Moving towards ecosystem-based management
– the role of marine mammals



Bjarni Mikkelsen

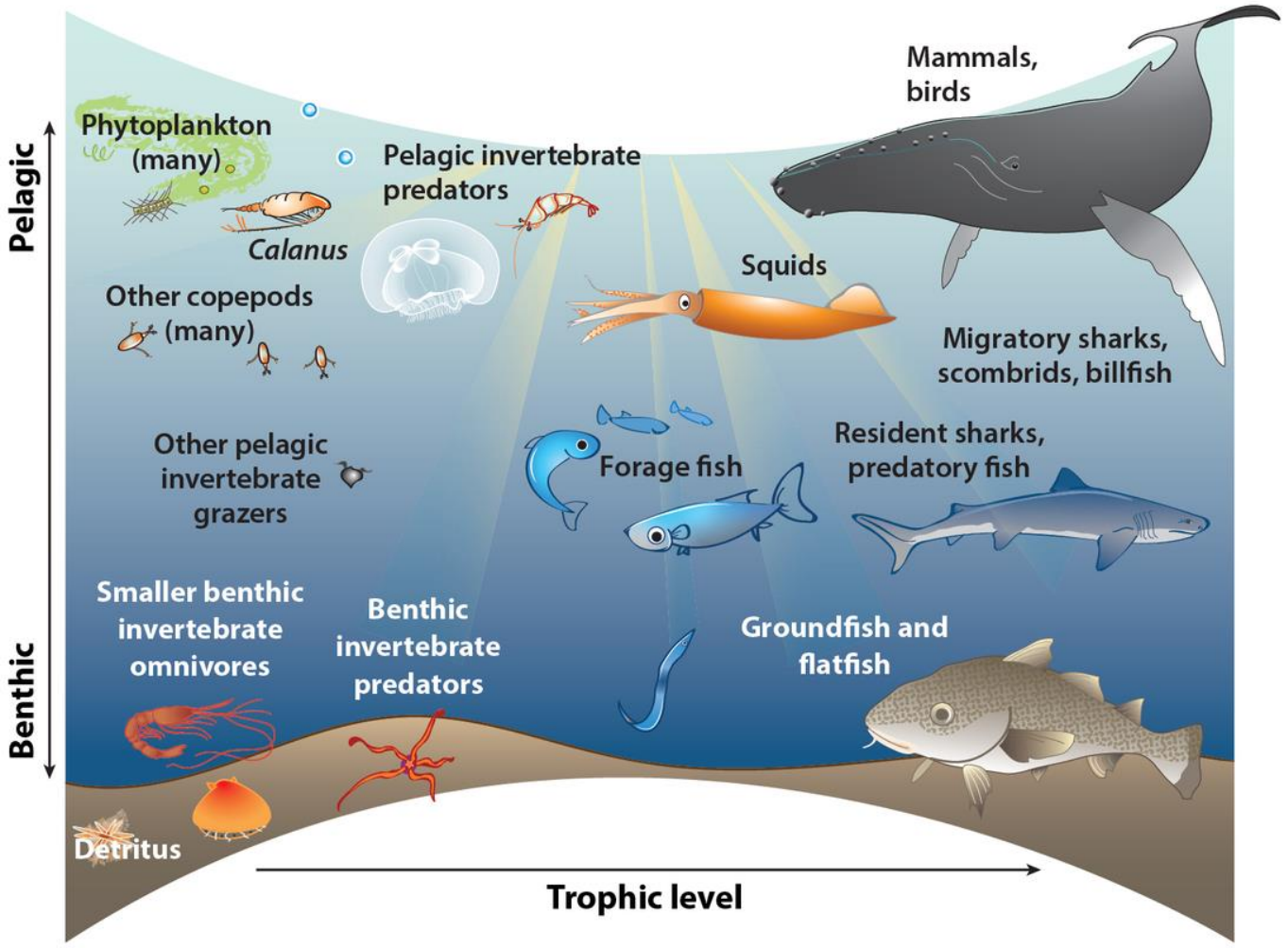
HAVSTOVAN
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Marine ecosystems

biological communities of interacting organisms and their physical environment

Ecosystem processes:

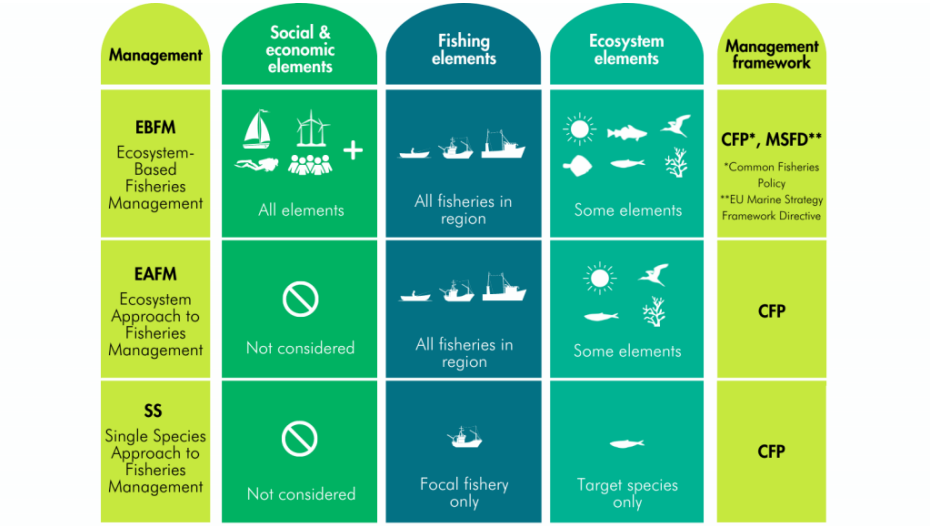
Species interactions
Migration and Life-cycle
Bottom-Up versus Top-Down Forcing
Direct versus Indirect Effects
Cascading effects
Alternative Stable States

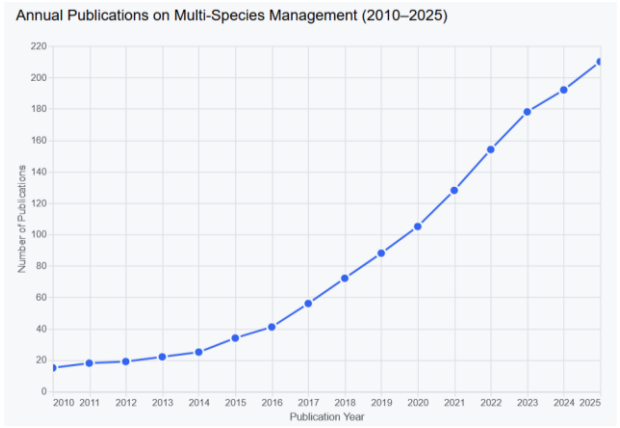


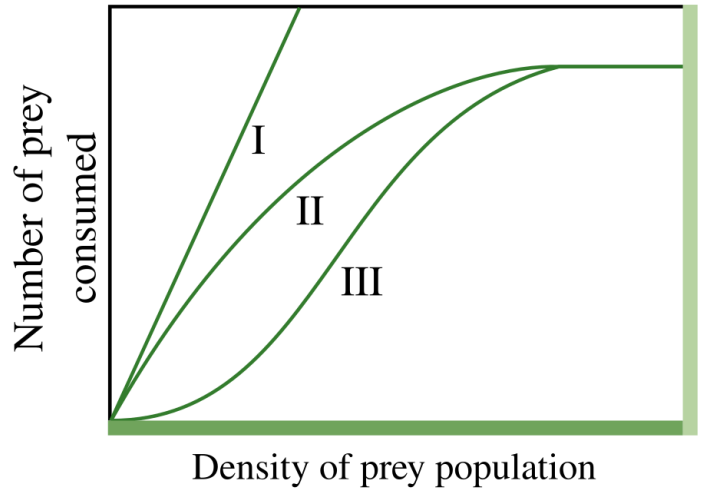
From single-species to multi-species management
– from static to dynamic mortality

$$Z = F + M \quad \longrightarrow \quad Z_{k,a,y} = \sum_f F_{f,k,a,y} + P_{k,a,y} + M_k$$

- integrating the “role” of marine mammals (diet, predation, top-down, predator-prey, functional response)

