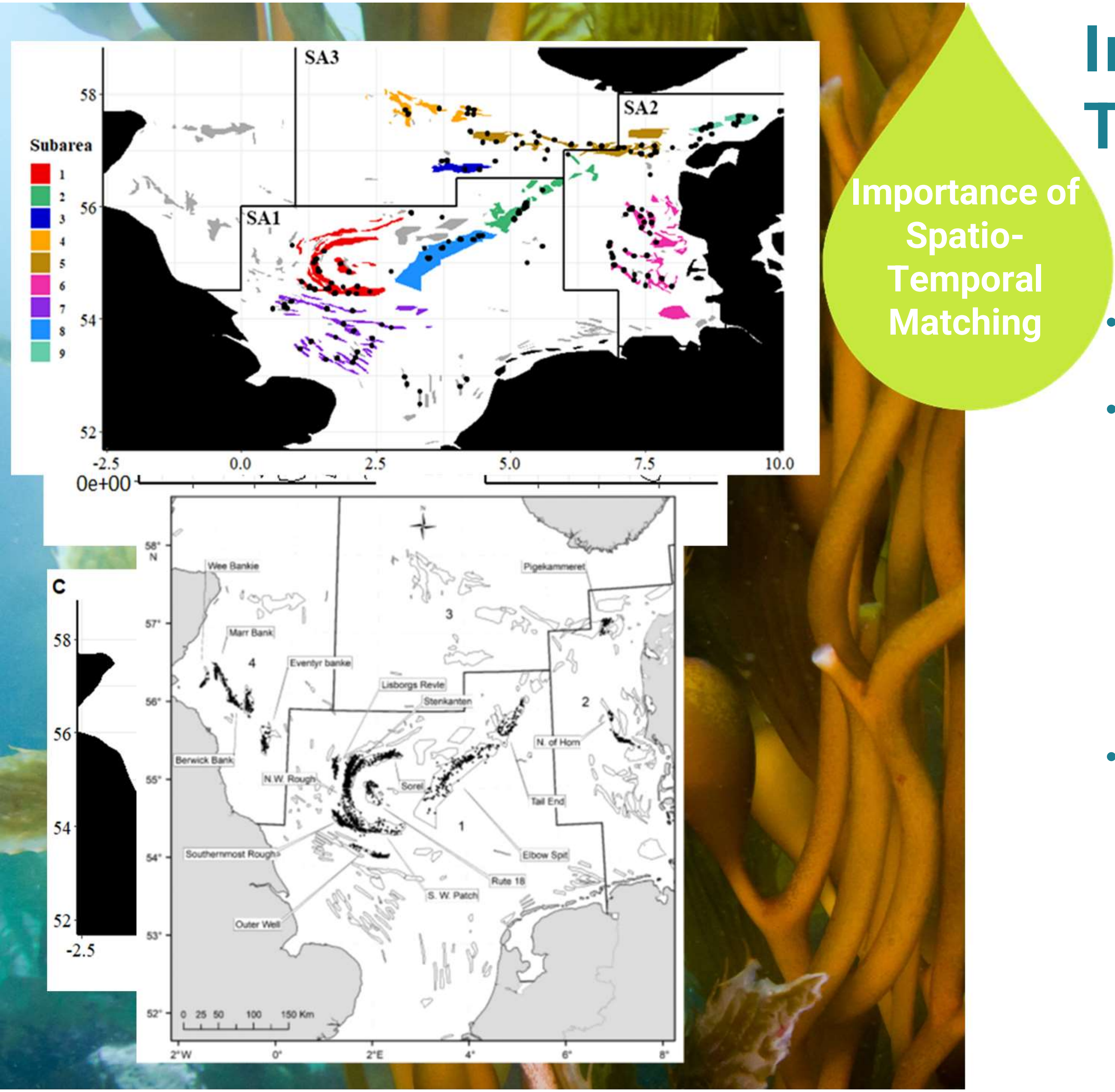


Importance of Spatio-Temporal Matching

Aligns environmental data with biological processes, (e.g. recruitment and growth).

