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PERSPECTIVE

Overfishing caused the largest sea urchin grazing event observed in the NE Atlantic

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Human threats to marine species and coastal ecosystems

- The major driver of extinction risk is resource use, including by both small- and large-scale fisheries and both targeted and by-catch
- The impact of fishing is often underappreciated and the reference condition unknown because of the global scale of overfishing and shifting baselines after centuries of fishing (Pauly 1995, Costello & Ballantine 2015)

The coastal zone in *Anthropocene* – drivers of change according to the UN intergovernmental panel on biodiversity and ecosystem services (ipbes)

Fisheries

Habitat loss/ -alteration (coastal hardening, bottom trawling)

Pollution (run-off, heavy metals, persistent organic pollutants, plastics,...)

Anthropogenic global warming

Figure 4. The Proportion of the Threatened Species of Each Taxon Affected by Different Drivers of Extinction Risk

Scale	Driver	Hydroza	Anthozoa	Gastropoda	Cephalopoda	Holothuroidea	Chondrichthyes	Actinopterygii	Reptilia	Aves	Mammalia
LOCAL SCALE	Coastal development	100	98.2	34.5			14.7	24	68.4	24.3	51.4
	Biological resource use	100	98.2	63.8	100	93.75	100	43.1	68.4	77.4	97.3
	Pollution	100	97.8	43.1		6.25	11.7	31.7	52.6	46.9	78.4
	Transportation	100	97.8	5.2			2.5	5.7	10.5	10.7	70.3
	Invasive species	100	97.8	6.9			0	13.8	31.7	83.1	45.9
GLOBAL SCALE	Climate change	100	99.1	3.4		6.25	2.5	35.9	63.2	50.8	51.4
	Human disturbance	100	97.8	17.2							
	Agri/Aquaculture			3.4		6.25					
	Energy/Mining			1.7							
	System modification			8.6							

