Evolving Challenges in Fisheries Science (and How We Are Tackling Them)

NOAA FISHERIES

Cisco Werner
Chief Science Advisor and
Director of Scientific Programs
NOAA Fisheries
cisco.werner@noaa.gov

NOAA Environmental
Leadership Webinar
June 9, 2020

Preface


NOAA OISST V2
Daily Average
SST Departure from Average
Thursday, Aug 06, 2015
1971-2000 Baseline
ClimateReanalyzer.org
World
+ 0.48 °C
Northern Hemisphere
+ 0.80 °C
North Atlantic
+ 0.39 °C
Equatorial Pacific
+ 0.82 °C
Southern Hemisphere
+ 0.22 °C
North Pacific
+ 0.92 °C

NOAA Fisheries Science Covers a Wide Scope

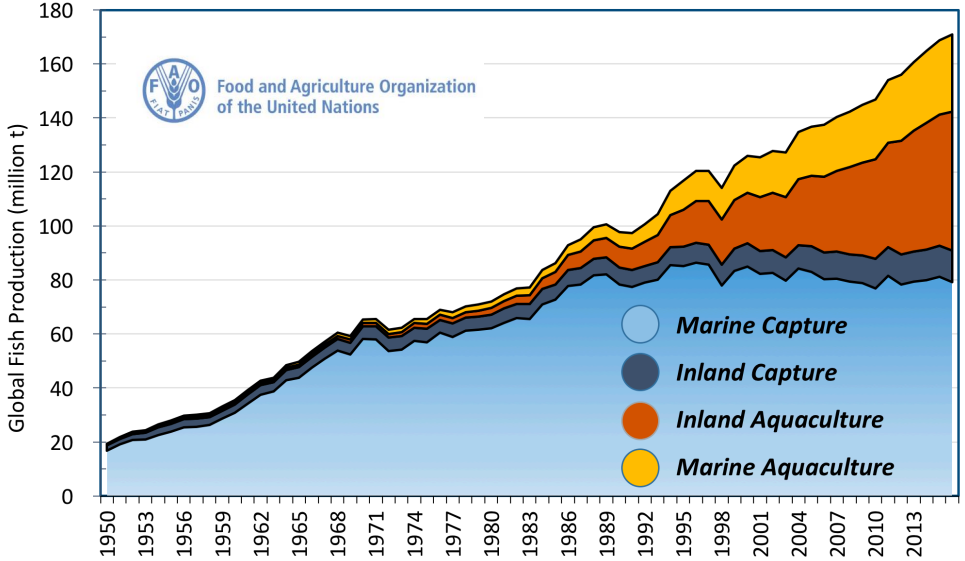
Legislative drivers include

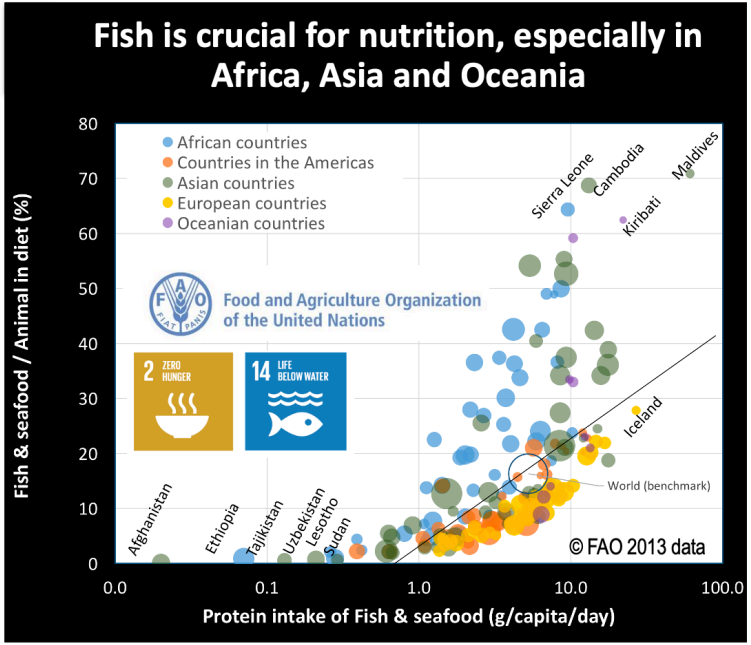
- Magnuson-Stevens Fishery Conservation and Management Act (**MSA**)
- Endangered Species Act (**ESA**)
- Marine Mammal Protection Act (**MMPA**)
- **E.O.** on Promoting American Seafood Competitiveness and Economic Growth
- National Environmental Policy Act (**NEPA**)

High-quality, timely **applied scientific information** for **conservation & management decision-making**

- Fisheries Information and Statistics
- Stock Assessments
- Economic and Social Analysis
- Marine Ecosystems Research
- Habitat Assessment and Research
- Monitoring and Analysis

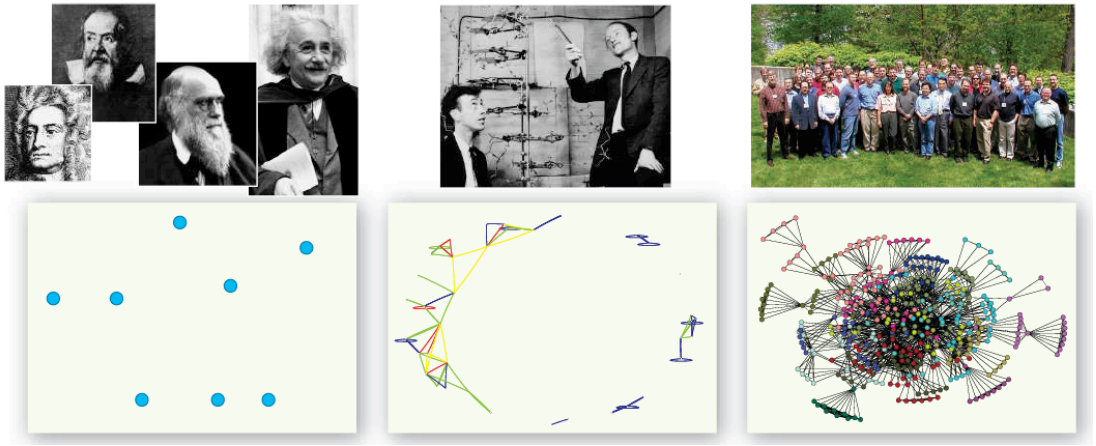
Importance of the oceans in the global food supply for continuing to meet the needs of a growing population.





- With world population approaching **9 billion people** (by ~2040), where agriculture already uses 40% of the Earth's land surface and over 70% of water used, **increased utilization of the ocean as a human food provider seems inevitable.**
- Solutions (capture fisheries and aquaculture) are available: but they also require broader **political & social commitment, technological innovation, and changes in behavior**.

Adapted from M. Barange, 2019 ICES ASC

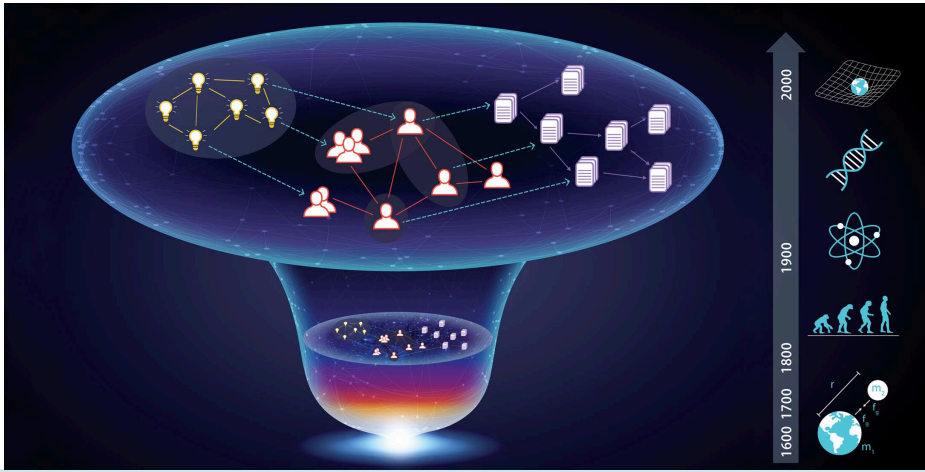


Network of natural, social and engineering scientists

"The size of collaborative teams is increasing, turning the scientific enterprise into a densely interconnected network…" (Barabási, 2005)

"Contemporary science is a dynamical system of undertakings driven by complex interactions among social structures, knowledge representations, and the natural world."

(Fortunato et al. 2018)

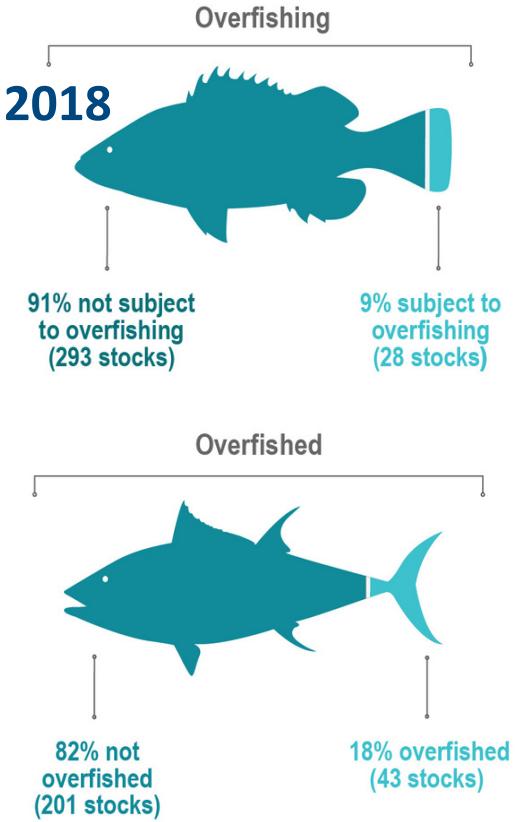


Outline

- **A quick look back – "taking stock"**
  - We have made a great deal of progress… are we done?
- **Secular & rapid rates of change**
  - Environmental variability
    - Movement/behavior/shifts
    - Changes in food web structure
    - Thresholds
  - Evolving "SeaScape"
    - Offshore energy
    - Aquaculture
- **Requirement for different ways to:**
  - Sample (data acquisition)
  - "Count" (assessments)
  - Make decisions (management)
- **Evolving technologies and models**
  - 'Omics, AI/ML, UxS, Cloud Computing
  - Data-driven science?
  - Earth System Models (S2S2D)
  - Climate & Fisheries
- **Discussion & Conclusions**

A quick look back, taking stock…

Notable advances in our sustainable fisheries and protected species



https://www.fisheries.noaa.gov/media-release/number-us-fish-stocks-sustainable-levels-remains-near-record-high

Recovering threatened and endangered species:

- 97 domestic,
- 66 foreign,
- 90 transnational

Recovery plans in different stages and may require:

- Restoring or preserving habitat.
- Minimizing or offsetting the effects of actions that harm species.
- Enhancing population numbers.