Akimova et al. (2016):

- Analyzed spatially-resolved correlations between North Sea stock estimates (recruitment & SSB) and environment (temperature and salinity) of nine commercially important fish stocks
- Correlations were examined across regions to identify areas where environmental variables most strongly influenced recruitment.
- Recruitment of cod and plaice was negatively correlated with temperature in the northwestern North Sea and the German Bight, respectively.
- Novel patterns also emerged, e.g. sprat R and SSB and salinity



Importance of Spatio-Temporal Matching

Aligns biological data with environmental processes

- Stock assessment model outputs measures of R (early life) and SSB (adults)
- Drawbacks:
  - Integrated across large areas with limited seasonal resolution
  - Adult estimates are always biased by fishing efforts
  - The connection and relationship with important life history events can be difficult to detect
- Alternative data sources with better spatial and seasonal resolution
  - Survey data
  - Fisheries data

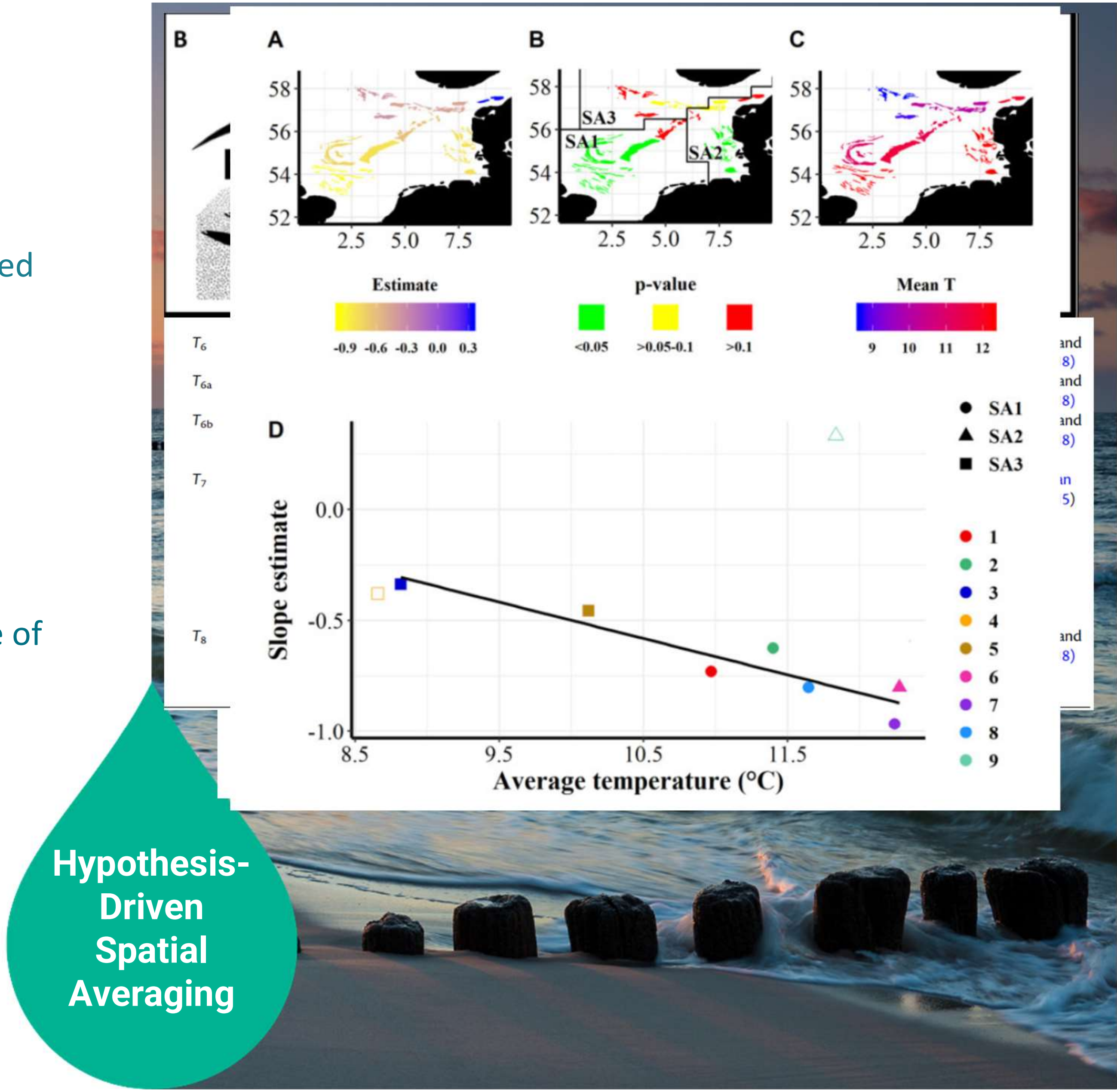
Hypothesis-Driven Spatial Averaging

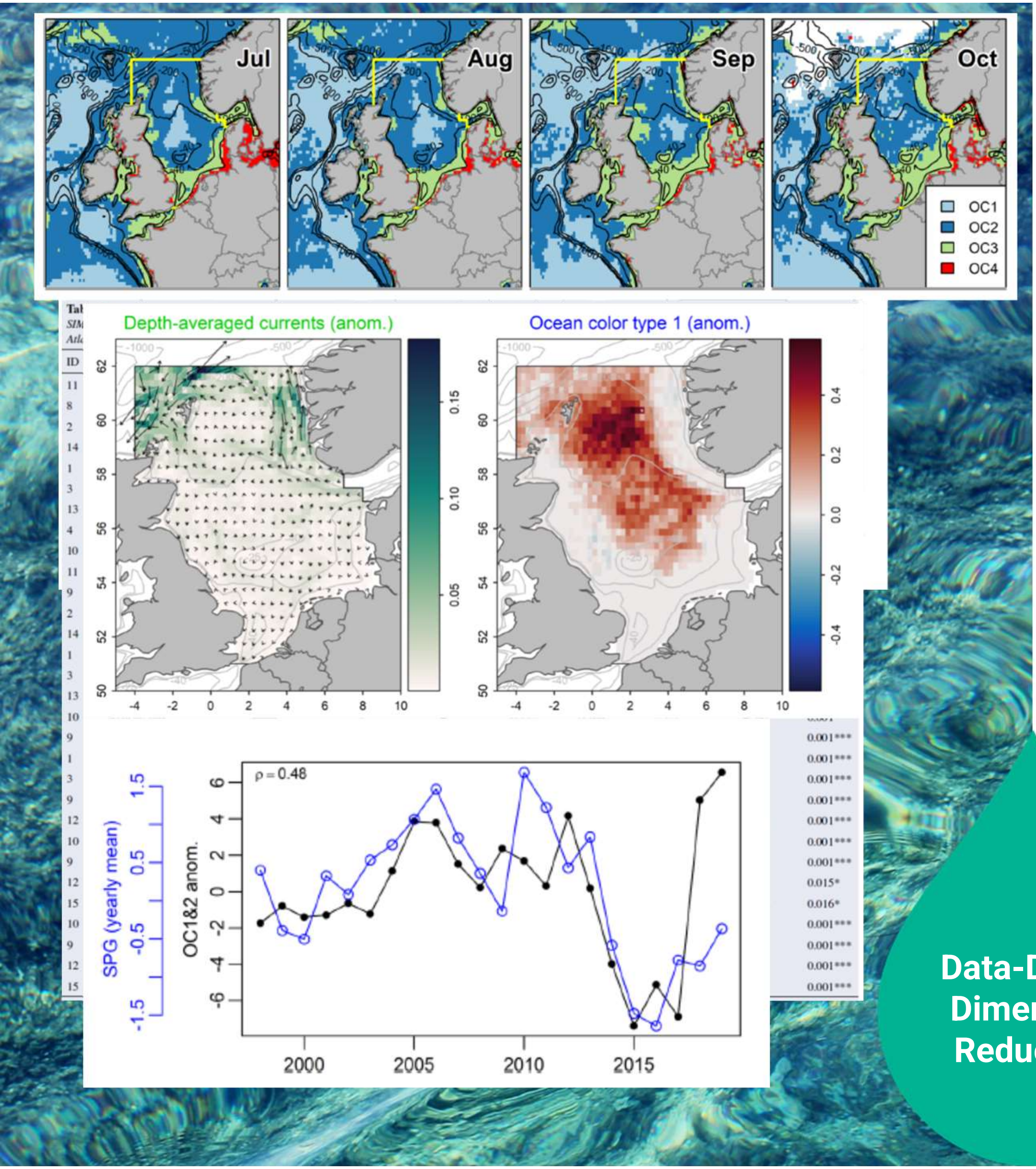
This approach involves selecting environmental variables and scales that match biological data based on established knowledge.