BIOLOGICAL COMPLEXITY →

Rogers & Aburto-Oropeza (2020) Ocean panel

Norway 1970s: Blooms of sea urchins
Strongylocentrotus droebachiensis

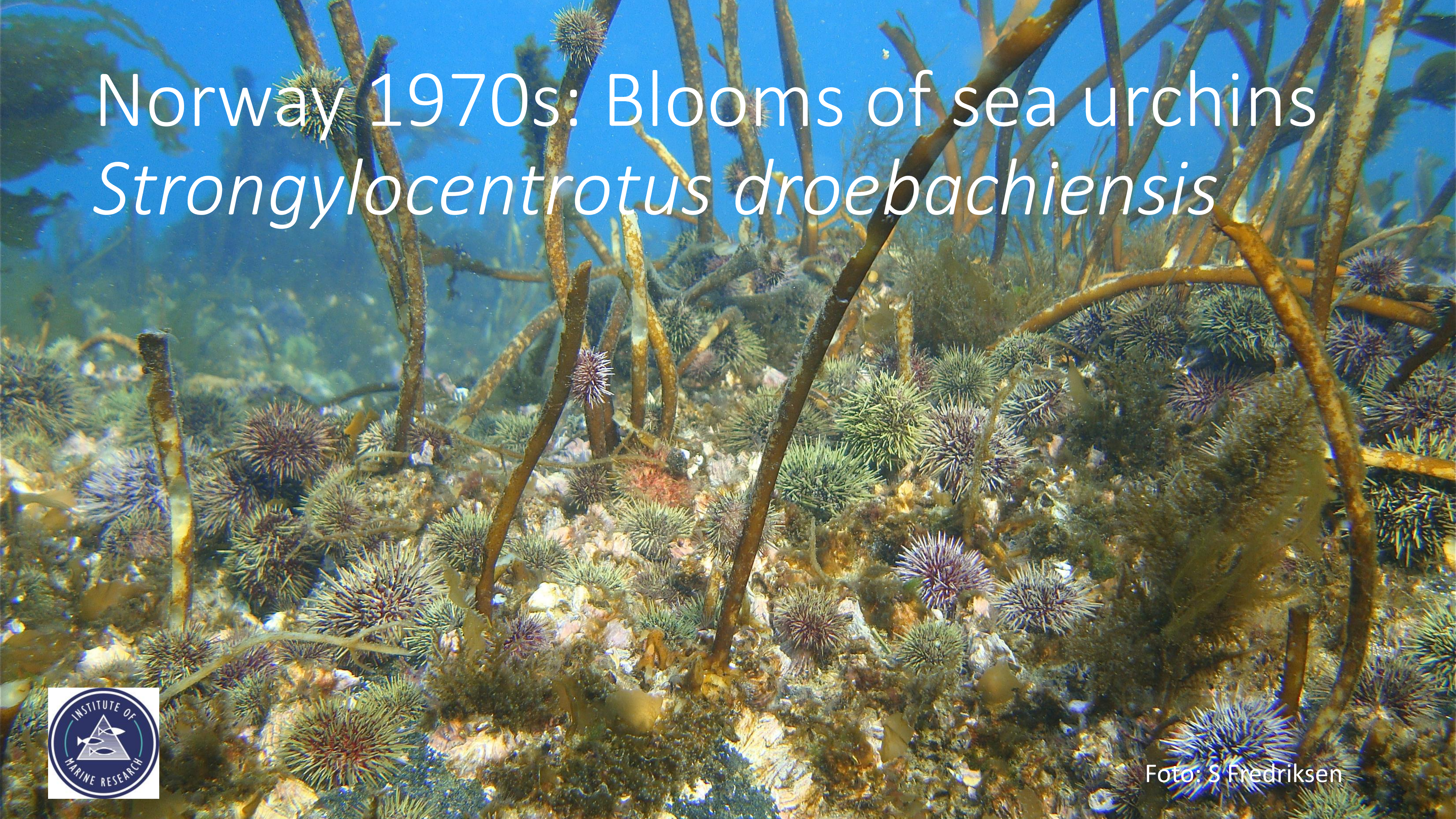
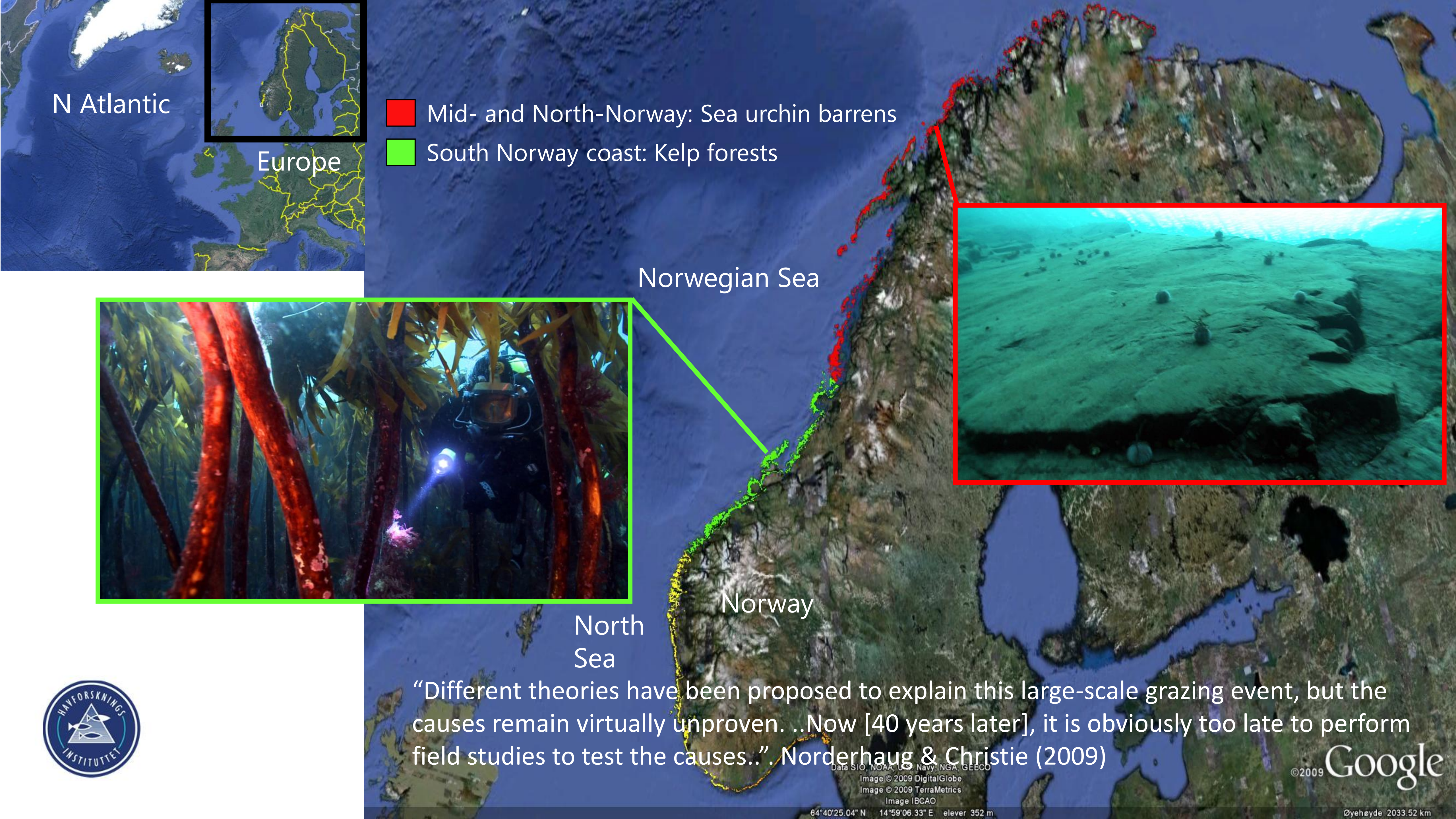