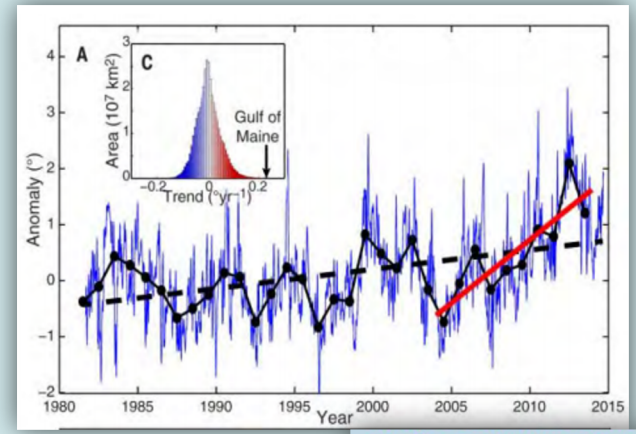
https://www.fisheries.noaa.gov/feature-story/recovering-threatened-and-endangered-species-report-congress-2017-2018

https://www.fisheries.noaa.gov/topic/endangered-species-conservation#species-in-the-spotlight

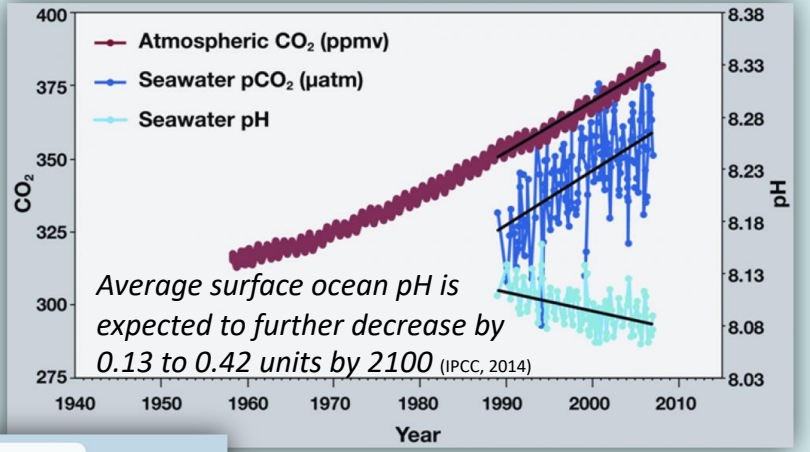
Nine species, for some their numbers so low that they need to be bred in captivity; others are facing human threats that must be addressed to prevent their extinction.

Should we stay the course?

Oceans are Changing *(rapidly)*

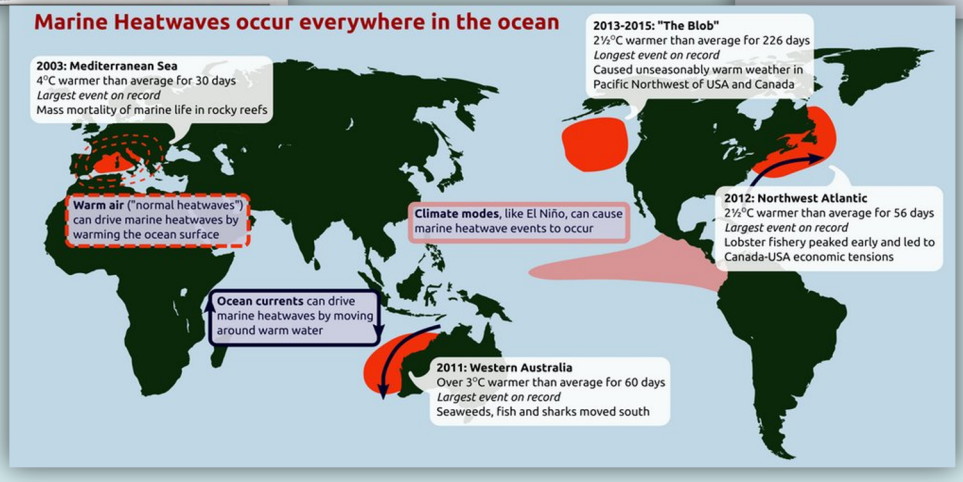


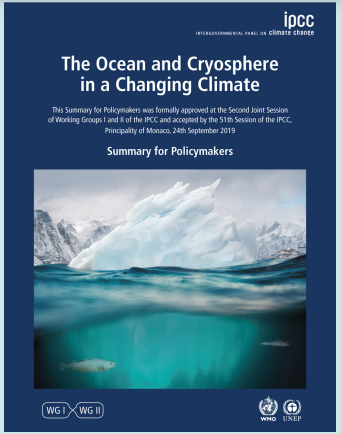
Temperature expected to increase by 2-4°C by end of century
(IPCC, 2014; Pershing et al. 2015, Science)



Average surface ocean pH is expected to further decrease by 0.13 to 0.42 units by 2100 (IPCC, 2014)

"Marine heatwaves have become longer and more frequent around the world"
- Eric Oliver, The Conversation





Credit: Eric Oliver/Dalhousie University

NOAA FISHERIES

Secular & rapid rates of change

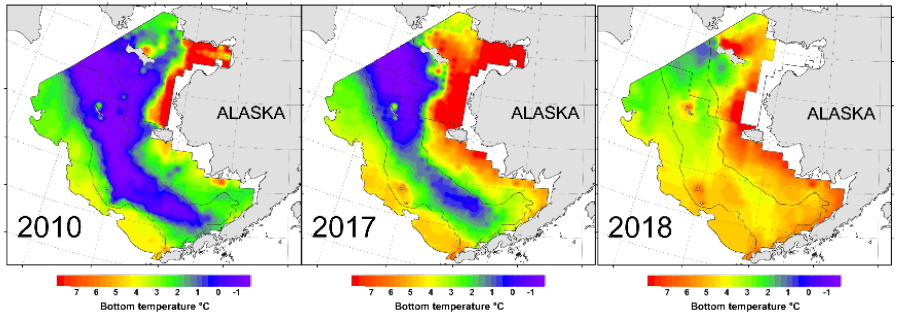
- Environmental variability
  - Movement/behavior/shifts
  - Changes in food web structure
  - Thresholds

https://www.seattletimes.com/seattle-news/as-bering-sea-ice-melts-nature-is-changing-on-a-massive-scale-and-alaska-crab-pots-are-pulling-up-cod/?utm_source=twitter&utm_medium=social&utm_campaign=article_inset_1.1

Shifts/movement ecology…

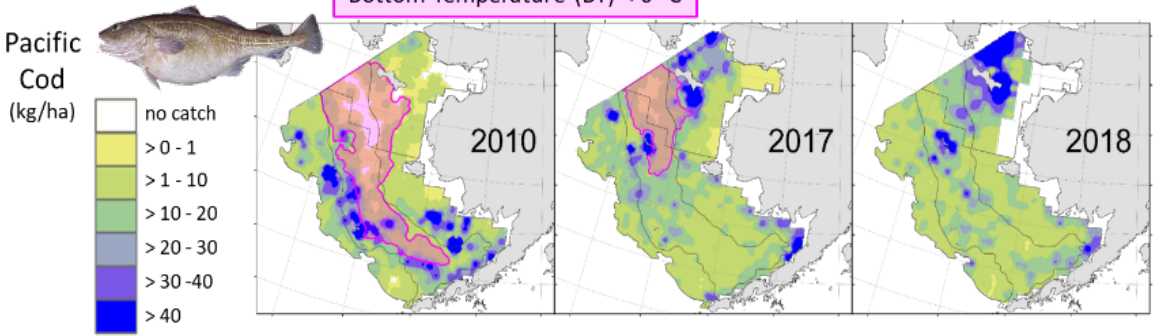
Pacific cod and pollock distribution moved shoreward and northward as cold pool (<2°C) was reduced.