Henriksen et al. (2021)

- Averaging environmental data over biologically relevant spatial and temporal scales.
- Related sandeel to bottom temperatures, revealing age-dependent responses.
- Warmer temperatures inhibited overwintering survival, demonstrating the biological relevance of spatial resolution

- **Advantage:** Ensures that the environmental data closely match the biological spatiotemporal scales of interest.
- **Disadvantage:** May overlook environmental patterns in other scales that could be biologically relevant.





Data-Driven Dimension Reduction

Techniques like Principal Component Analysis (PCA, EOFs) and clustering methods (e.g. SOMs) are used to reduce data complexity by identifying dominant patterns.

Taylor et al. (2021)

- Reducing data complexity using clustering and EOFs.
- Used Ocean Color satellite-data: Identified four main OC types in the North Sea
- OC types correlated strongly with bio-optical, physical, and zooplankton community variables.
- OC types varied seasonally and interannually, often linked to large-scale processes such as the strength of local wind-driven currents and variability in the Subpolar Gyre Index.

Data-Driven Dimension Reduction

- **Advantage:** Effectively captures major patterns in the data, potentially revealing unexpected environmental influences.
- **Disadvantage:** The resulting patterns may not correspond to the specific spatial or temporal scales relevant to the biological process under study.

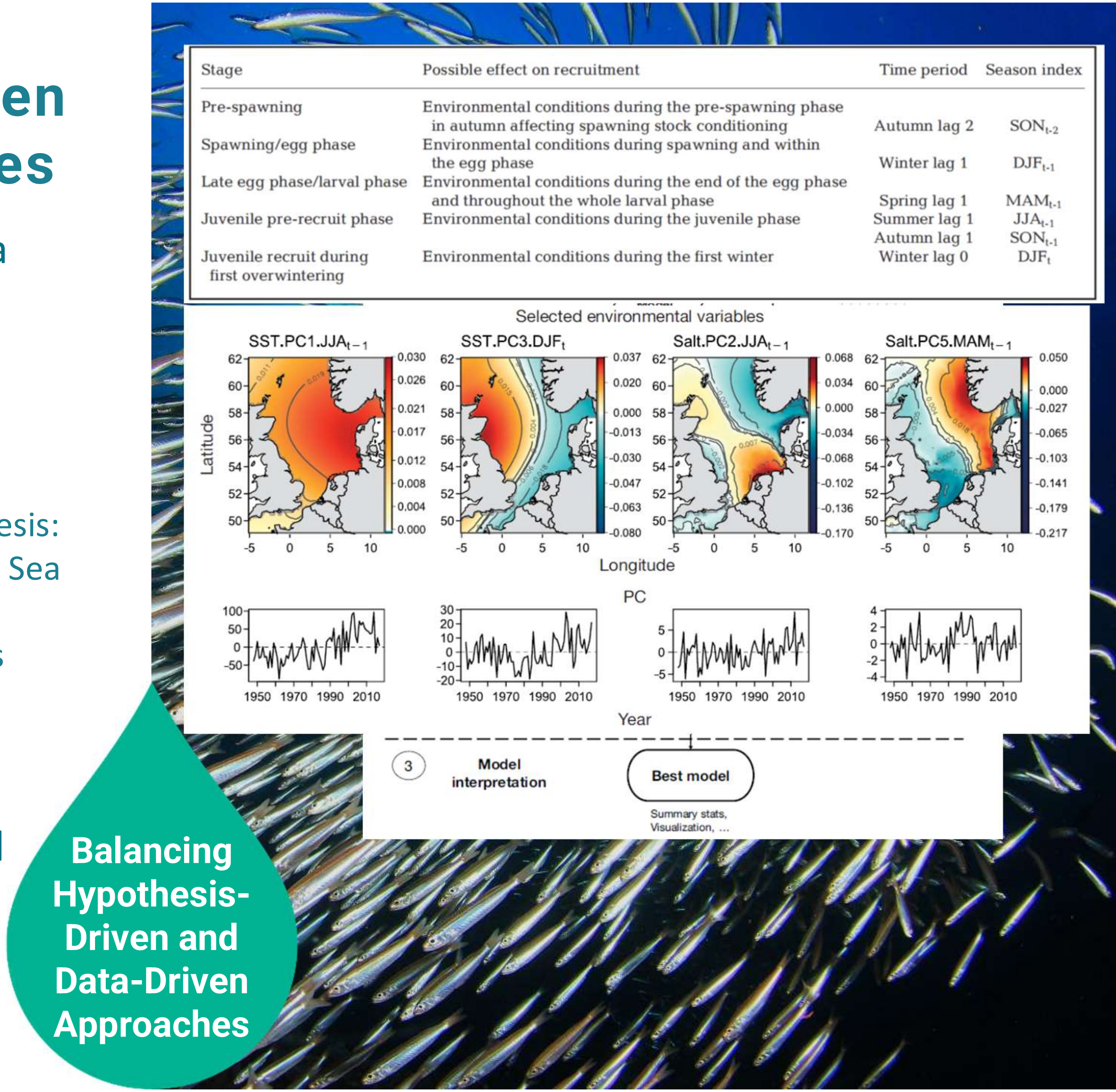
Balancing Hypothesis-Driven and Data-Driven Approaches