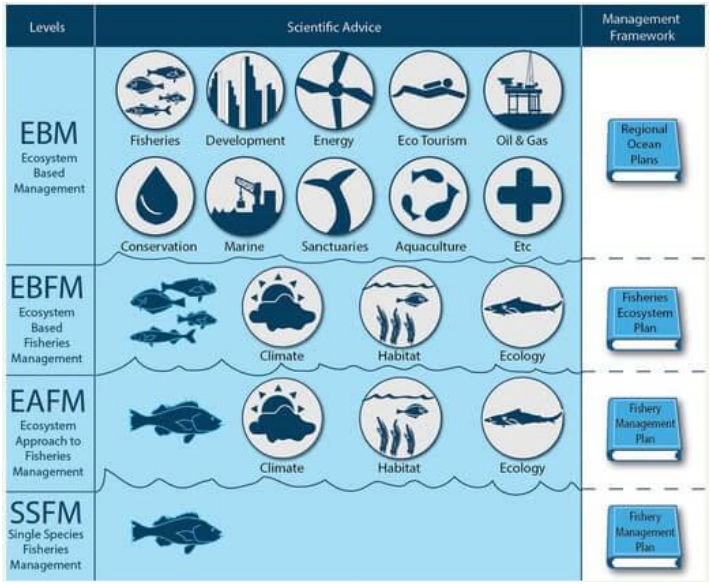




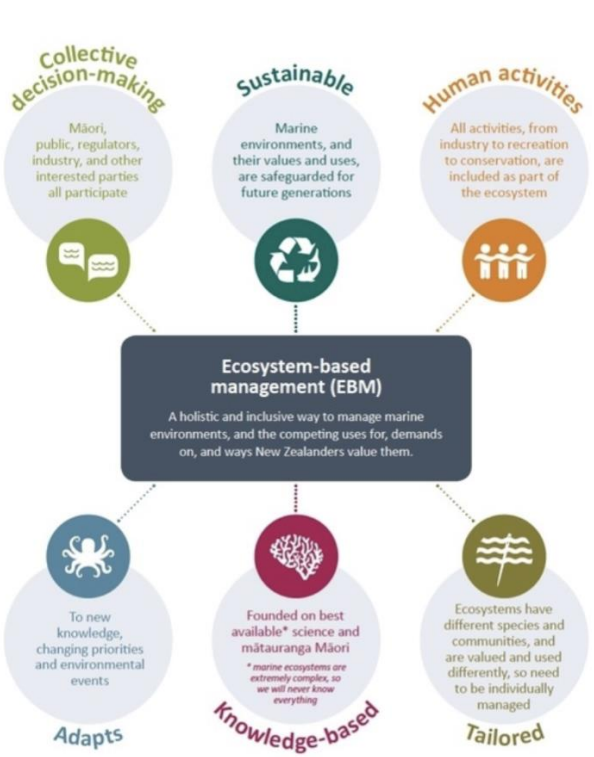


Ecosystem-based management

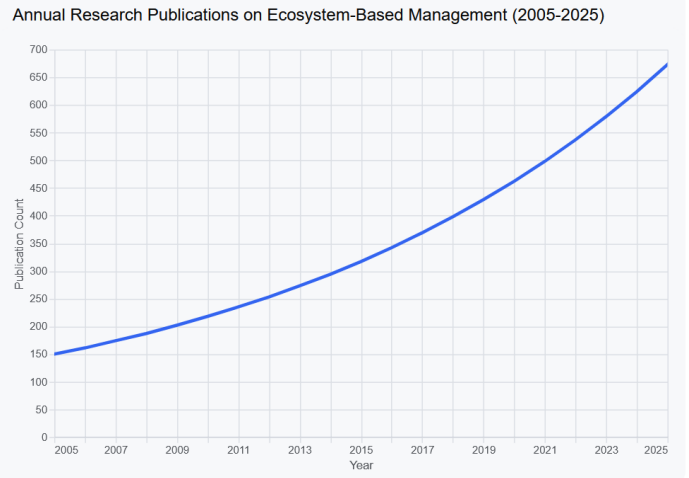
A holistic strategy that manages **human** activities and natural resources by considering the entire ecosystem—including biological, physical, chemical, social, economic, and human components—rather than isolated species or single sectors. A stepwise process, adding complexity!



Feature	Traditional Management	Ecosystem-Based Management (EBM)
Primary Focus	Single species, specific sector, or individual activity.	Entire ecosystem, cross-sector trade-offs, and multi-species interactions.
Human Element	Humans are often viewed as an external stressor or separate entity.	Humans are integrated directly as a fundamental part of the system.
Scope	Narrow, localized, or highly specialized metrics.	Broad, regional, and place-based addressing air, land, and sea connections.
Strategy	Reactive to immediate population drops or acute crises.	Proactive and adaptive, focusing on long-term ecological resilience.

