Forage fish knowledge in Canada

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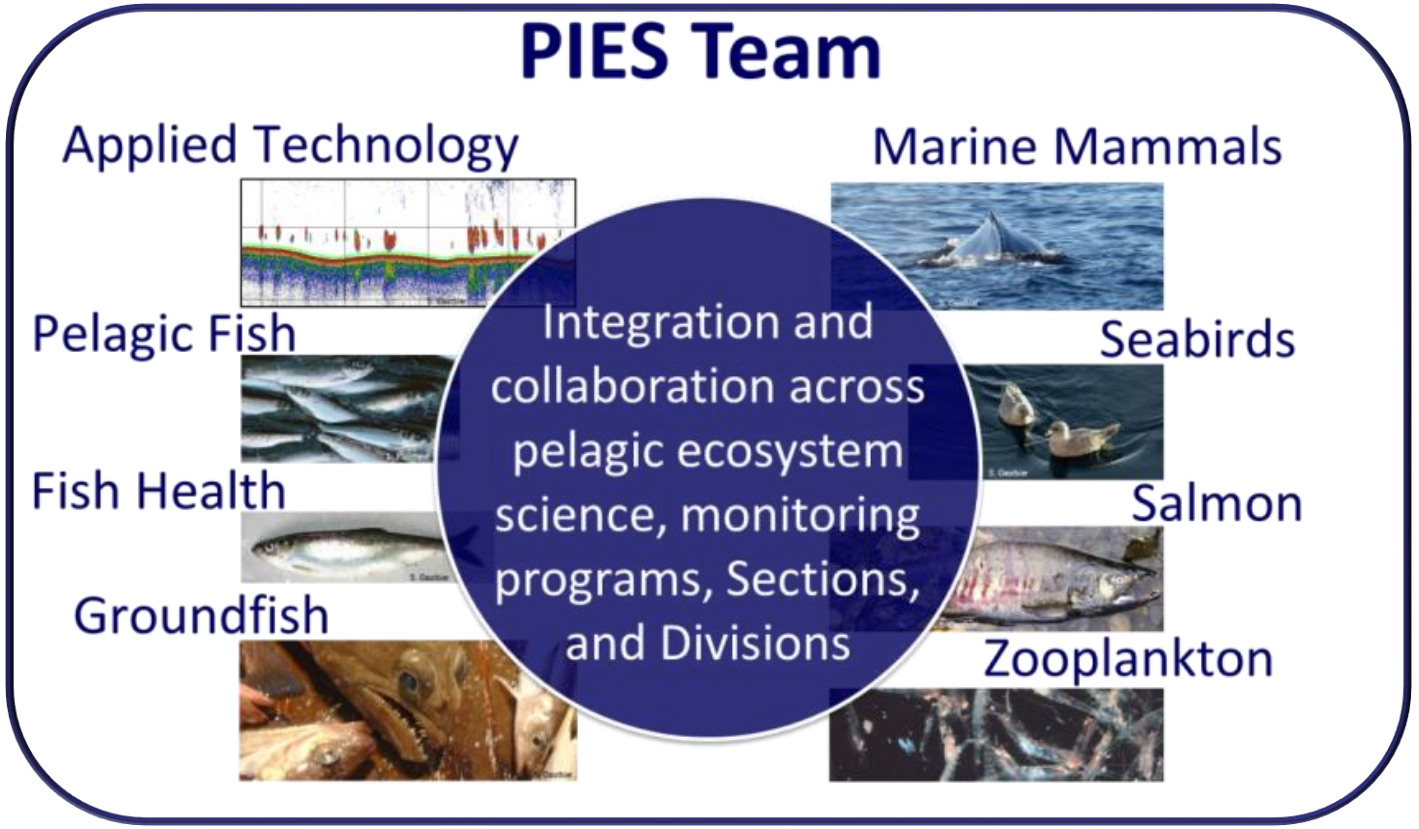
Outline

1. National Workshop: Filling in the Forage Fish Gap
2. National forage fish knowledge gaps - literature mapping
3. Next steps – e.g., EAFM
4. Summary

