There is light in the dark: Bioluminescence in the high Arctic polar night

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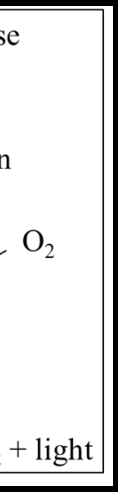
Marine Night

Circadian rhythms of Arctic zooplankton
CircA

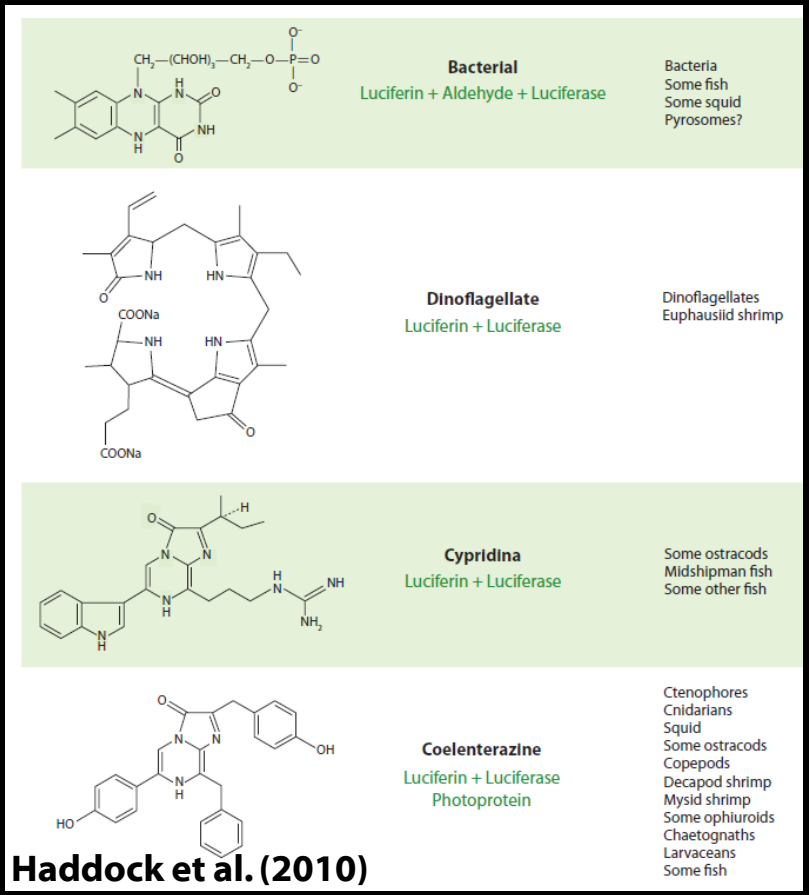
http://www.mare-incognitum.no/

What is bioluminescence?

- Light production by organisms through a chemical reaction
  - Not fluorescence/phosphorescence (re-emission)
  - Enzyme/photoprotein mediated process
- Spectral emission varies by species and habitat
  - Typically 450-490nm in pelagic marine species