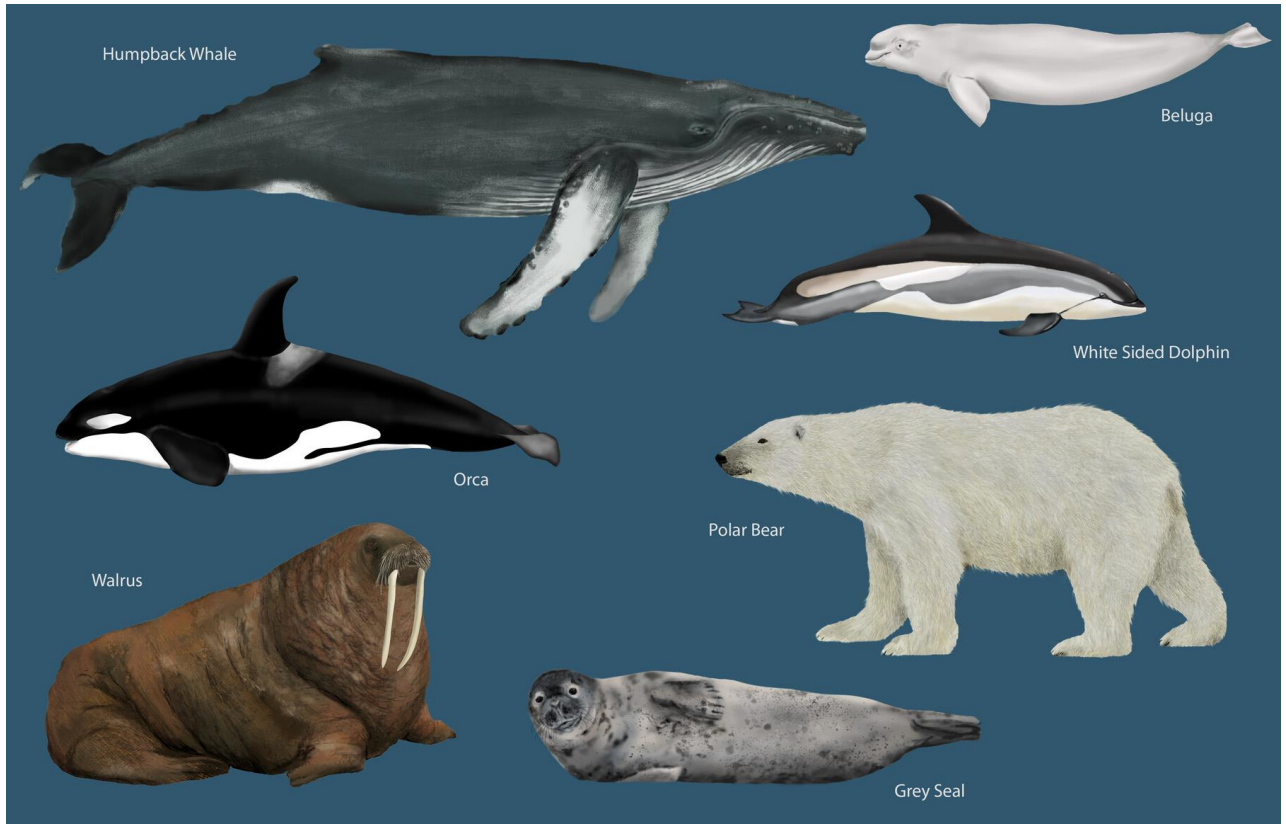






Diversity of marine mammals

Large size, long-lived, wide-range movements and distributions (from polar to tropic, coast to ocean, surface to deep depths), increasing abundance (recovering past over-exploitation), high metabolic rates, broad range of ecological niches, ecosystem sentinels





Assessing the ecological role of marine mammals

A need to understand contribution and impact to food webs, energy flow and biogeochemical cycles - quantified from field observations, populations surveys and metabolic models

- Abundance, distribution, life cycle

- surveys (ship, aircraft, observations, photos..), acoustics, eDNA, tracking

- Trophic impact on food webs

- metabolic demands (food consumption - from body size, energetic requirement, prey availability),

- feeding habits (stomach, scat, stable isotopes, fatty acid signatures)

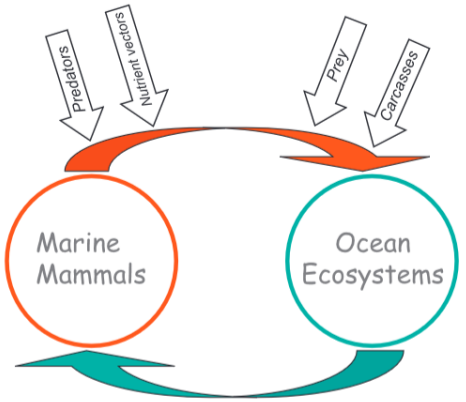
- thermodynamic and food web models - like bioenergetic or mass-balance food web models – estimates top down pressure on fish, squid and invertebrate populations (indirect impact; trophic cascading)

- Ecosystem engineering and biogeochemical roles

- Nutrient cycle (“whale pump”, “conveyor belt”)

- Carbon sequestration (“whale falls”)

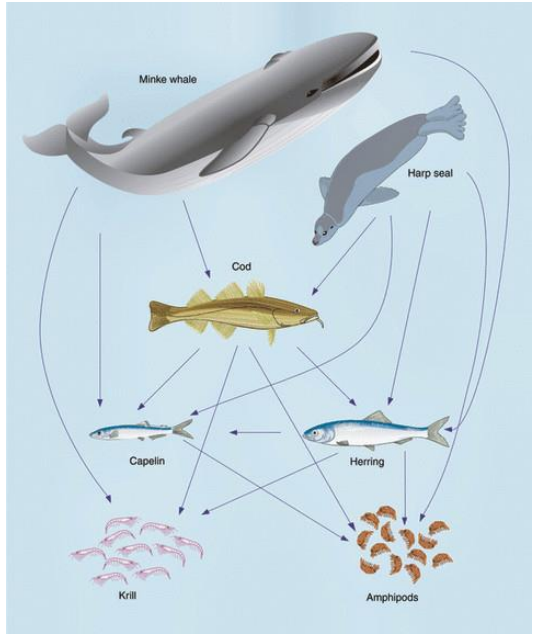
- Habitat modifications (physical changes)