Population shift/expansion <10 years

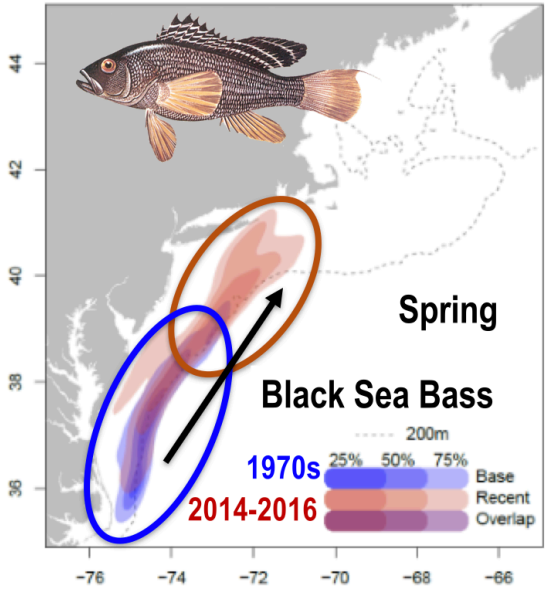


Bottom Temperature (BT) < 0° C

Min. BT = 1.6° C



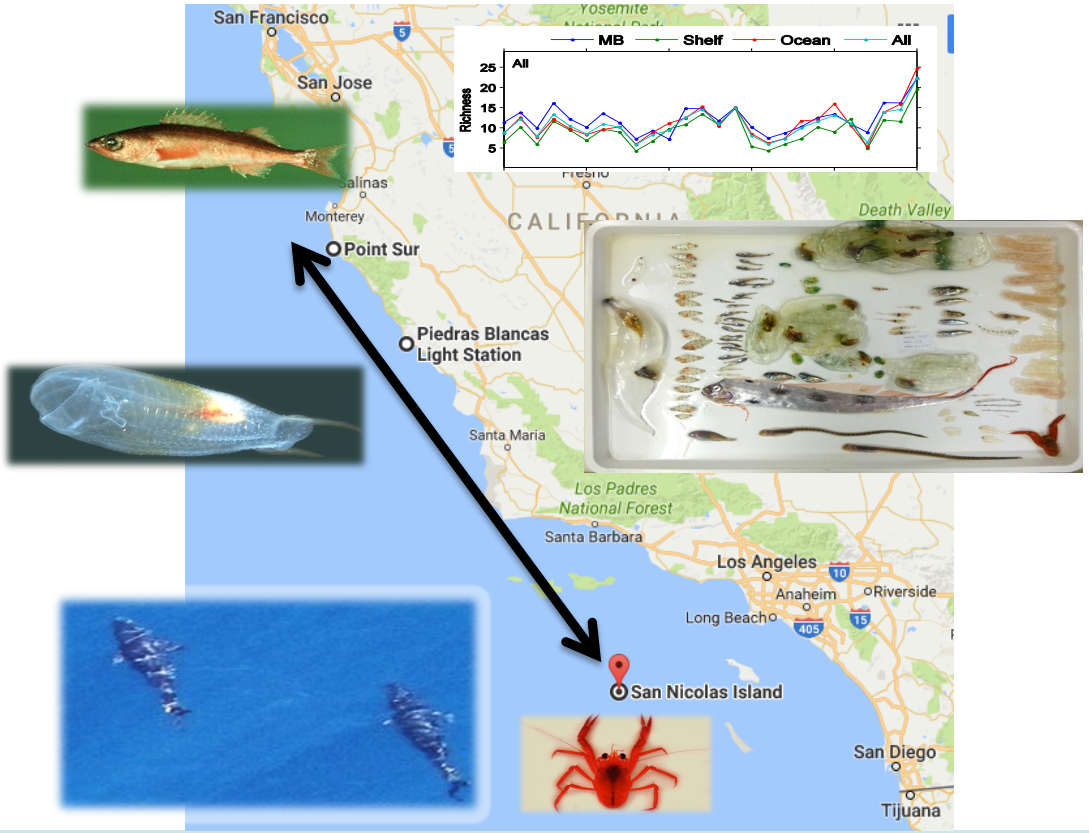
(Courtesy of B. Foy, S. Barbeaux, K.Holsman, B. Lauth, L. Britt, S. Zador; AFSC, 2019)



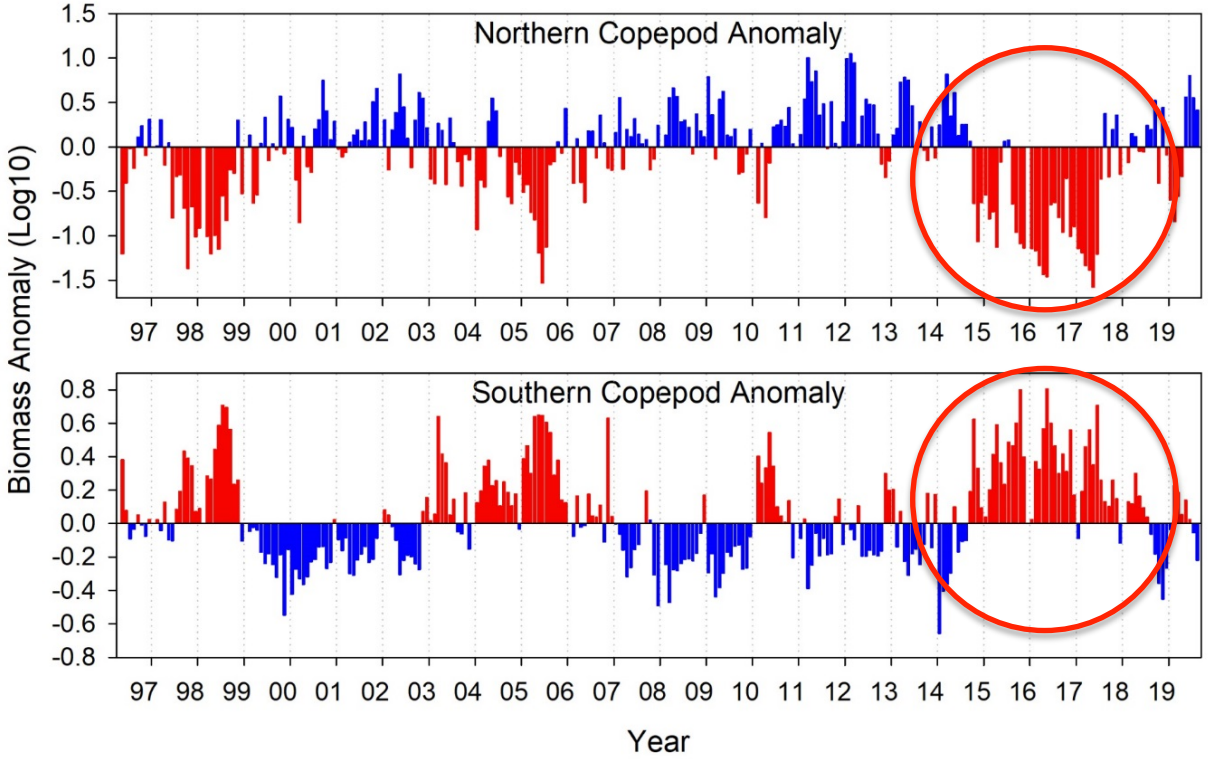
Population shift/expansion ~40 yrs

https://www.nytimes.com/2016/12/30/science/fish-climate-change-northeast.html

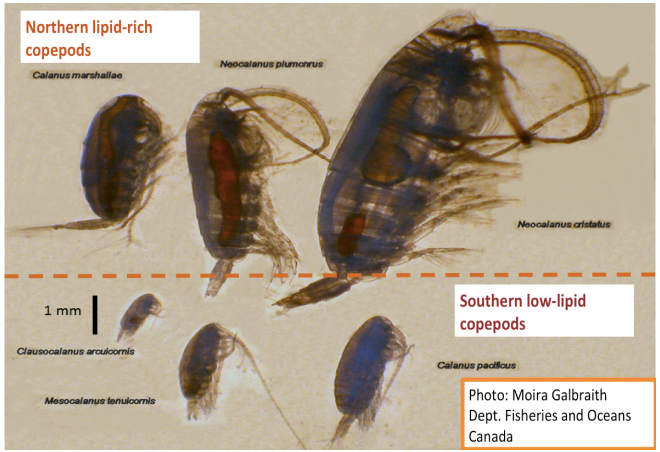
Changes in communities…



Food web structure – changes in zooplankton composition

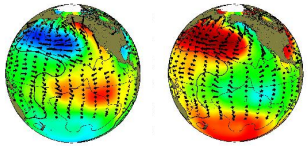


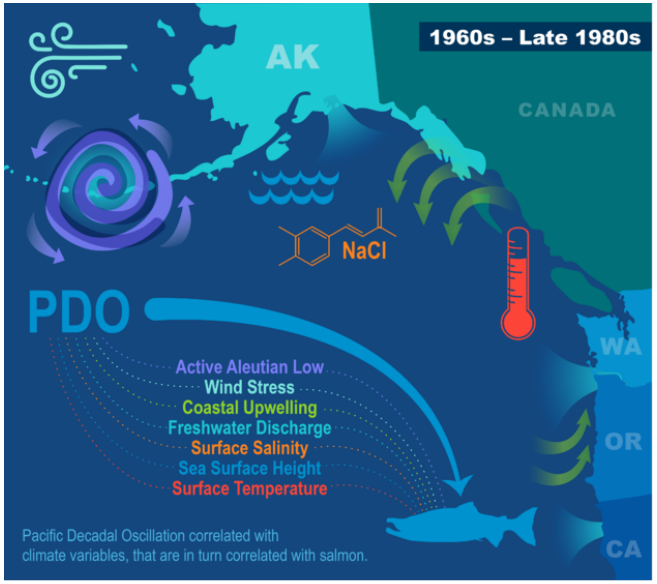
(Courtesy Toby Garfield, Chris Harvey et al.; CC-IEA)

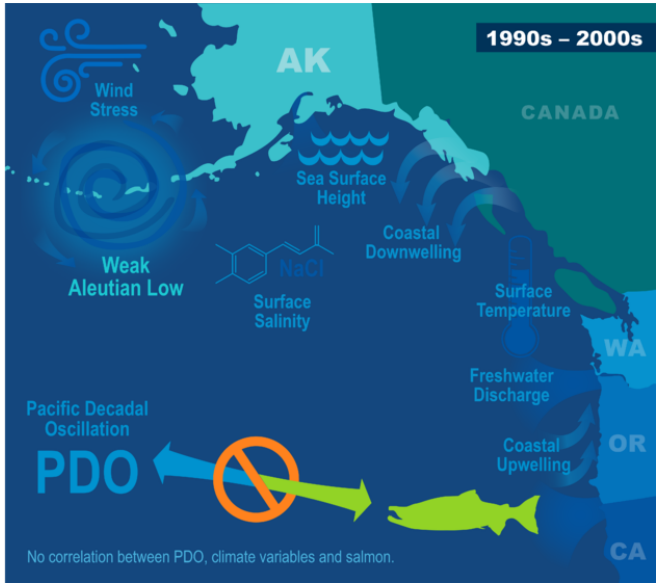


Copepod taxa biomass anomaly collected 5 nautical miles off Newport (OR): northern, cold water, lipid-rich species and southern species, warmer waters, lipid poor.