Pelagic Integrated Ecosystem Science Team



- Why?
  1. changes survey data use
  2. reduced financial support
  3. reduced staff availability
  4. consequent increased work load
- Goals: implementation of integrated research plans, collaborative monitoring:
  1. improved understanding of structure, function, and dynamics of pelagic ecosystems
  2. efficient, enhanced use of existing info and surveys to improve understanding
  3. integrated science advice to marine resource management clients
- Strategic Plan and TORs
- Activities: submitted SPERA proposals

Forage fish workshop

- National workshop; SPERA; 3-day, March 13-15, 2018, Nanaimo, BC
- 31 participants: DFO regions, other Canadian and U.S. government departments, non-profit organizations, universities

Forage fish workshop

Objectives

i. identify data gaps for select forage species
ii. compare and contrast forage fish monitoring methodologies and
iii. provide practical recommendations on forage fish monitoring including survey designs and cross-validation of methods

Forage fish workshop

- Pre-workshop:
  - literature review; select non-commercially important Pacific forage fish
  - Participants:
    - identified species not well sampled and life history info
    - list methods used to sample species
    - identified advantages and constraints
- Workshop format: presentations on sampling methods, data gaps in Regions
- Three US West Coast forage fish experts invited
- Two break-out sessions
- Discussion of recommendations

Monitoring forage fish populations

Monitoring method	Advantages	Constraints	Solutions/Considerations/ Recommendations
Midwater trawl nets (midwater & surface)	• Multiple pelagic fish species • Verify acoustic echosign • Biological samples • Fish distribution, biomass • Predator diets as samplers of forage fish	• Misses 0-5 m of water column • Affected by currents, tides • Vessel size may limit use in shallow waters • May not account for shifts in fish distribution • Not good samplers of benthic forage fish • Net catchability (size selection, herding, net avoidance); • Patchy, non-randomly distributed fish difficult to sample	• Use combination of methods and tools (e.g., acoustic-trawl surveys, sensors to assist, use in-net cameras • Apron on trawl to capture top of water column • Fish avoidance may not be an issue at different life history stages

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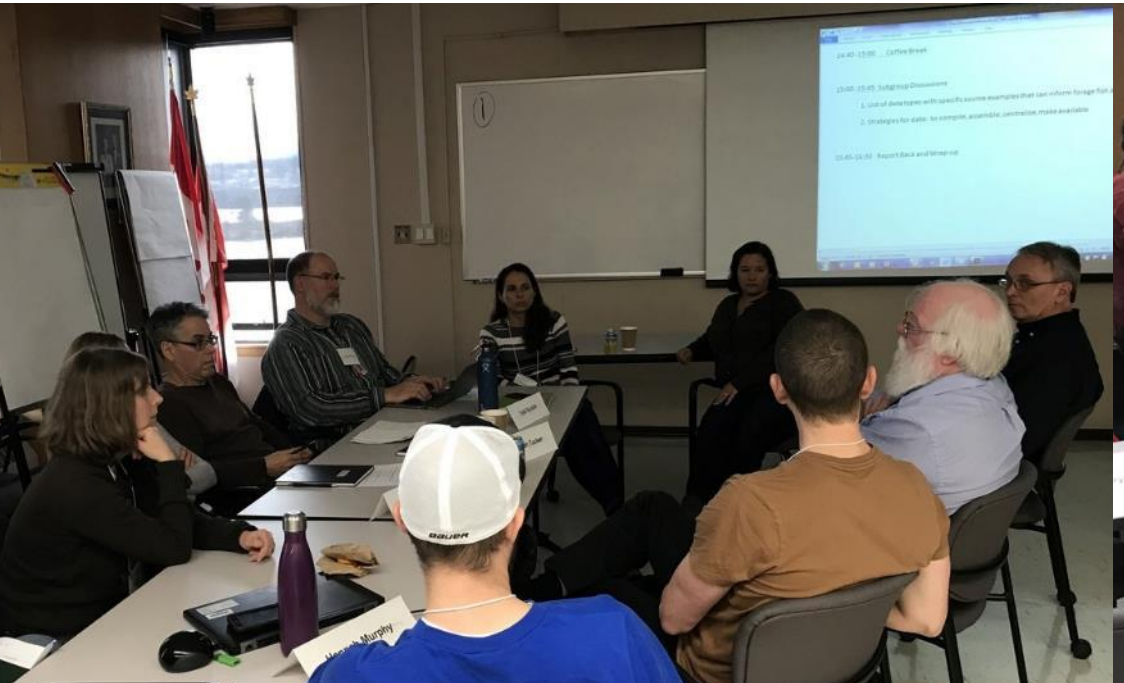
Acoustic surveys	• Can be used nearshore (small vessels) and offshore (large vessels) • Multispecies including smelts • Biomass estimates • Broad, continual spatial coverage	• Down-looking acoustics misses the upper water column and near-bottom • Should be validated with trawl data • Does not sample low density species or intermixed species as well • Weather-dependent • Potential avoidance in surface waters that vessel disturbs • Detectability varies by species • Expert required to interpret data	• Use sonar to assess what is missed in surface • Use complementary tools to help verify (in-net cameras, stereo-drop-cameras, MOCNESS, trawls,) • Autonomous platforms to address blind-zones; upward-looking sounders • Quality assurance for consistency across platforms • Use smaller platform and systems to get nearshore