Foto: S Fredriksen


N Atlantic
Europe
Mid- and North-Norway: Sea urchin barrens
South Norway coast: Kelp forests
Norwegian Sea
North Sea
Norway
HAVFORSKNINGS INSTITUTTET
“Different theories have been proposed to explain this large-scale grazing event, but the causes remain virtually unproven. ..Now [40 years later], it is obviously too late to perform field studies to test the causes..”. Norderhaug & Christie (2009)
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2009 DigitalGlobe
Image © 2009 TerraMetrics
Image IBCAO
©2009 Google
64°40'25.04" N 14°59'06.33" E elever 352 m
Øyehøyde 2033.52 km

Fishing bills in Fishery Directorate archives

- Paper bills fishermen received when they delivered the catch locally
- A grey data source to fish landings with quit high spatiotemporal resolution

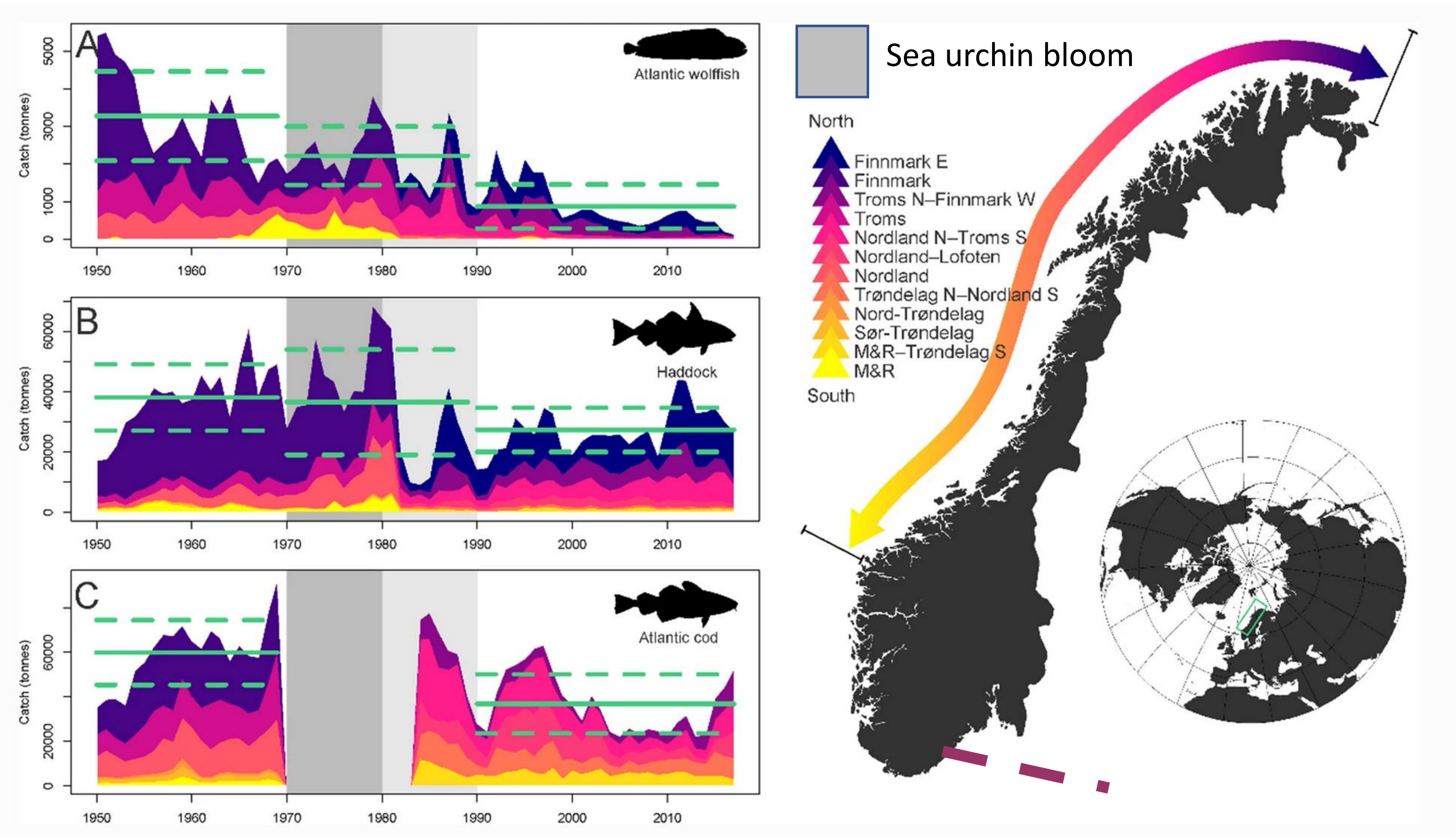
Tabell VIII. Fangstmengden av de ulike sorter fordelt etter ilandbringelsesmåneder 1955. Finnmark.[1] Tonn.