Changing climate is shuffling relationships among variables and processes







- Until recently, the PDO accurately described the climate pattern north of 38°N, and the NPGO south of 38°N.
- PDO and NPGO captured climate shifts that resulted in reorganizations in biological communities over vast oceanic regions.

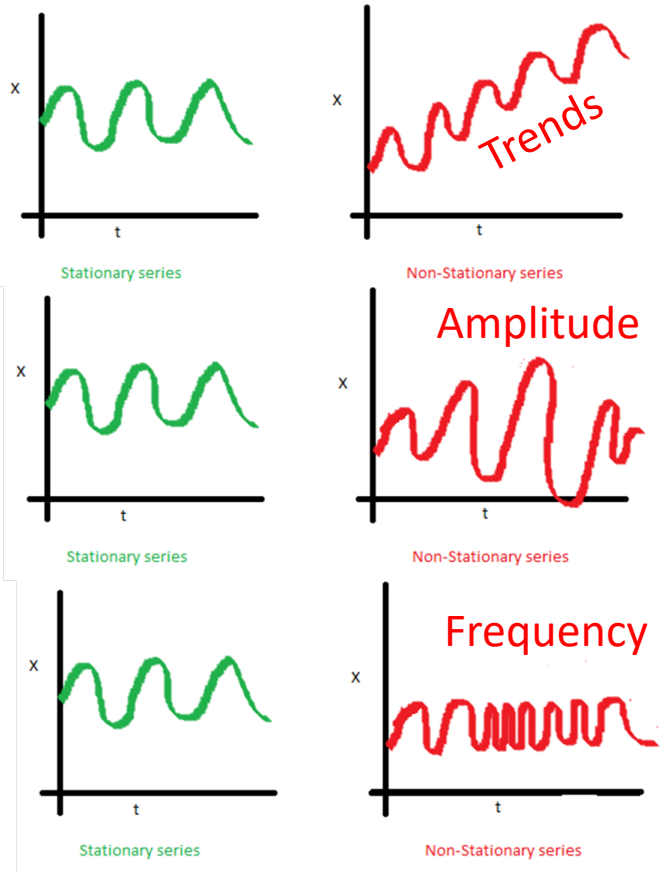
- Resulting from continued changes of the world's oceans, correlations between the PDO and NPGO indices and regional climate and biological variables that have previously been strong, are now weaker or have disappeared.

From stationarity to non-stationarity

- **Stationarity** – when systems that fluctuate within an unchanging envelope of variability; a foundational concept in fisheries and other resource management efforts.

- **Non-stationarity** – times series whose properties (e.g., mean, variance, etc.) change with time and, thus, are harder to predict.
  - Some changes in components of the Earth System (hydrologic cycle, cryosphere, oceans, etc.) are related to evolution of the Earth's climate.

(Milly et al. 2008)



Changes in sea-scape

Offshore wind development

- Recognize the physical, biological, economic, and social interactions among the affected aquaculture and fishery-related components of the ecosystem

Aquaculture

https://www.fishfarmingexpert.com/article/world-s-first-offshore-fish-farm-arrives-in-norway/

- Collaborate across sectors to improve science, management, and operations
- Develop science framework to assess cumulative impacts and strengthen science and management
- Optimize benefits among a diverse set of societal goals.

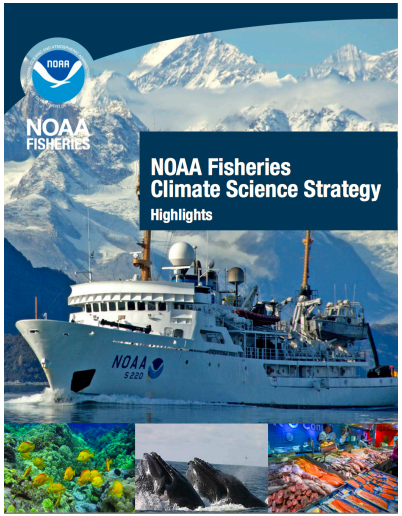
(Courtesy Jon Hare and Andrew Lipsky; M. Rust)

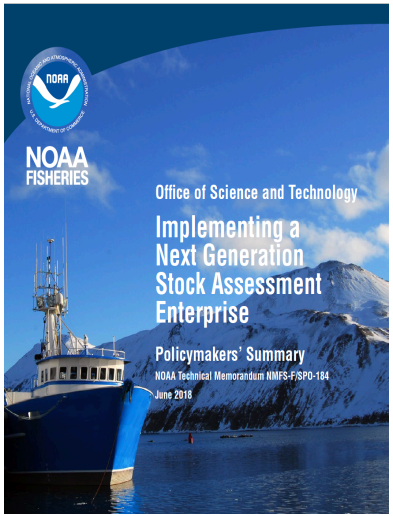
Recapping a few key points…

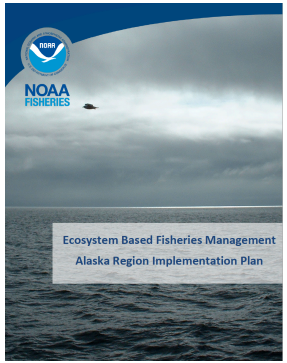
- The changes in oceans and their *ecosystems* are unprecedented.
- They have given us the opportunity to take a peek into what may be either recurrent conditions or a future “new baseline”.
- We need to be ready and better-prepared to deal with surprises.

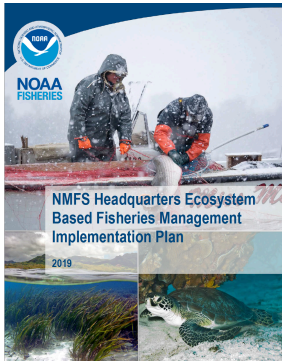
We need different ways to:

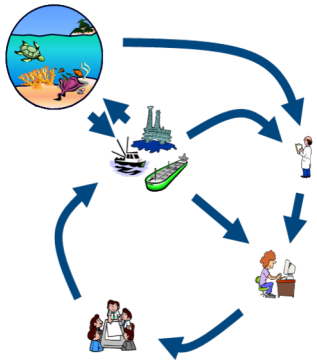
- Sample (data acquisition)
- “Count” (assessments)
- Make decisions (management)







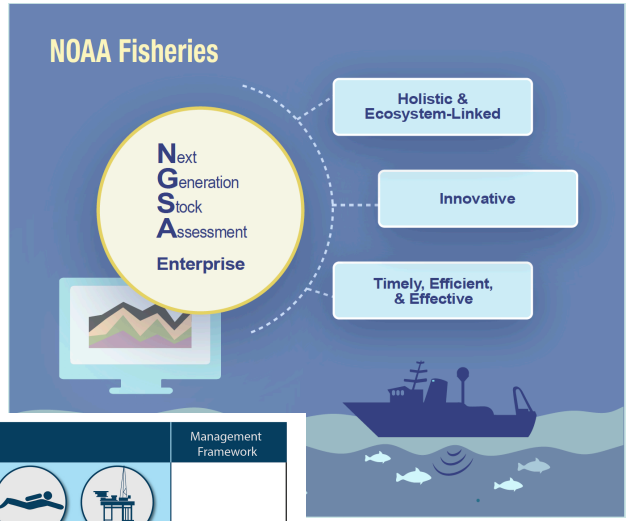


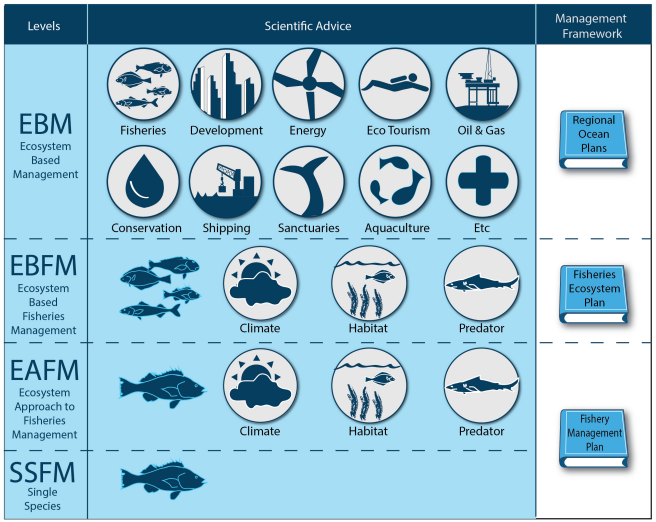


Methot, Link, Lipton, Lynch, Merrick, Cyr, and many others…

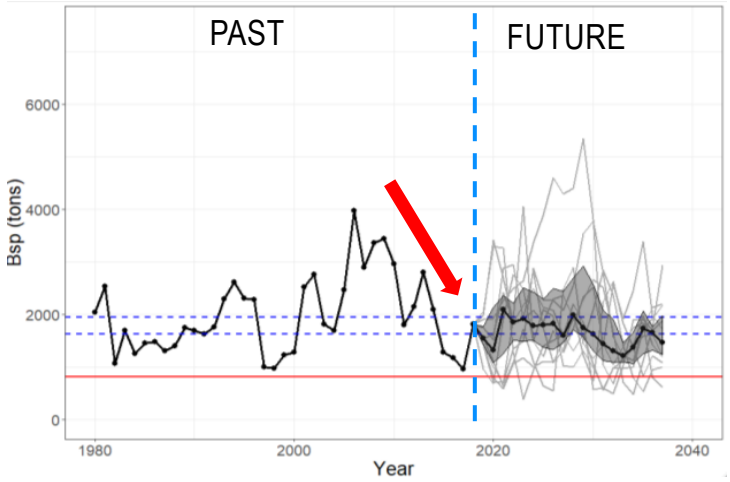
Stock Assessments and Ecosystem Approaches