Discussion #1

1. List data types with specific source examples that can inform forage fish assessment
2. Identify strategies for data: compiling, assembling, centralizing, and distribution.



Discussion #1

1. List data types with specific source examples that can inform forage fish assessment
2. Identify strategies for data: compiling, assembling, centralizing, and distribution.

- Data (or metadata) repository would help people find what is available
  - Challenges:
    - identification of data that are not already available
    - standardization of data formats
    - acoustic and optics data files are large
- Establish network of people working on forage fish
- Workshop recommendations, with linkages to government priorities, could be put forward to the Science Executive Committee

Discussion #2

1. Implementation of complementary approaches
    a. List of complementary sampling that can be integrated into existing programs
    b. How can we implement these? Requirements / Standardization?
    c. Qualitatively: How difficult is it to implement them? What level of resources is needed to implement them?
2. New efforts or sampling programs to monitor forage fish
    a. List of new time-series that would best address identified gaps, along with their advantages and constraints.
    b. Identify the priorities, as well as hypothesis-driven objectives

Discussion #2

Complementary sampling:

- Diet: fish, predators, stable isotopes
- Oceanographic sampling
- Zooplankton sampling
- Egg and larval fish sampling
- Genetics
- eDNA
- Optics
- Traditional knowledge
- Distribution maps
- Focus on area (multi-species) rather than single species

Issues: standardization of sampling, methods, gear


Moored echosounder


Zooplankton

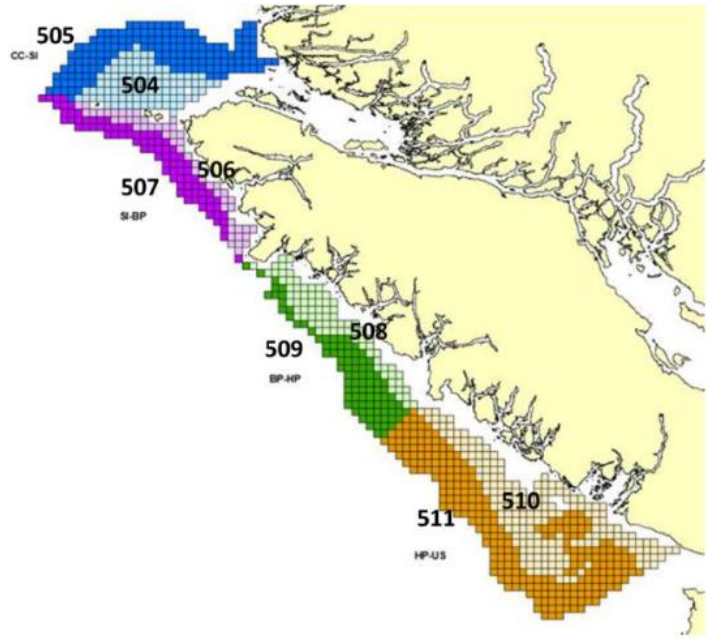

Moored stereo-cameras


Portable EK80


Diets (King et al. 2018)

Integrated Pelagic Ecosystem Science (IPES) Survey

Goal: understand factors affecting distribution, abundance, food web linkages of pelagic fish species e.g., Pacific herring, juvenile salmon