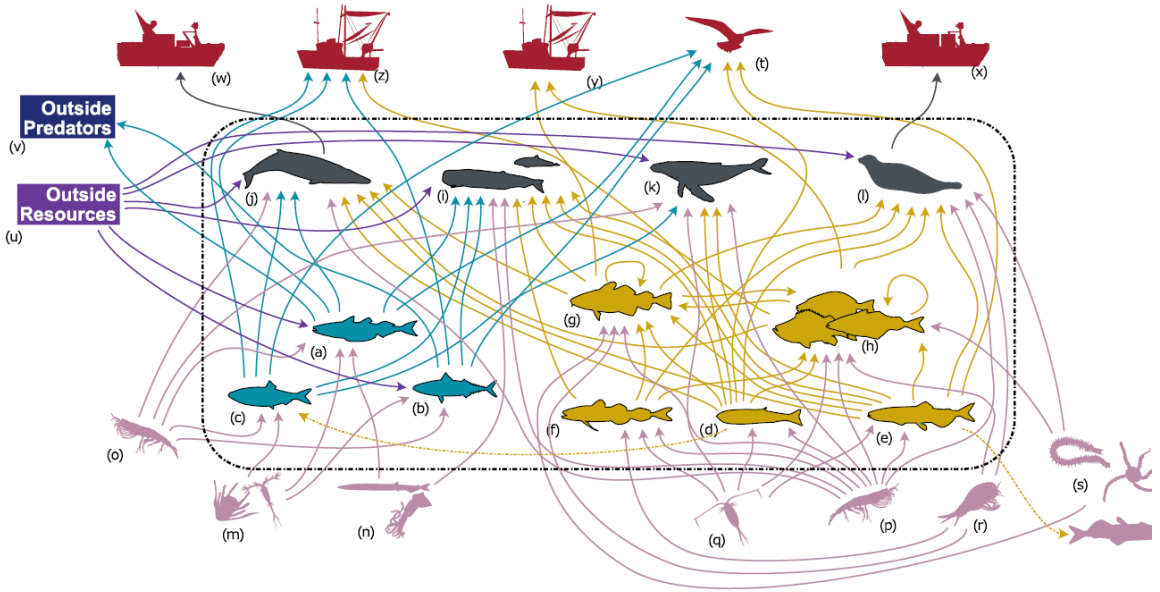


The role of marine mammals
- implementing modelling approaches

- Perturbation approaches: species interactions maintain ecosystem in equilibrium - direct observations of interactions and ecosystem changes

- Constructionist approaches: model interaction webs (energy flow) - information on diets, metabolic rates, species distributions, abundances, residence time, life histories, behaviours





Consumption as measure of ecological role

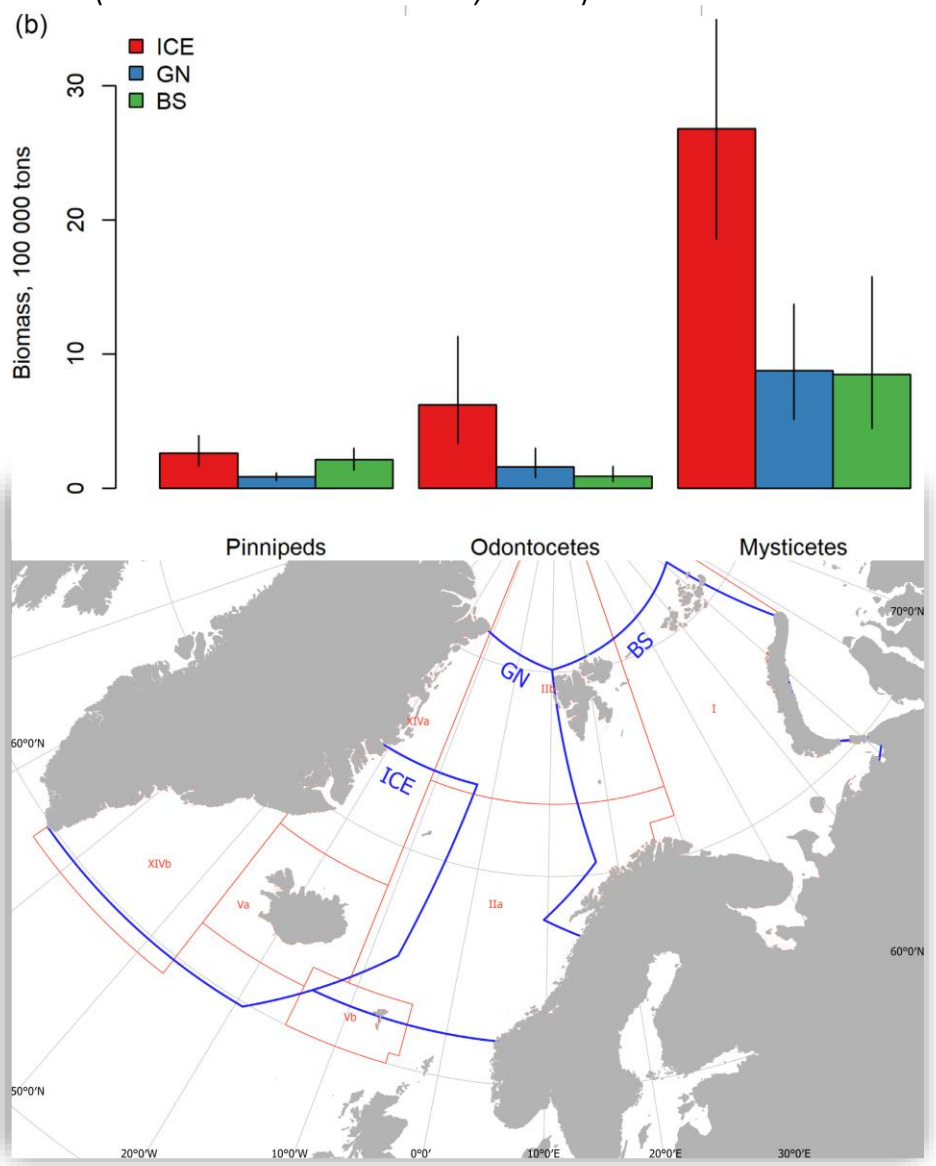
"Marine mammal consumption and fisheries removals in the Nordic and Barents Seas (Skern-Mauritzen et al, 2022)"