- Conduct **process research**
- **Holistic approaches:** spatial, species interactions, environmental drivers
- More complete and explicit inclusion of **uncertainty** (ensemble modeling, decision analysis/MSE)





Adaptation Strategies: variability … "non-stationarity"



- Robust management strategies to reduce risks
- Precautionary approaches
- Plan for extremes
- Forecasts to help plan and target fishing
- Adapt timing of fishing season
- Flexible regulations

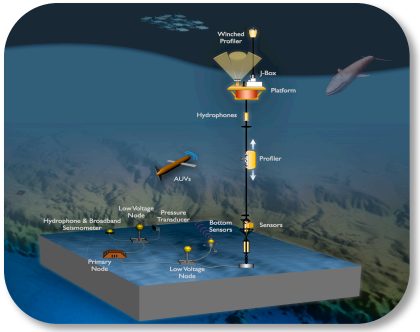
Managing for variability – ***not stability*** – is the key to adaptation

Need strategies to dampen highs and lows affecting livelihoods, logistics and economies

Modified from Éva Plagányi, FAO Fisheries Sustainability Symposium, Rome, Nov 2019

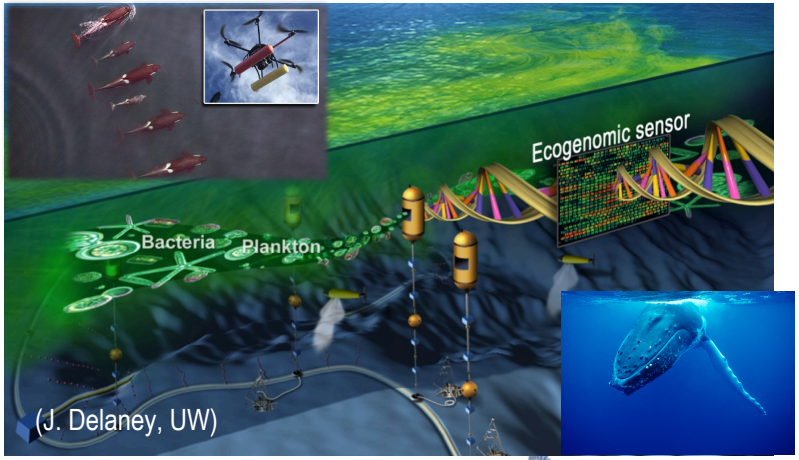
Next Generation Data Acquisition Plan

- Last comprehensive evaluation of our surveys was the 1998 "***NOAA Fisheries Data Acquisition Plan****.
- There is a need to re-visit our data-collection needs and strategies in view of:
  - Changes in "questions"… fish stocks' distributions, vital rates, etc.
  - Need to include ecosystem considerations
  - Changes in fleet composition (ships)
  - Partnerships with industry and communities
  - New technologies & new analytical capabilities

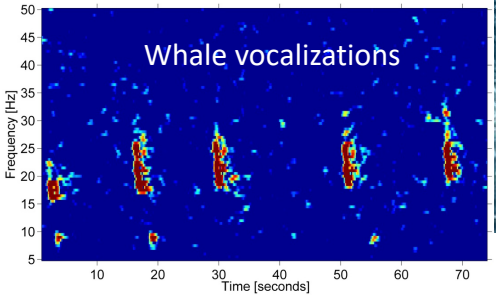


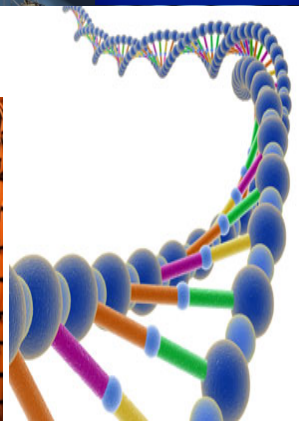
*https://www.st.nmfs.noaa.gov/st4/documents/DataPlan.pdf

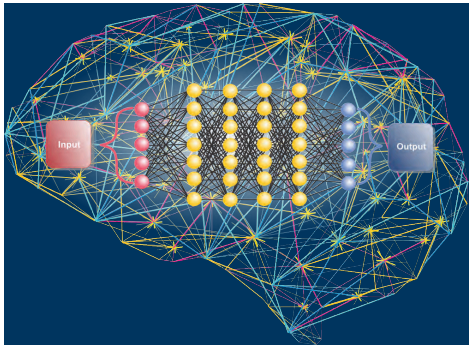
Expansions in observing and computational capabilities…



- Autonomous systems
- Advanced technologies
- ”Oceans” of data
- Artificial intelligence

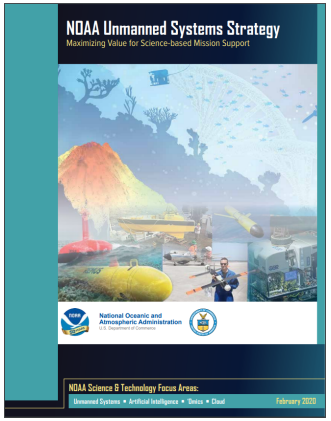






Evolving approaches: new technologies and analytics

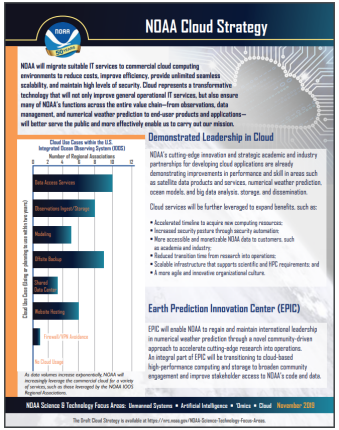
Unmanned Systems



Artificial Intelligence

'Omics

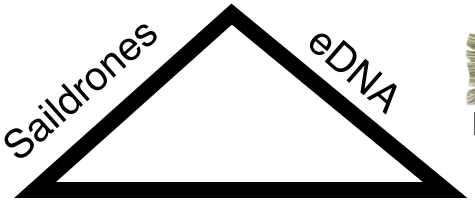
Cloud Computing



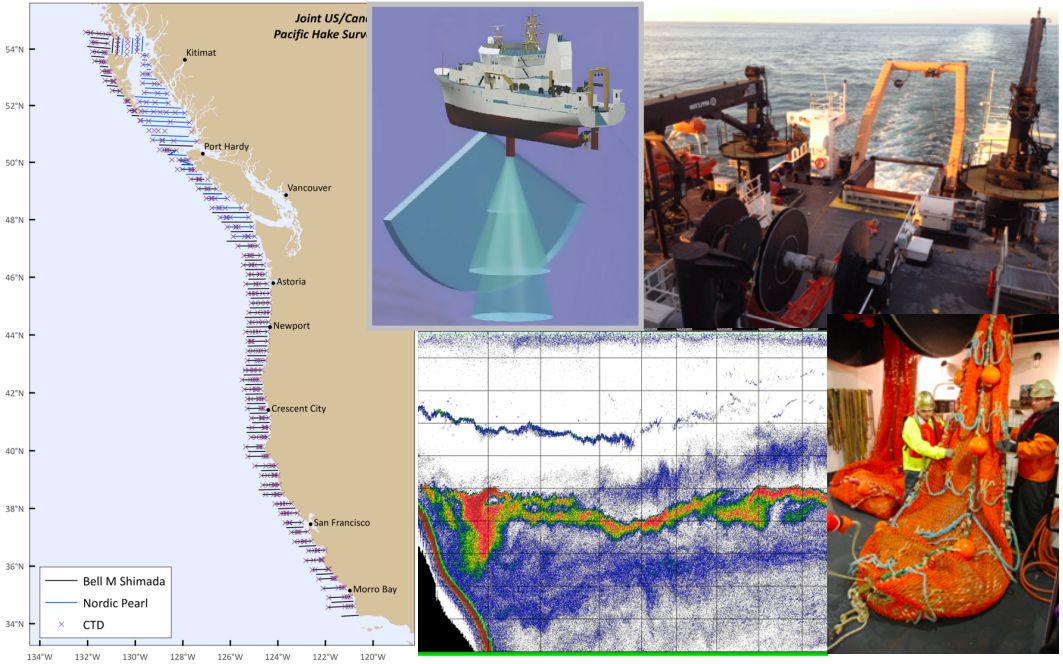
"… NOAA's strategies on UxS, 'Omics, Cloud and AI, will be crucial to understanding our vast ocean resources … and, in partnership with Federal agencies, the academic community, non-profit organizations, and the private sector, NOAA is helping advance America's ability to understand, manage, and conserve our ocean resources…"

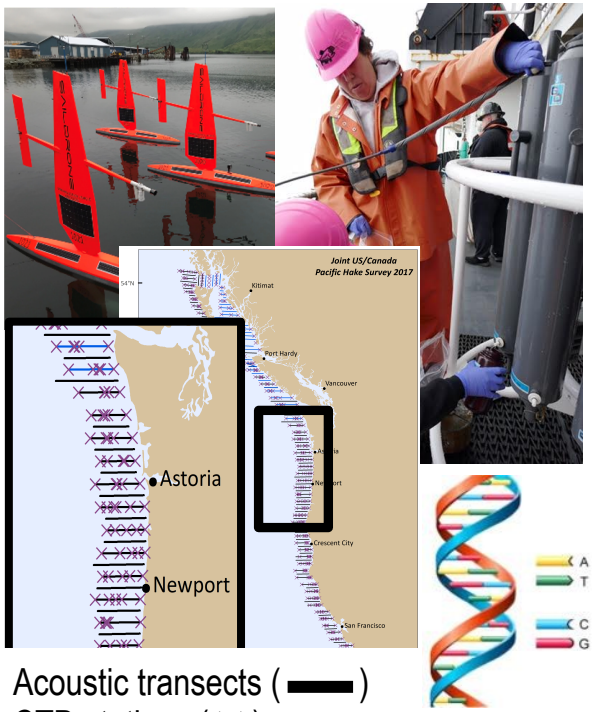
https://www.noaa.gov/media-release/noaa-finalizes-strategies-for-applying-emerging-science-and-technology