- Annual, summer, pelagic trawl survey
- 8 strata based on depth and biological communities
- Random selection of 4 x 4 km blocks, allocated by strata sizes
- Randomly assigned depth (0, 15 m)
- Selected blocks fished during both day and night
- Environment (CTD, chl, domoic acid)
- Zooplankton
- Acoustic data along transects (non-fishing hours)
- Species biomass, abundance, length, weight, diets, genetics (salmon, eulachon), energy density, age, biological and tissue samples, etc

Knowledge gap	Objectives	Research priority or opportunity
Effects of climate and oceanographic forcing effects on fish	Identify factors affecting abundance and distribution (spatially and by depth); forecast biomass of commercially & non-commercially important spp.	Region-wide ichthyoplankton surveys and adult forage fish abundance surveys
Spawning habitats of forage fish	Identify spawning habitat; link to species distribution changes and vulnerability assessments to provide baseline coastal monitoring in collaboration with Indigenous communities; provides advice to mgt that cannot currently be provided	Beach spawning surveys; habitat suitability modelling
How does the forage fish community support resiliency and biodiversity of MPA networks?	Identify forage fish communities, diversity, and trophic interactions for marine spatial planning	Dedicated acoustic surveys (with sample verification); surveys of nearshore and spawning habitats for coastal MPAs
Benthic forage fish habitats	Identify spawning habitats of other forage fish that have a benthic life history	Surveys of benthic habitat (use new tools, such as bottom-type mapping or ROVs); conduct habitat distribution modelling
Bycatch mortality of unassessed species	Determine mortality associated with unassessed species; apply stock assessment tools to assess status of non-commercially important species	Modelling, MSE

Recommendations

1. identify sampling methods that can be easily implemented into existing programs
2. identify new methodologies that may have higher cost burdens but have potential
3. bring together historical data and perform literature reviews at regional levels
4. develop a formal working group on forage fish

Follow-up from workshop recommendations

- Proposed working group (with TORs, members, scope, frequency, structure, guiding principles), back & forth with SEC, supported in theory, back & forth, ...
- Small amount of funds made available
- Objectives addressed:

a) Convene meeting to: i) identify key issues and objectives at the Regional and National level, ii) identify and scope the species and information to include, iii) develop a report template, iv) identify next steps, timelines, and deliverables

b) Literature review: summarize up-to-date knowledge, knowledge gaps, collate info on potential factors affecting forage fish abundance and distribution, and complementary types of info

c) Potentially, assemble base information to enable mapping of forage fish distribution, habitat, and spawning habitat; create or collate distribution range info of forage species; collate info on spawning areas

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Canada's forage fish: an important but poorly understood component of marine ecosystems

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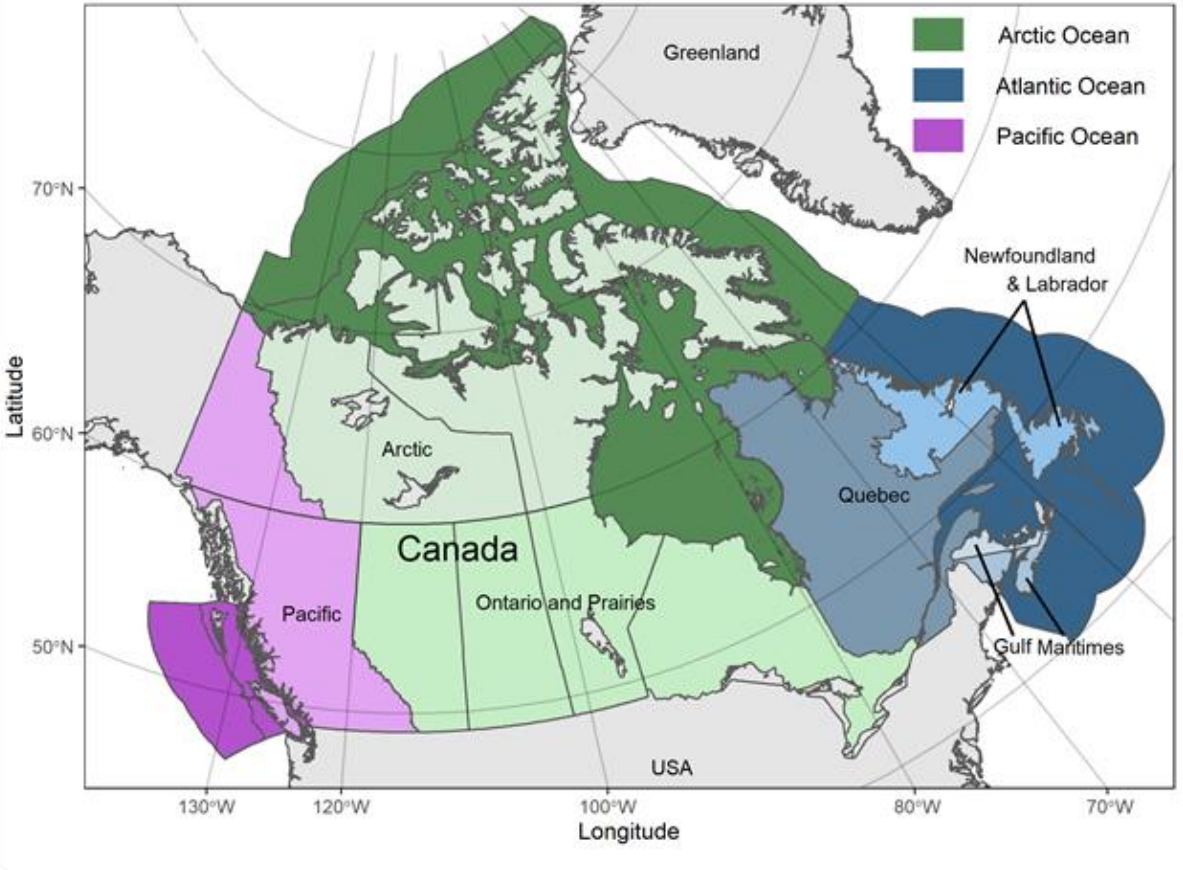
Objectives: identify