Fiskesorter	Januar	Februar	Mars	April	Mai	Juni	Juli
Lodde	—	—	10 395	29 572	1 540	—	—
Kveite	16	32	39	54	138	59	36
Rødspette	6	11	30	9	14	68	36
Blåkveite	—	5	5	40	204	121	60
Brosme	44	148	28	30	244	37	10
Hyse	807	1 500	499	2 881	5 857	2 033	882
Skrei	2 217	7 064	3 695	—	—	—	—
Loddetorsk	—	—	2 704	8 992	23 928	11 143	—
Annen torsk ...	—	—	—	—	—	2 844	2 419
Sei	7	1	34	89	190	133	1 936
Biprod. av skrei	—	1 020	465	—	—	—	—
Lever av loddetorsk	—	—	—	676	1 989	712	—
Feitsild	—	—	—	—	95	453	26
Småsild	—	176	—	—	2 849	2 025	175
Uer............	29	193	135	156	285	172	60
Steinbit	2	29	82	147	478	332	92
Annen fisk m. v.	—	—	—	—	—	—	—
Andre biprod....	—	194	356	193	278	391	433
I alt	3 128	10 373	18 467	42 839	38 089	20 523	6 165
Prosent	1,4	4,8	8,5	19,7	17,6	9,5	2,8