Prey consumption (mill. tonnes) by 21 taxa in three regions modelled from abundance, residence time, diet and energy requirement; and compared with fisheries removals

ICE: consumption 13.4 mill. tonnes (fisheries 1.55 mill. tonnes / 8.6x)
GN: consumption 4.6 mill. tonnes (fisheries 1.45 mill. tonnes / 3.2x)
BS: consumption 7.1 mill. tonnes (fisheries 1.16 mill. tonnes / 6.1x)

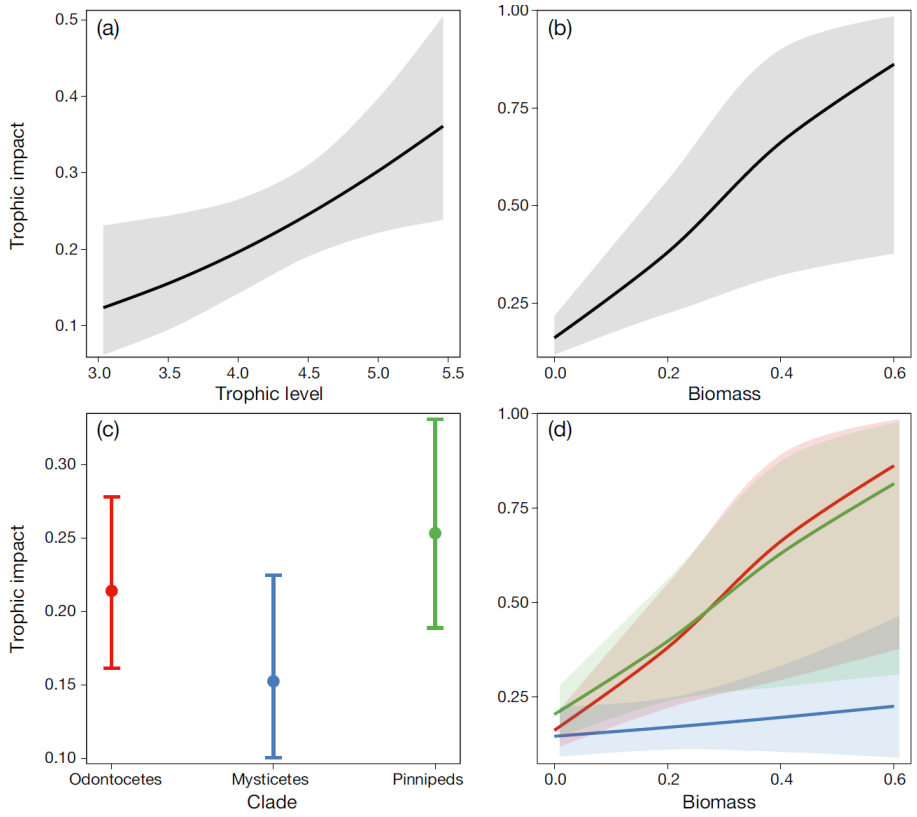
- Fisheries operate generally at higher tropical level
- Direct competition strongest in GN and weakest in BS
- Significant changes in mammal consumption over the last decades
- Ongoing population recoveries
- Current rapid physical and biological changes of high-latitude systems

Changing distributions and abundances should be considered when establishing fisheries harvesting strategies, to ensure effective fisheries management and good conservation practices of top predators in such rapidly changing systems



Trophic level determining ecological role

"The role of mammals as key predators in marine ecosystems (Rupil et al. 2022)"



Metanalysis of 55 food web models, to explore the underlying forces that define the ecological role, with a focus on predatory effects