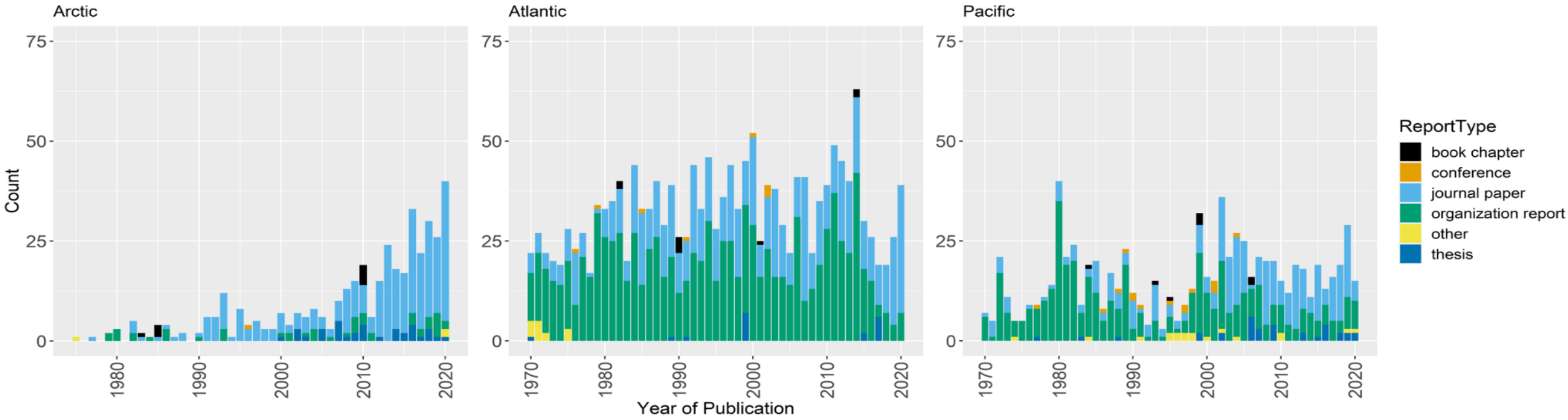
- knowledge clusters and gaps
- pressures studied relative to fish outcomes