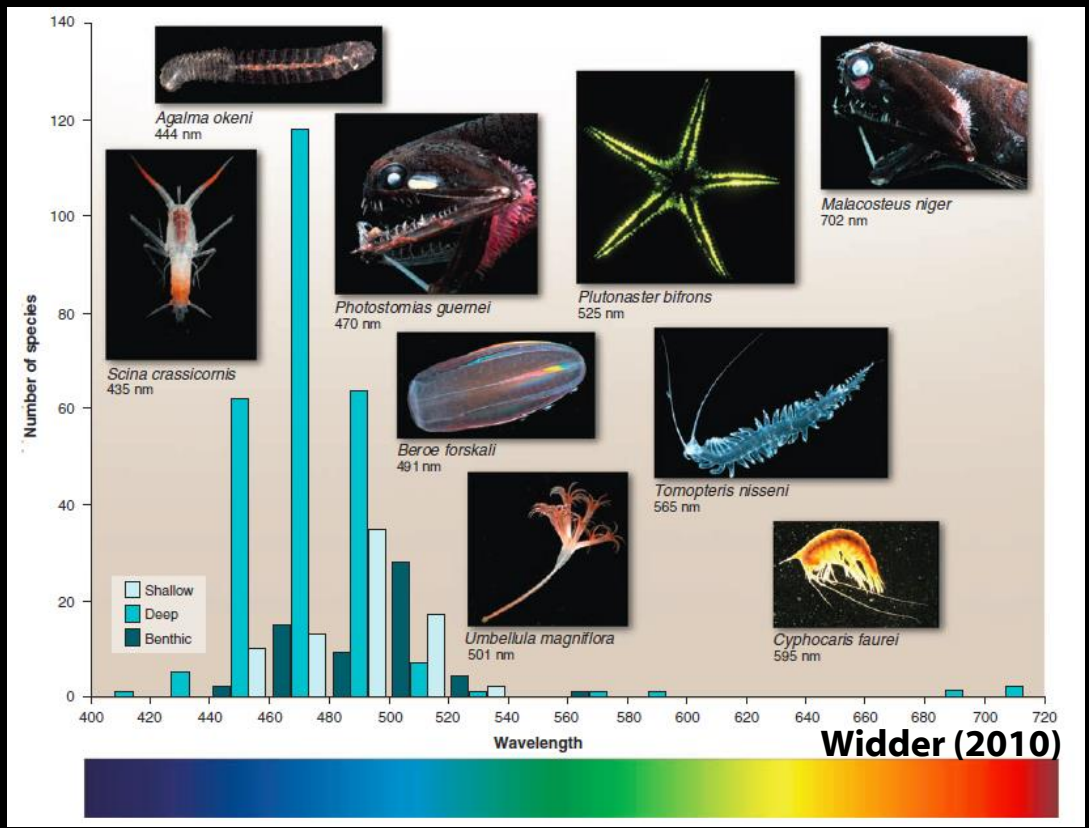


BL is classified by its luciferin type



Haddock et al. (2010)

BL is ubiquitous, but most common in deep sea

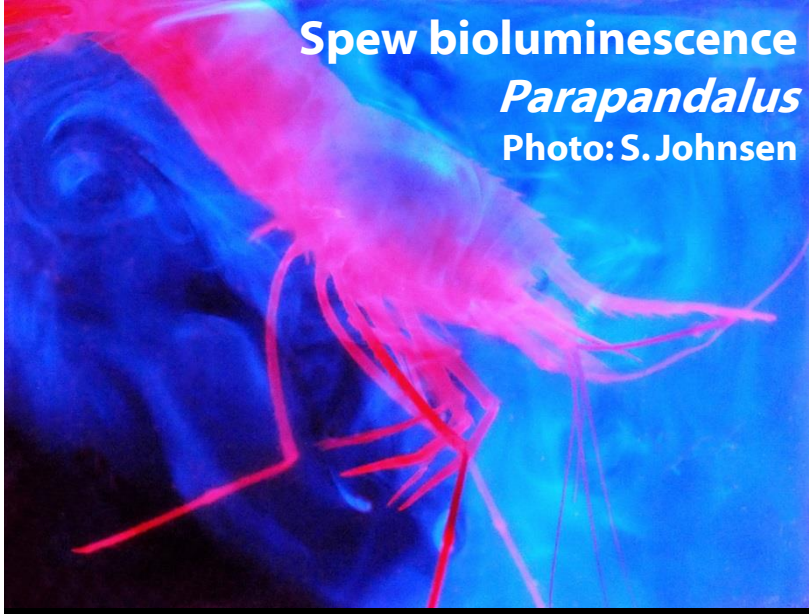


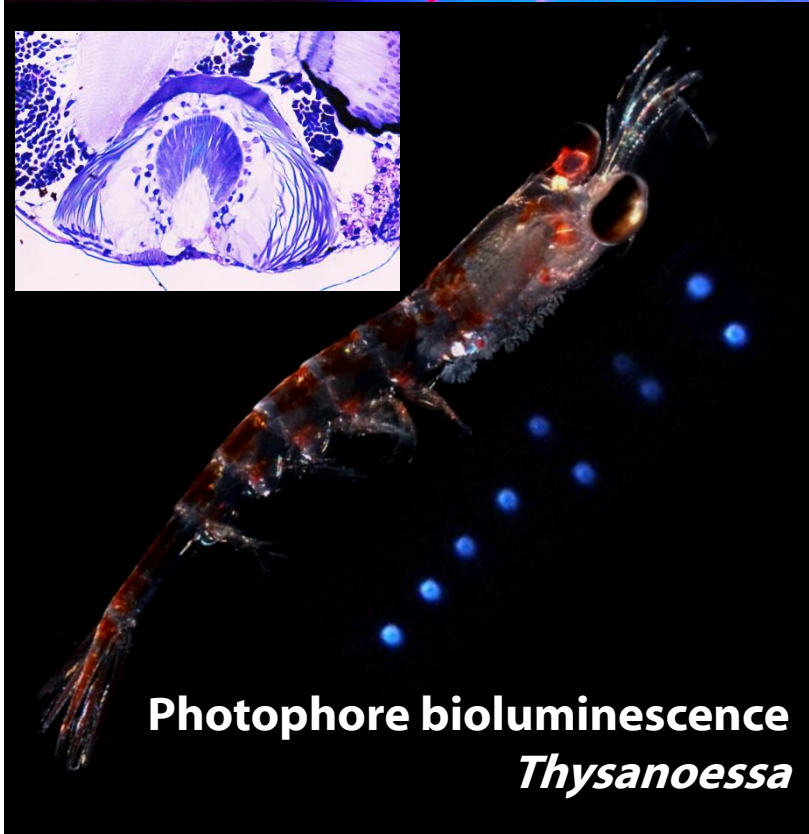
Widder (2010)