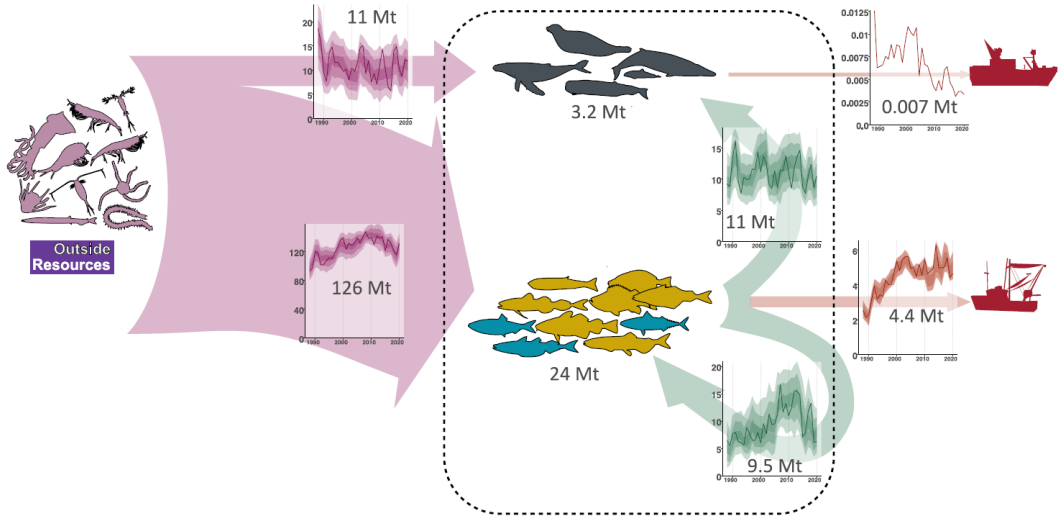
- trophic impact positively related to trophic level
- additional clade-dependent effect of group biomass in trophic impact: the higher the biomass, the higher the trophic impact of odontocetes and pinnipeds, suggesting that food intake contributes to the predatory effects of these clades through biomass variation
- no latitudinal pattern in the ecological role of any clades
- no effects of metabolic rates on trophic impact

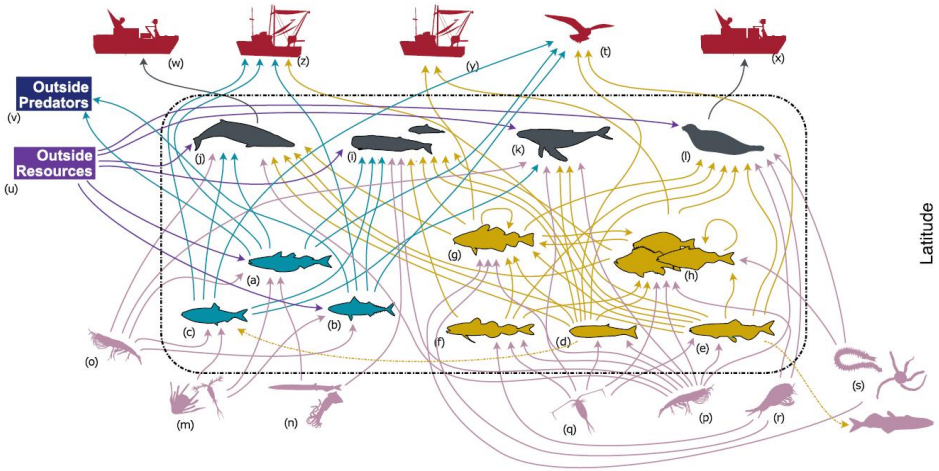
- predatory effects of marine mammals are mainly defined by their trophic levels and food intake
- since odontocetes and pinnipeds feed on higher trophic levels and have higher trophic impact, these 2 clades can be more vulnerable to competition from fisheries overexploitation
- odontocete declines can cause significant changes in marine communities
- meta-analytic approach contributes to the understanding of predatory effects

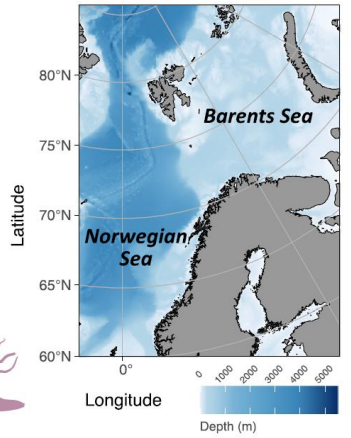
The role through fish interactions

"Tropic food web models, case Barents Sea (Planque et al, 2024, 2026)"

- annual fish consumption 135.5 million tonnes (including 9.5 million tonnes of fish)
- annual marine mammals consumption 22 million tonnes, of which 50 % (11 million tonnes) were fish
- fisheries and hunting captured 4.4 million tonnes of fish and 7 thousand tonnes of marine mammals
- increase in marine mammal biomass has potentially large negative —but highly uncertain— effects on fish biomass
- increase in fish biomass produces smaller, positive effects on marine mammals
- long-term simulations reveal dampened impacts, indicating partial compensation over time.