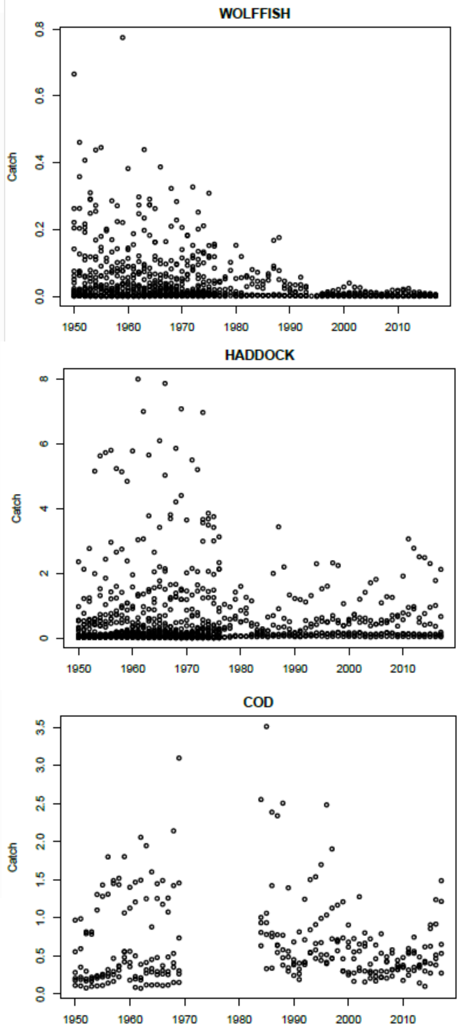
Source: Norway Directorate of fisheries

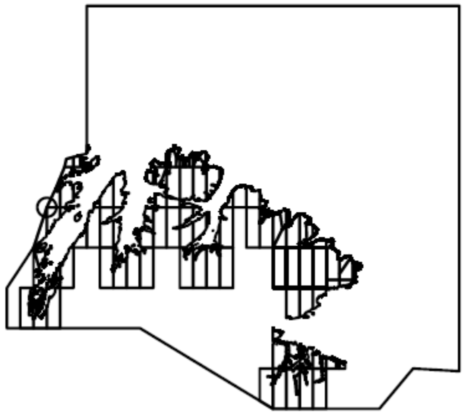
Overfishing of urchin predators

Total catches



Catch per area





Norderhaug et al. (2021)

Norderhaug et al. (in prep.)

Modernisation of the coastal fishing fleet during the last century

Photo: The national archives of Norway

- Larger boats, (bigger) engines, power block, nylon lines
- Government aid after WW2
- Perceived as traditional and sustainable

Previously unwanted fish ("Ufisk") on the menu

Fish species vulnerable to fishing

Table 1 Fishery target species categorized as principal predators on green sea urchins *S. droebachiensis* ('category 1' according to Planque et al. 2014)

Species	Indices of vulnerability	Gear	Modernization	References
Antlantic wolffish *Anarhicas lupus*	Internal fertilization, late maturing, low fecundity, paternal care of demersal eggs, homing to feeding and spawning grounds	Longline Bottom trawl[b] Gillnet	ABCD	Eliassen et al. (1981), Keats et al. (1985), Falk-Petersen et al. (2010), Simpson et al. (2013) and Gunnarson et al. (2019)
Spotted wolffish *Anarhicas minor*	Internal fertilization, late maturing, low fecundity, paternal care of demersal eggs	Longline Bottom trawl[b] Gillnet	ABCD	Eliassen et al. (1981), Gunnarson et al. (2008) and Simpson et al. (2013)
Norwegian coastal cod *Gadus morhua*	Spawning aggregation, spawning site fidelity, population structure	Gillnet Longline Handline Bottom trawl Danish seine	ABCE	Jorde et al. (2007), Skjaeraasen et al. (2011), Dahle et al. (2018) and Enoksen and Reiss (2018)
NEA haddock *Melanogrammus aeglefinus*	Spawning aggregation, Population structure[a]	Gillnet Longline Handline Bottom trawl Danish seine	ABCE	Jiang and Jørgensen (1996), Reiss et al. (2009), González-Irusta and Wright (2016) and Tam et al. (2016)

Indices of vulnerability: biological, life cycle or life history attributes with consequences for the species' vulnerability to harvesting. Gear: mode of capture/fishing gear directly or indirectly affecting the target species. Modernization: technological development and demand (1960s–80 s) affecting targeting of the species (see *Notes* at bottom of table)

A = increased engine power; B = increased vessel size; C = introduction of nylon fiber; D = advent of market/demand, E = introduction of the hydraulic net hauler/line hauler

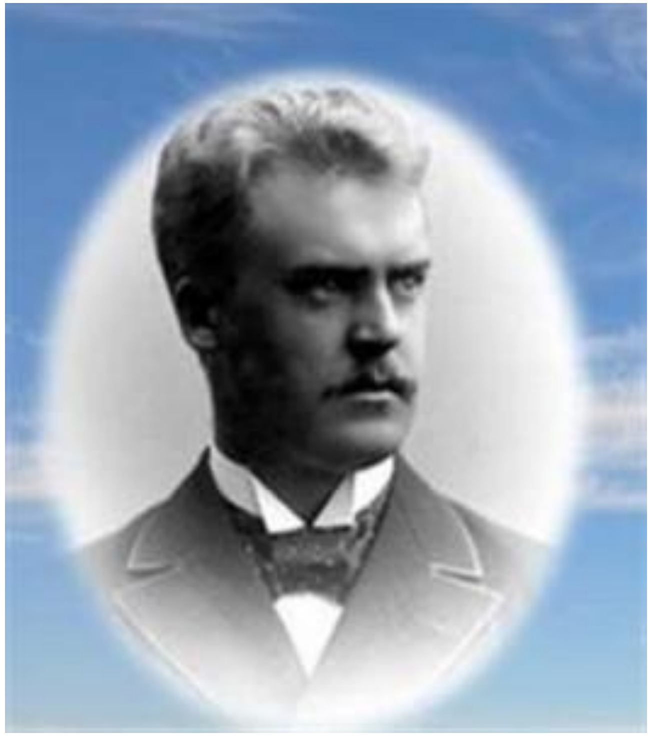
[a]Spatial scale of population structure poorly known (Reiss et al. 2009)