Summer of 2019



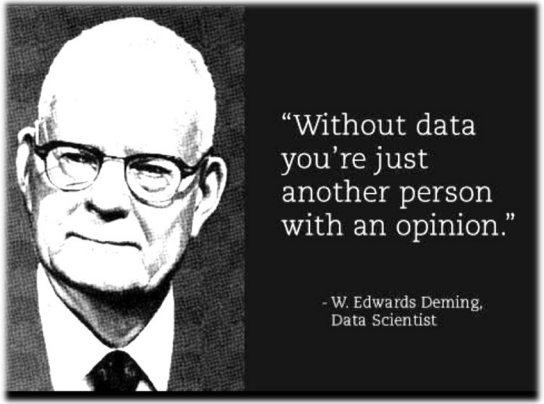
eDNA to detect and support estimates of Pacific Hake

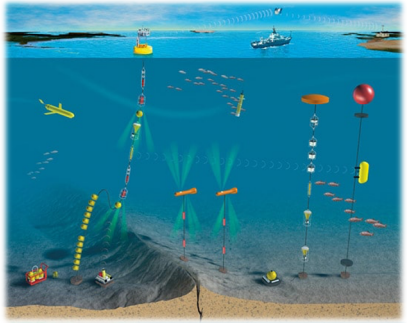


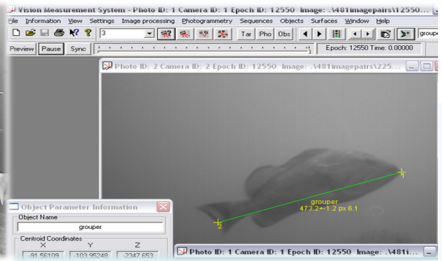


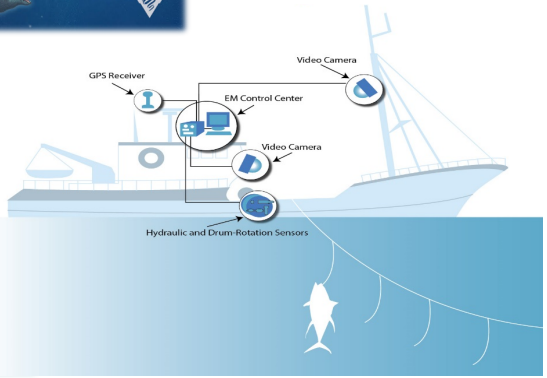
Acoustic transects (▬)
CTD stations (✕)

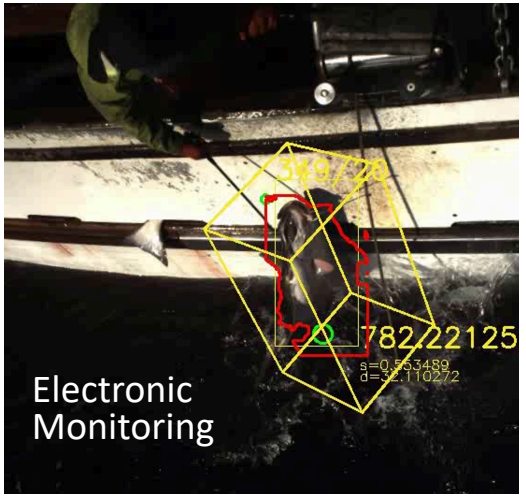
Evolving approaches
"Data-driven science"









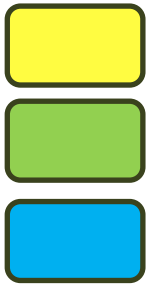


(Courtesy B. Richards, W. Michaels, J. Durban, and B. Alger)

New (and more) data bring advantages and also many challenges

It used to be…

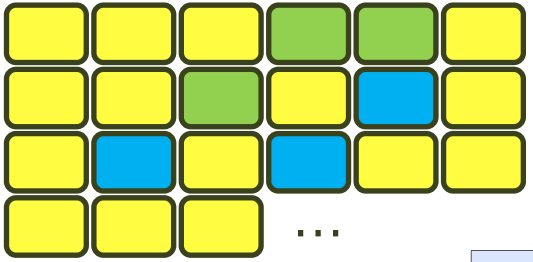
days,
weeks

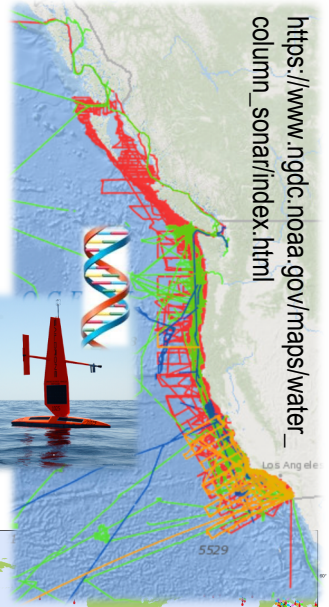


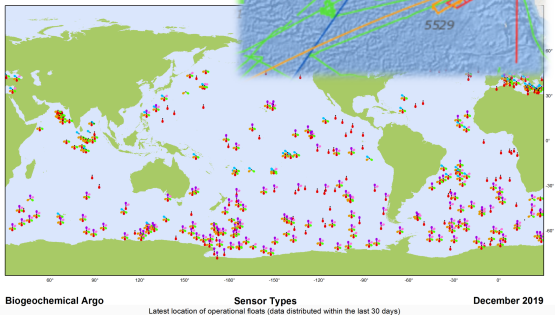
- Careful calibration
- Careful ground truth
- **Hypothesis-driven:**
  we (kind of) know what to look for

But now…

weeks,
months,
years



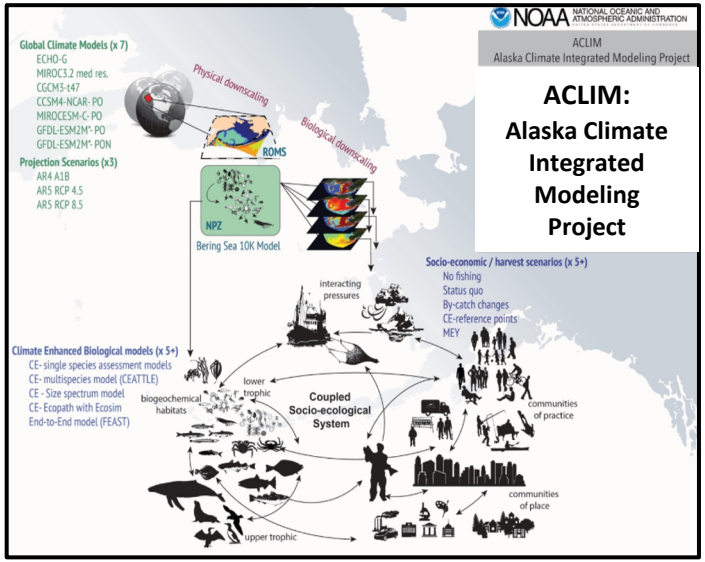




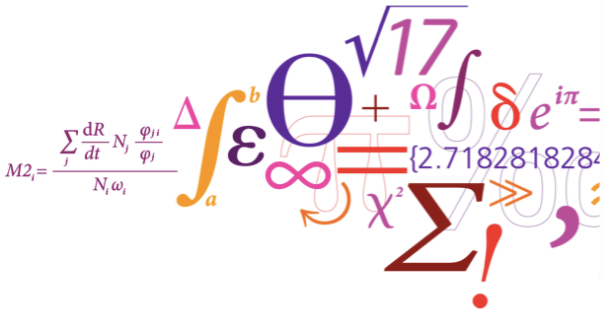
- Limited calibration
- Limited ground-truth
- **Data-driven:**
  where/what should we look for?

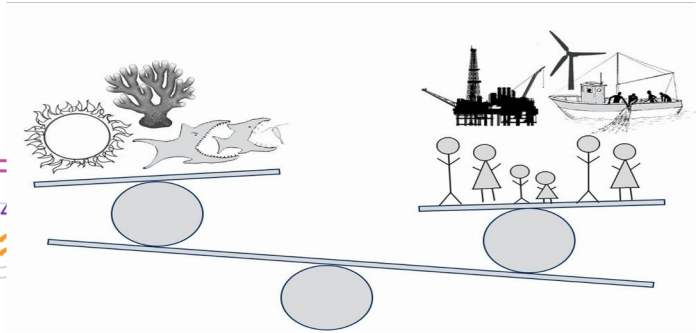
(Courtesy Wu-Jung Lee, APL-UW; OCEANS '19)

Evolving Approaches …
Modeling & Integration



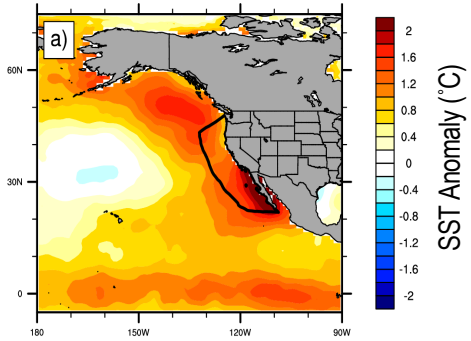
https://www.fisheries.noaa.gov/alaska/ecosystems/alaska-climate-integrated-modeling-project