Canada's forage fish

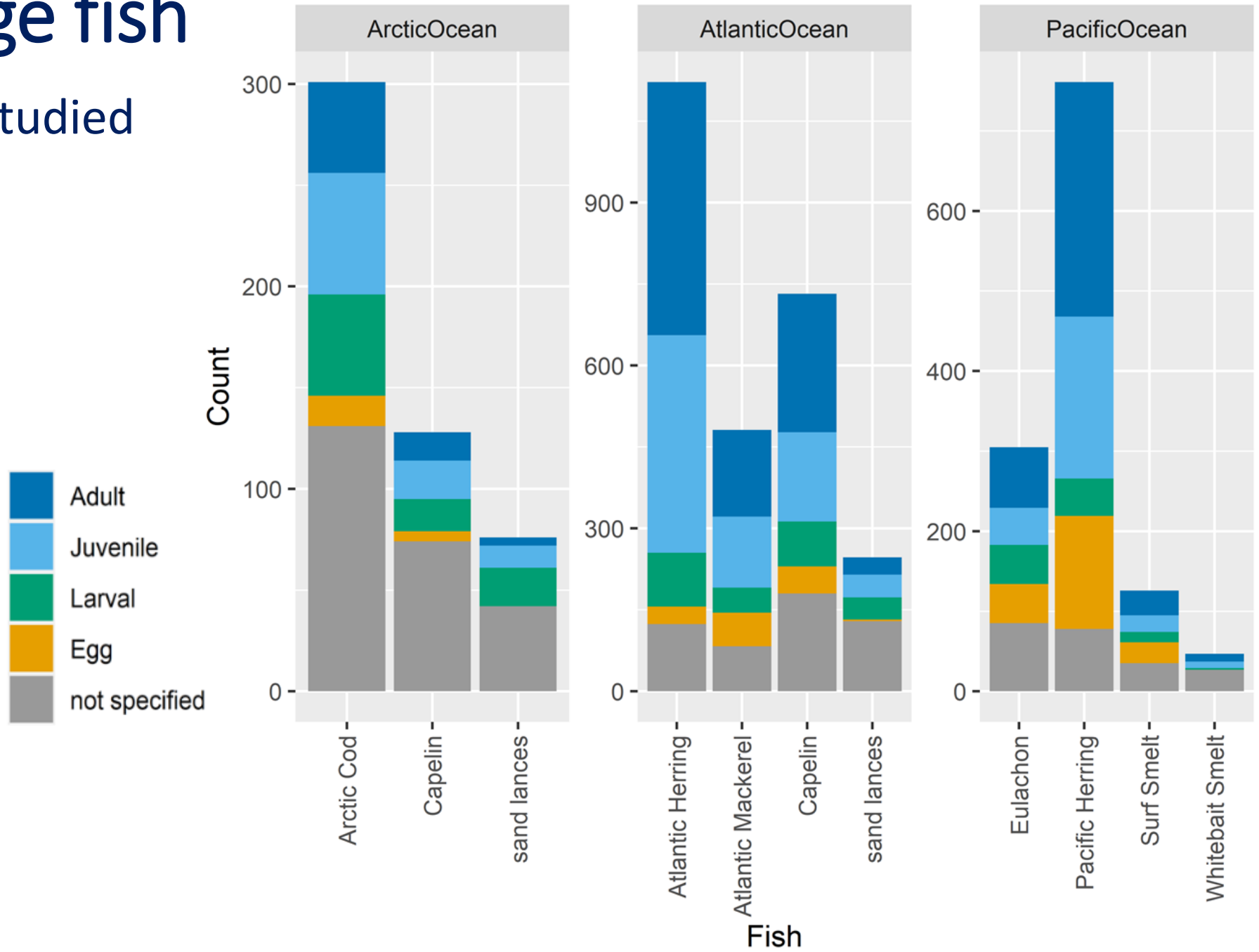
Systematically mapped 50 years of scientific literature (1970-2020) for 11 forage fish in Canada's 3 oceans

- Collaboration for Environ. Evidence for Evidence Synthesis in Environ. Mgt.; ROSES reporting standards
- Search terms identified
- Federal Science Library, ProQuest, Dissertations & Theses Global, Web of Science, Google Scholar
- Screened articles
- Extracted meta-data