Combining both approaches can provide a comprehensive understanding.

Kühn et al. (2021)

- Applied PCA (EOFs) and clustering (SOMs) and machine learning to identify spatio-temporal
- Environmental data tailored predefined hypothesis: SST and salinity anomalies were linked to North Sea cod recruitment.
- This approach identified nonlinear relationships between environmental factors and life stages

Bridging hypothesis-driven frameworks with data-driven models enables tailored insights.



Stage	Possible effect on recruitment	Time period	Season index
Pre-spawning	Environmental conditions during the pre-spawning phase in autumn affecting spawning stock conditioning	Autumn lag 2	SON_{t-2}
Spawning/egg phase	Environmental conditions during spawning and within the egg phase	Winter lag 1	DJF_{t-1}
Late egg phase/larval phase	Environmental conditions during the end of the egg phase and throughout the whole larval phase	Spring lag 1	MAM_{t-1}
Juvenile pre-recruit phase	Environmental conditions during the juvenile phase	Summer lag 1 Autumn lag 1	JJA_{t-1} SON_{t-1}
Juvenile recruit during first overwintering	Environmental conditions during the first winter	Winter lag 0	DJF_t

Conclusion and Recommendations

Conclusion and Recommendations

- Resolution decisions depend on species-specific biology, lifecycle stages, and environmental drivers.
- Hypothesis-Driven: Ideal for well-studied populations/stocks
- Data-Driven: Suited for systems with high variability or less biological knowledge.
- A combined approach provides robust, biologically relevant summaries.