[b]Wolffish are by-caught in bottom trawling, and bottom trawling is detrimental to wolffish habitat

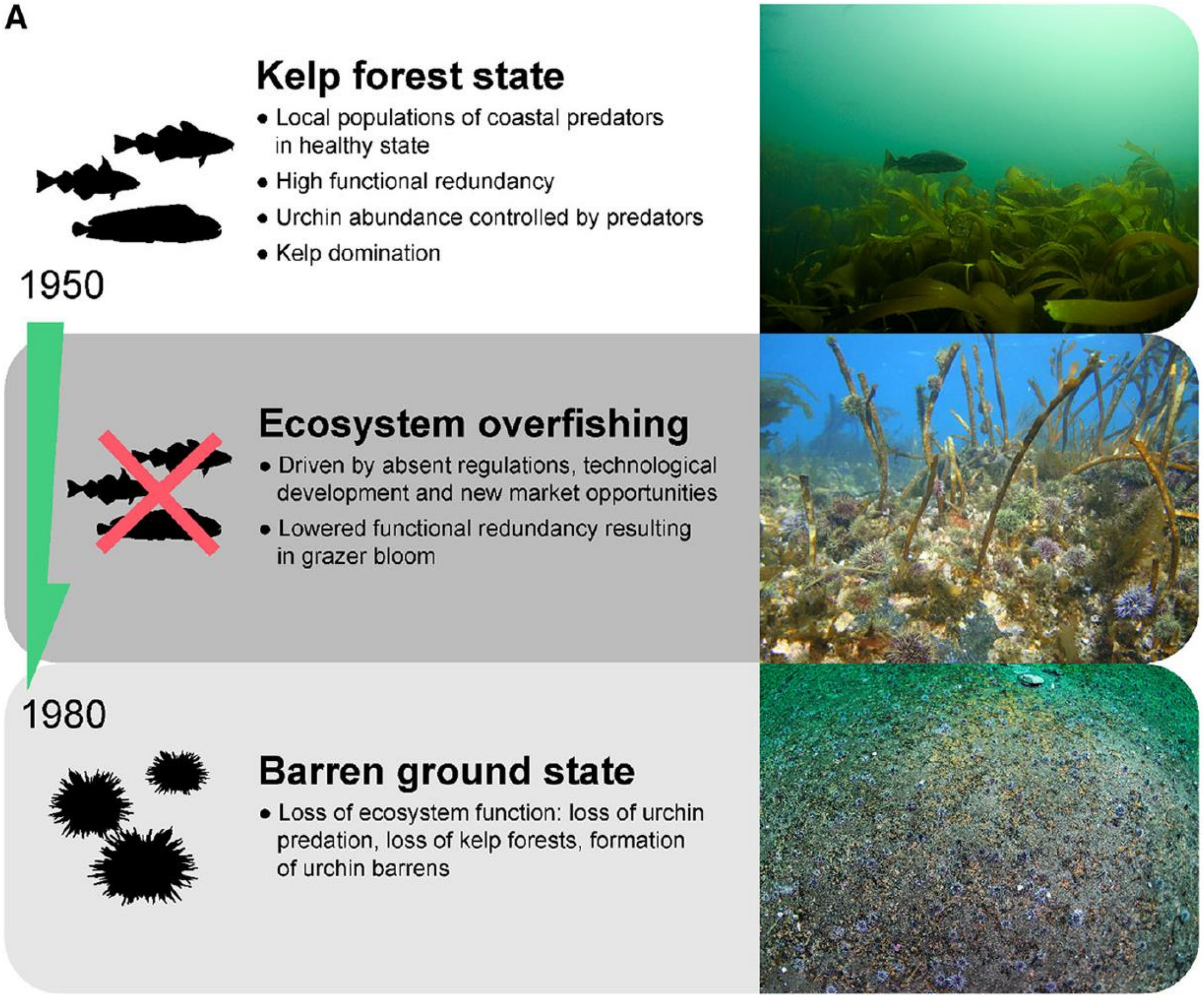
Norderhaug et al. (2021)