Canada's forage fish

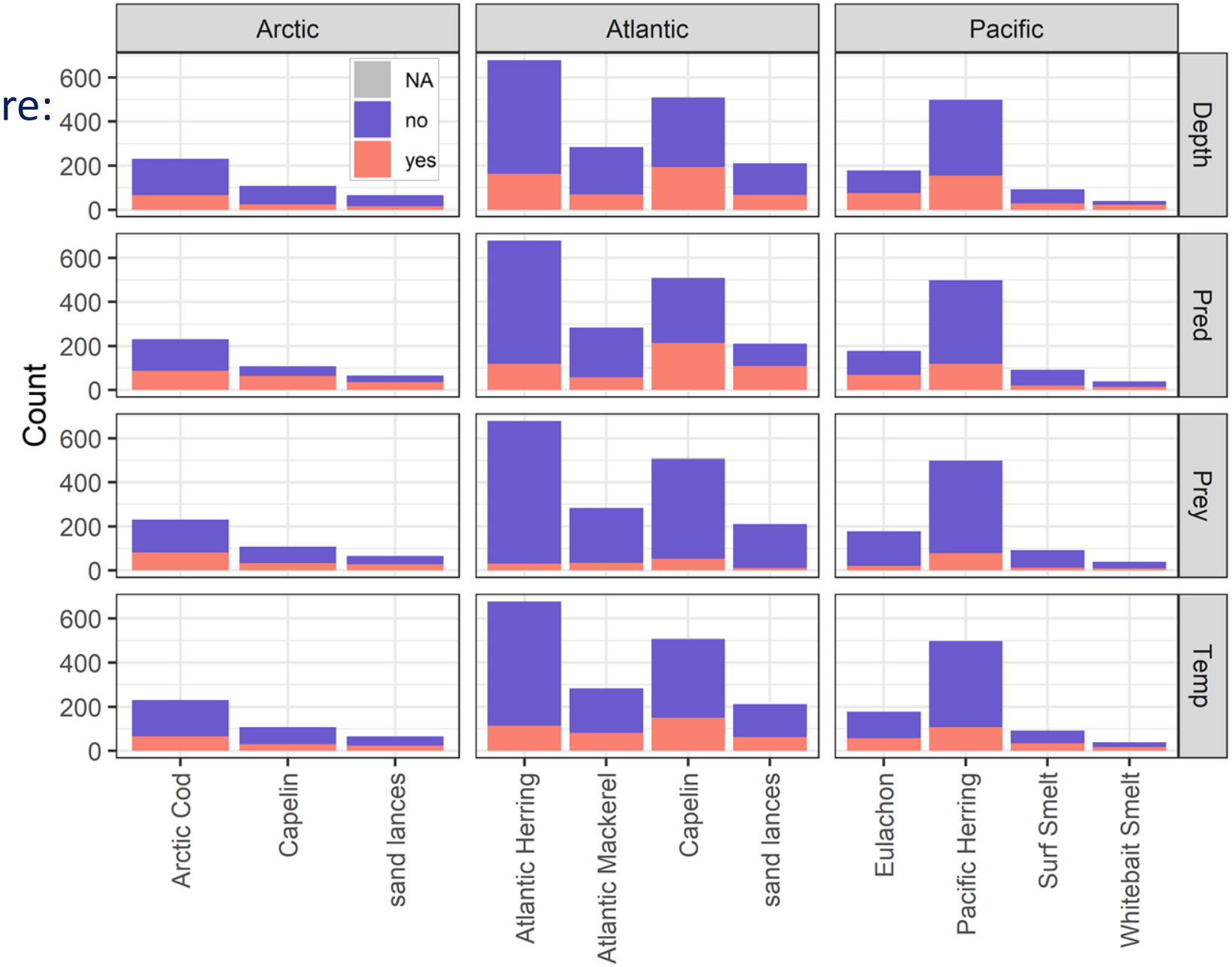
Life history stages studied



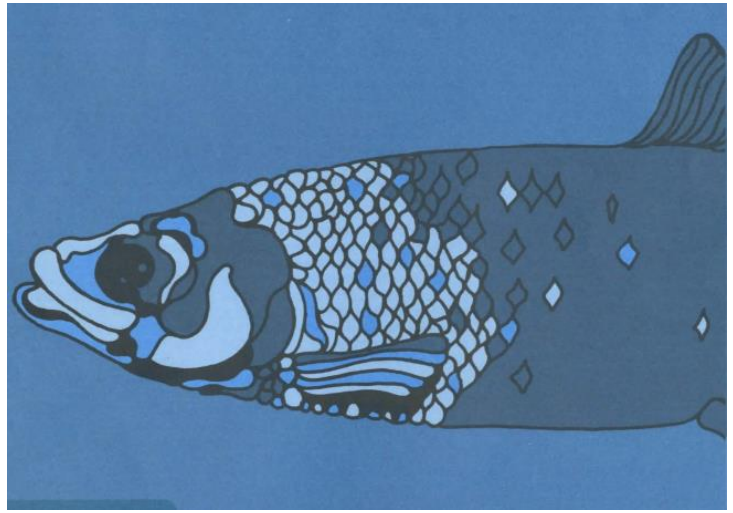
Canada's forage fish

Depth, predators, prey, temperature:

- Some baseline info. for all
- Less info. for non-commercially exploited species
- Prey is least studied, overall



Atlantic, Atlantic Herring



Fish outcomes

Pressure	Distr	Growth Life History				Migration		Performance				Prod.			Reprod.						Survi
	DistributionHabitatUse	Condition	Foraging	MassOrSize	Other	Other	Spawning	Energy	Other	Stress	Swimming	BiomassOrAbundance	Other	Recruitment	EggAbundance	EggSizeOrWeight	Fecundity	Maturation	Other	Spawning	Survival.Mortality
Climate (NAO, NPGO, etc)	2	1										2		2							
transport (currents, etc)	24	1	1			2	1				1	2	2	3						2	
ice	2	1											2	2							
temperature	38	2	1	12	3	2	6					10	7	20	1	1		3		12	3
salinity	16	1	1	1								2	1	15	1					1	
oxygen	1																				1
upwelling (magnitude or timing)	1																				
phytoplankton (primary productivity)	3	1	1	1								2		4							4
zooplankton (secondary productivity)	13	1	2	1		2		1				2		2							3
predators	5		1	1								5		7							17
competitors	17		3	2		1						4		6							2
density dependence	1	1	1	3	2							2	1	12	2		2	1			3
fisheries	2											77		3	1					2	69
other human pressures	2	1	1	1	1		1		1											1	
other pressure	15	8	3	6		2	3	6	1	1		15		12	9	3	7	7	2	3	8
not linked to a pressure	82	33	8	235	4	5	24	21				57	5	69	10	1	9	93	5	39	56

count: 200, 150, 100, 50, 0

Conclusions

Forage fish knowledge gaps:

- Non-commercially exploited species
- Early life history stages
- Diets
- Migration, performance, survival
- Effects of some pressures

Conclusions

Future research could focus on:

- the early life history stages of forage fish species
- non-commercially exploited species that support marine food webs
- the trophic role(s) of forage fish species

This study has identified areas for future research that can:

- address policy requirements
- contribute to cumulative risk assessments
- inform an ecosystem approach to fisheries management (EAFM)

National EAFM Case Study
Incorporating ecosystem information into science advice for Haida Gwaii Pacific Herring

Case Study Leaders: Jennifer Boldt, Chris Rooper, Jaclyn Cleary

Objectives

1. identify pressures hypothesized to affect life history stages of Pacific Herring
2. identify indicators of pressures and responses
3. summarize the status and trends of pressures and responses
4. examine pressure-response relationships
5. develop a standardized format

Identification of Indicators

- Recommended indicators (PICES WG 36, Bundy et al. 2017, Boldt et al. 2014)
- Filter criteria: available, measurable, theoretical basis,... (Bundy et al. 2017, Rice and Rochet 2005)
  - Theoretical basis: used literature mapping for Pacific Herring: expanded it to include literature 1931-2020; mapped to different life history stages (egg, larvae, juveniles, adults)

Multi-model approach (Boldt et al. 2021):

- Data exploration:
  - Status and trends
  - Single pressure-response models: GAM, linear, GAMM, LMAC
- Multi-factor regression approach: identify thresholds
  - Gradient forest analysis
- Multivariate analyses:
  - Dynamic Factor Analysis

Summary Forage Fish Knowledge Gaps & Opportunities

Gaps

- Non-commercially exploited species
- Early life history stages
- Diets
- Migration, performance, survival
- Effects of some pressures
- Spawning and benthic habitats
- Contribution to resiliency and biodiversity

National Forage, Pelagic Fish Working Group!

Opportunities

- Integrated ecosystem surveys → EAFM
- Add complementary sampling to existing surveys
- Collect standardized zooplankton, environmental, diet data
- Advanced technologies
- Acoustics data
- Ichthyoplankton
- Model habitat suitability, MSE