Marine Heat Waves (S2S) forecast skill

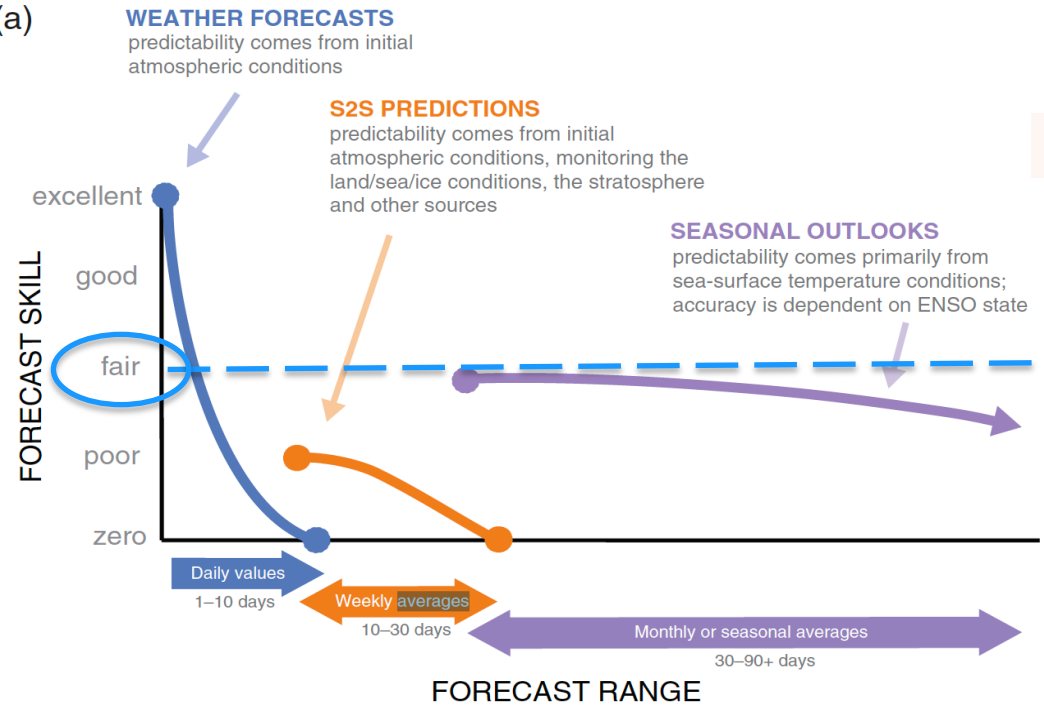
(could we have predicted the 2014-16 NE Pacific Marine Heat Wave?)



Thus far, different types or aspects of MHWs are:

- **more or less predictable depending on the forcing mechanisms at play**, and
- events that are consistent with predictable ocean responses could inform ecosystem-based management of the ocean.

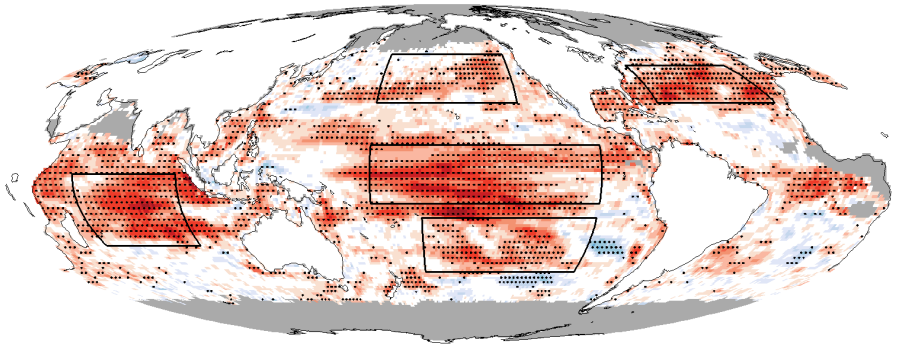
Jacox et al. (2019) doi: 10.3389/fmars.2019.00497



White et al. (2017), Meteor. Applications.

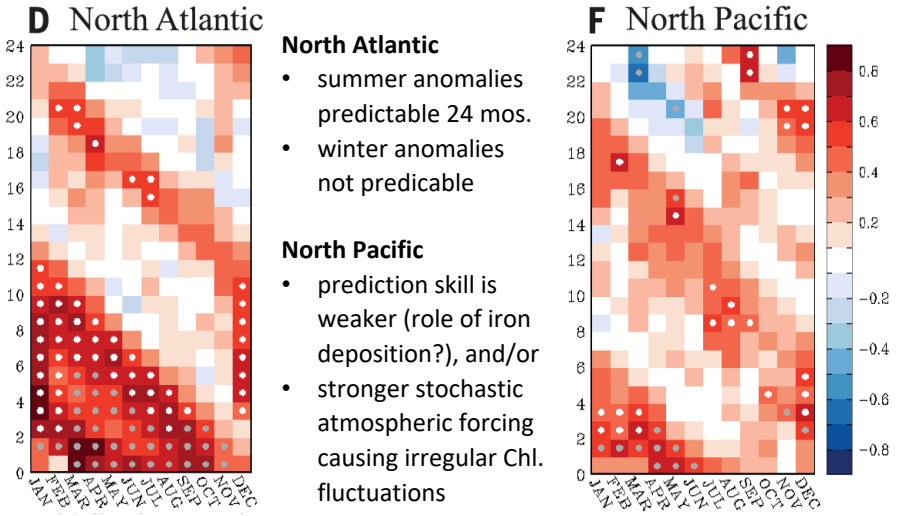
Longer time-scales require consideration of Earth System Models (ESMs): integration of atmosphere, land, water, ice, biology (and the human dimension)

ESMs: T, S, pH, nutrients, biogeochemistry (models' initialization and data assimilation)



Chlorophyll prediction skill (1-3 months lead time)

Global marine biogeochemical prediction system produces skillful chlorophyll predictions one season in advance in many ocean regions.



North Atlantic

- summer anomalies predictable 24 mos.
- winter anomalies not predicable

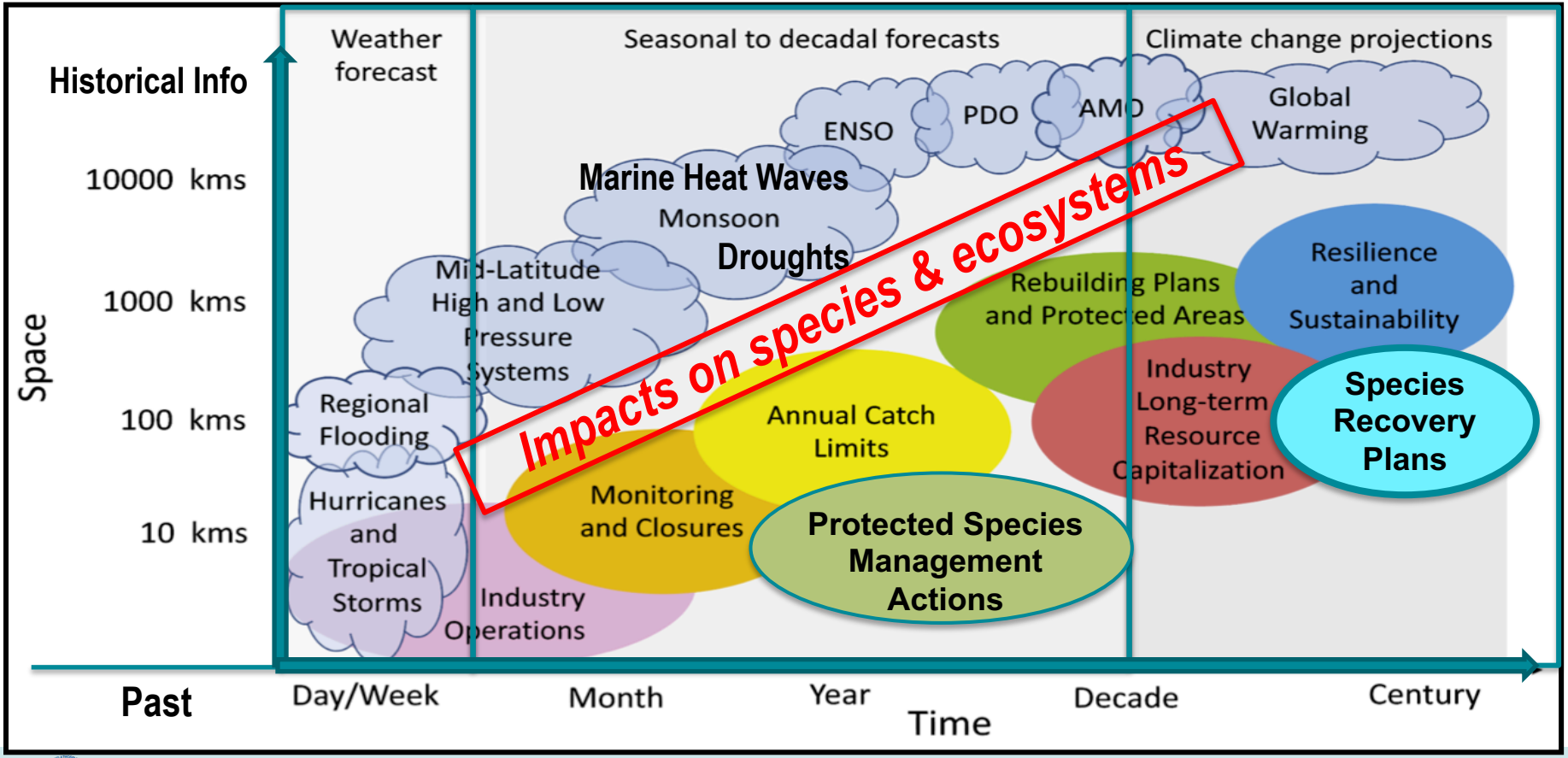
North Pacific

- prediction skill is weaker (role of iron deposition?), and/or
- stronger stochastic atmospheric forcing causing irregular Chl. fluctuations

- Incorporating chemical and biological data into forecasts remains one of the hardest challenges in OBCG.
- ARGO and BGC-ARGO to observe large-scale ocean and plankton ecosystem patterns.