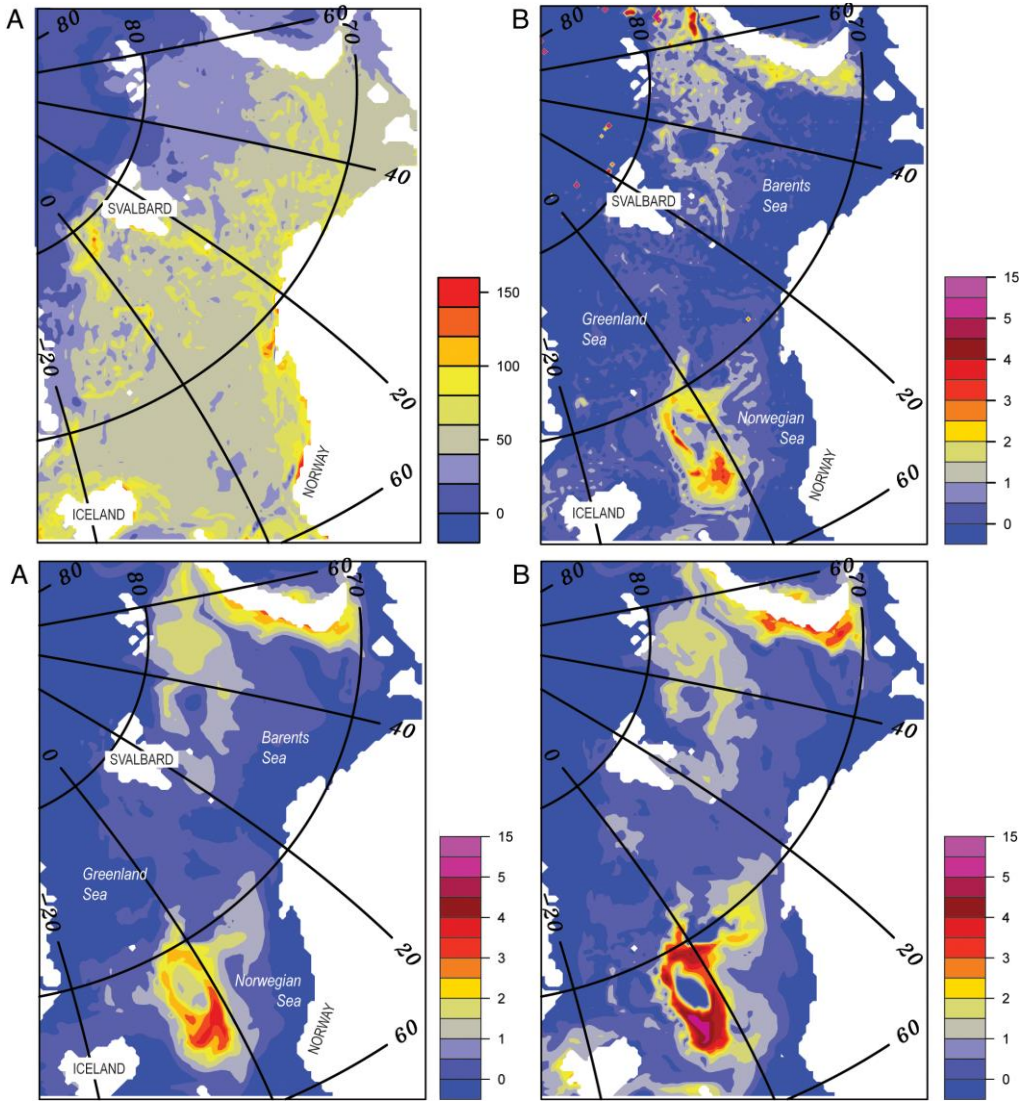






Impact on ocean primary production as a ecological role

"Impact of baleen whales on ocean primary production across space and time (Freitas et al. 2025)"



Daily nutrient input (nitrogen, phosphorus, iron) by baleen whales in high-latitude feeding grounds modelled

- nitrogen excreted via urine, phosphorus released through faeces
- annual effects are modest (<2%) in most areas
- greatest impacts (up to 10%) occur during summer stratification and in offshore areas far from other nutrient sources
- increases in primary production have cascading effects on the food web, driving rises in meso-zooplankton biomass
- highlights the ecological significance of nutrient cycling by whales
- underscores the value of integrating whale nutrient data into ecosystem modelling to assess the broader impacts of whales on marine productivity.

Conclusions

The role of marine mammals on ecosystems is traditionally considered through direct predation

Marine mammals are significant consumers in marine ecosystems - impact vary in time and space and across functional groups

Marine mammals, because of large body sizes, high abundance, and diverse behaviours, can function as ecosystem engineers and top-down regulators, influencing everything from local habitat structural balance, productivity, health to potentially global climate cycles

Compensatory feed-back mechanisms, acting at various time scales, complicate the fully understanding of the role of marine mammals in the ecosystem

Ecosystem-based management - the future

International management bodies acknowledge the general need to move towards holistic ecosystem-based managements, acknowledging the need to manage also stressors from human impact on ecosystems

ICES
CIEM

Food and Agriculture Organization of the United Nations

NAMMCO

INTERNATIONAL WHALING COMMISSION