Emerging understanding of population structures

- Historical perception of the coast being seeded with fish eggs from an inexhaustible source from the ocean (Johan Hjort, 1914)
- Molecular methods has changed this perception during the last decades
- Many coastal stocks are vulnerable to local fishing due to limited connectivity

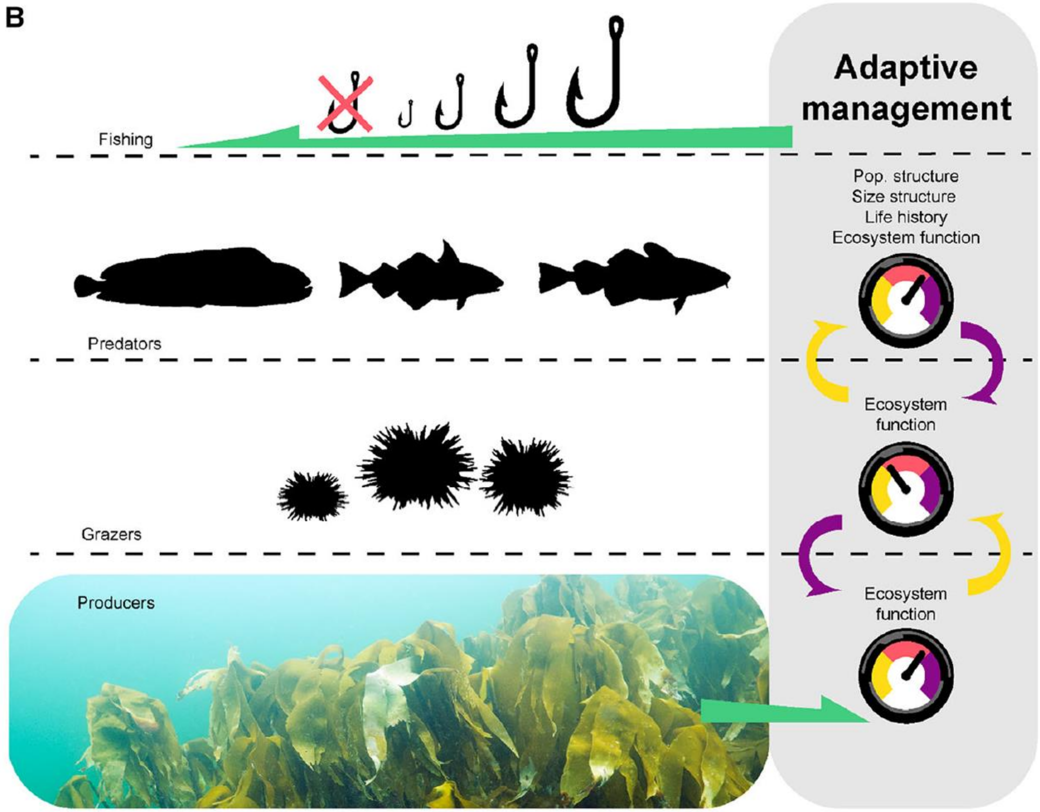


Loss of functional redundancy



Norderhaug et al. (2021)

«Easy restriction syndrome» Cardinale et al. (2017)



Managing vessel length

Managing ecosystems

Norderhaug et al. (2021)

What did we learn?

- Overfishing likely caused a grazer bloom of the sea urchin *Strongylocentrotus droebachiensis* resulting in overgrazing of more than 2 000 km^2 kelp *Laminaria hyperborea* forest along the Norwegian coast in the 1970s
- Alternative (grey) data sources are important to get the perspective needed to understand human impacts on coastal fish stocks
- We are still underappreciating the effects of fishing and only during the last decades molecular methods have showed us how vulnerable many of these stocks are to harvesting
- A local population dynamics perspective is necessary to account for limited connectivity (avoid «easy restriction syndrome» Cardinale et al. (2017))
- Management actions to combat climate change may fail if we dont take into account fishing. Top predators like cod may have stabilizing properties of coastal ecosystems («super genes», Sodeland et al. 2022).

«At the present it is almost fashinable amongst experts to be concerned for the wellbeing of fish stocks due to increased fishing, use of steam engines and efficient gear. Other experts however are less concerned and convinced that the self-preserving force of nature is strong enough to preclude any destructive effects by humans» - **Arthur Feddersens book The Ocean – Its discovery and conquest, 1903**