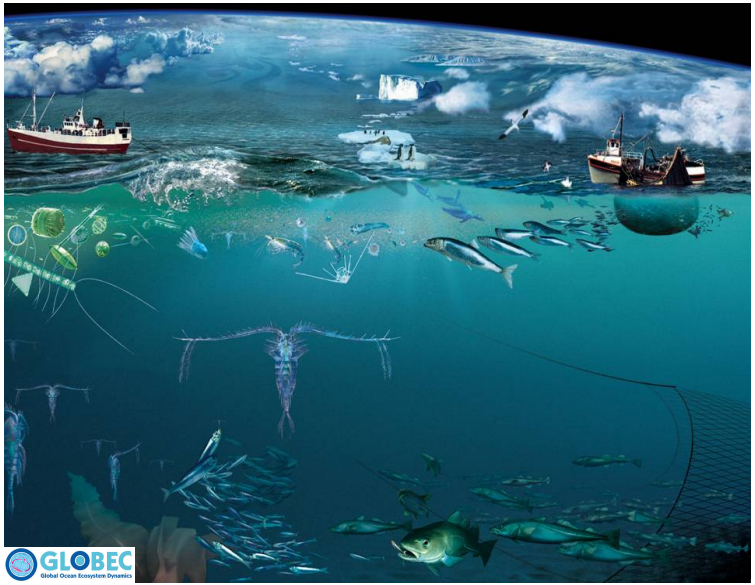
Park et al. (2019) Seasonal to multiannual marine ecosystem prediction with a global Earth System Model. *Science*.

NMFS Climate Information Needs



Climate and Fisheries Initiative

developed by
NMFS' Science Board &
OAR's Senior Research Council
to identify how to provide climate science needed for effective management of marine resources

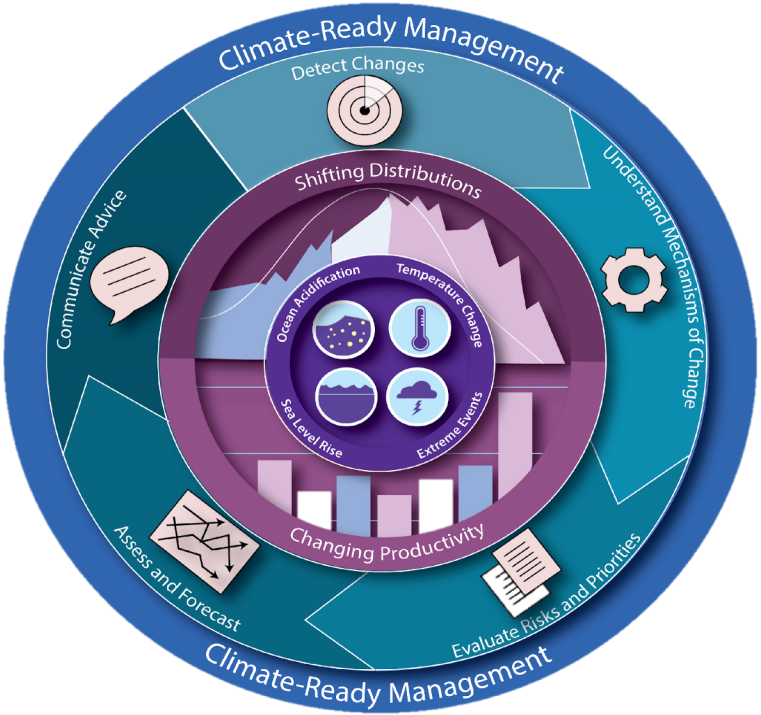


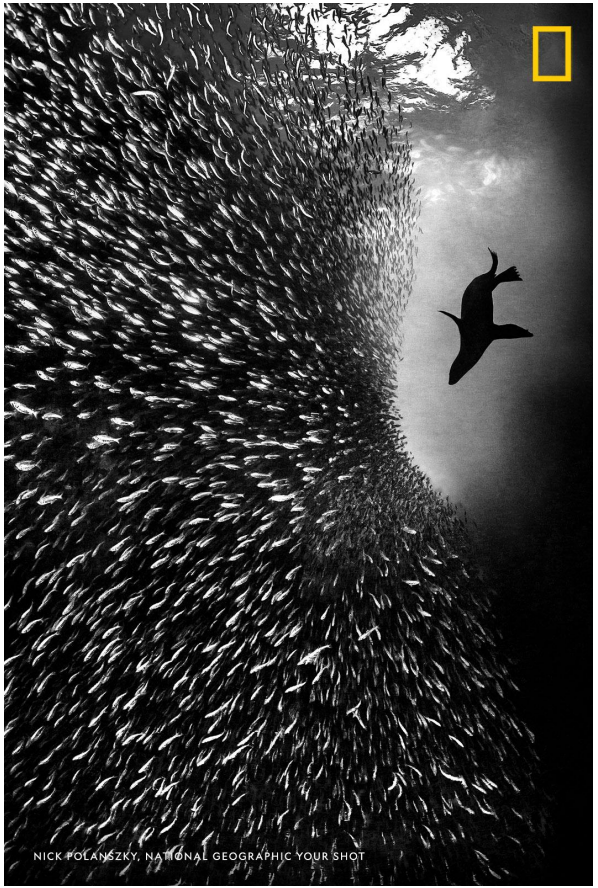
Vision

NOAA and its stakeholders *have robust climate- and ocean-related forecasts, predictions, and projections to guide management and adaptation strategies* that reduce risks and increase resilience of marine/coastal resources and the people who depend on them

W. Higgins, D. Detlor, R. Griffis, M. Jacox,
D. Tommasi, A. Hollowed, C. Stock, et al.

Concluding Remarks



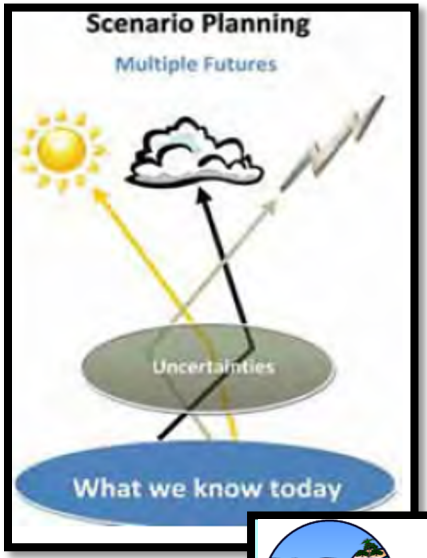


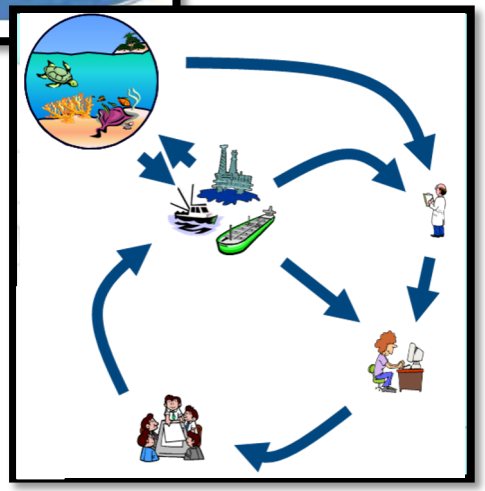
https://spo.nmfs.noaa.gov/sites/default/files/TMSPO188.pdf

Science Advice for Future Management Actions

Plan for future scenarios (**we know *it* is going to happen!**)

- Structured scenario planning, e.g., **management strategy evaluations (MSEs)**
- Plan for **emerging fisheries**
- Utilize and include decision support tools in stock assessment reports: **communicate risk and tradeoffs**
- Facilitate regular **engagement between scientists, managers, academia, and affected communities** (e.g., through regular and open dialogue at workshops and debriefs)

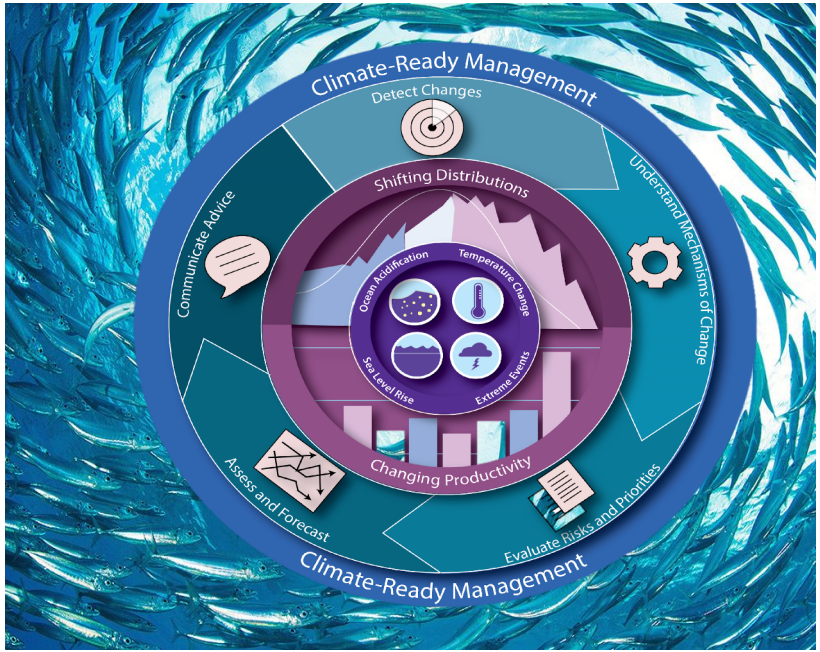




MSEs, EBFM –> trade-offs

Physical-ecosystem-human linkages in a rapidly changing ocean: what will we need to know … and how will we get there?

- **Everything!**
- Hypothesis- and data-driven science
  - Data collection
  - Analytical approaches
- Modeling
  - S2S2D
  - Climate & fisheries
- Co-production of advice: science, management ***and*** stakeholders/communities



Thank you

Please contact me with any questions or comments at cisco.werner@noaa.gov