DEFENSE	Startle	Dinoflagellates, squid, stern-chaser myctophid
	Counterillumination	**Many:** crustaceans, fish, squid
	Misdirection: smoke screen	**Many:** crustaceans, polychaetes, scyphozoans, chaetognaths, squids, tube-shoulder fishes, ctenophores, siphonophores, larvaceans?
	Distractive body parts	*Octopoteuthis* squid, brittle stars, polychaetes, siphonophores
	Burglar alarm	Dinoflagellates, jellies, others?
	Sacrificial tag	Pelagic sea cucumbers, jellies, polychaetes
	Warning coloration (deter settlers)	Jellies, brittle stars? (tube worms, clams)
OFFENSE	Lure prey or attract host (bacteria)	Anglerfishes, siphonophores, cookie cutter shark, squid?
	Lure with external light (evaluate habitat?)	Sperm whale? megamouth shark?
	Stun or confuse prey	Squid, headlamp myctophid?
	Illuminate prey	Flashlight fish, dragonfishes
	Mate atttraction/recognition (swarming cue)	Ostracods, *Japetella* octopus? lanternfish, flashlight fish, anglerfish? syllid polychaetes, others?

Haddock et al. (2010)

Flash Glow Prey Predator 2° Predator





What is known of Arctic bioluminescence?

- BL has been reported for all seasons
  - Vestfjord, Norway in summer (Lapota et al. 1989)
  - Beaufort Sea in fall (Lapota et al. 1992)
  - Kongsfjord, Svalbard in winter (Berge et al. 2012, Johnsen et al. 2014)
  - Greenland Sea in spring (Buskey 1992)

- Generally small BL community (copepods, larvaceans, krill, ostracods, ctenophores) but can be very abundant at specific times and depths

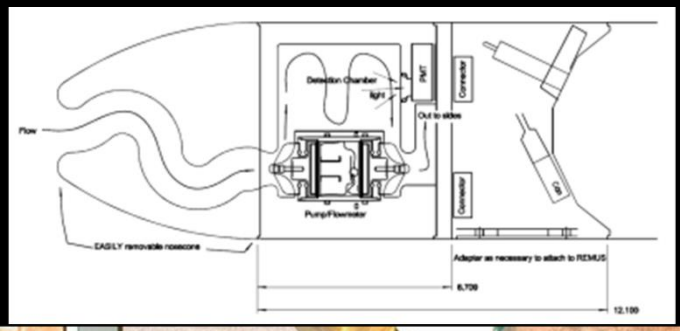
- Dinoflagellate contribution is greater in coastal water

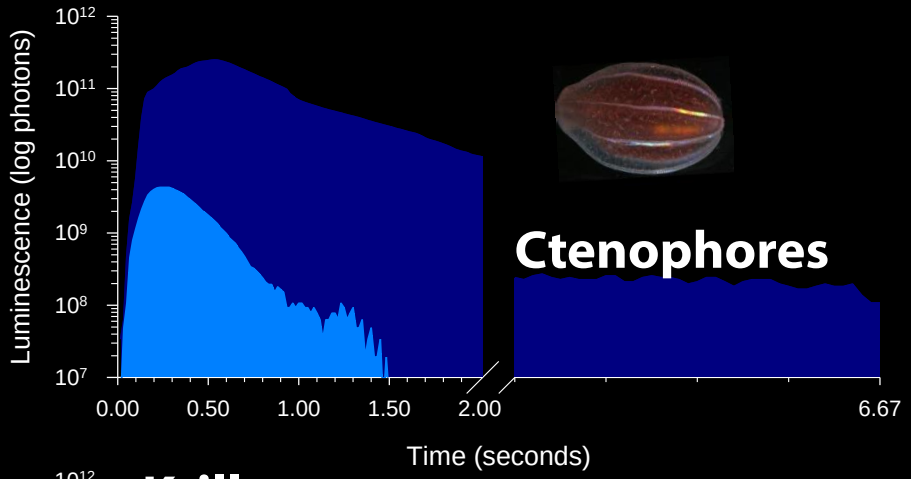
- In all, very few studies…

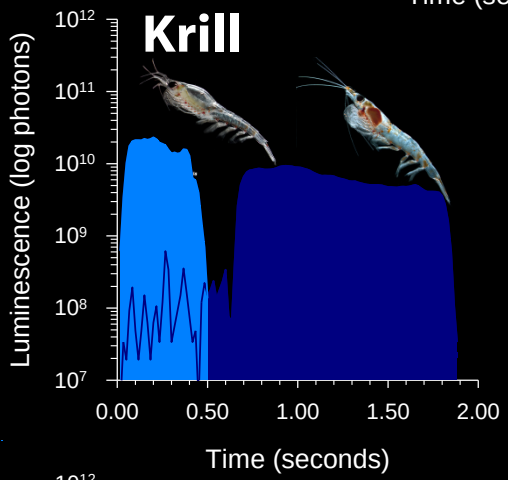
Underwater Bioluminescence Assessment Tool (UBAT)

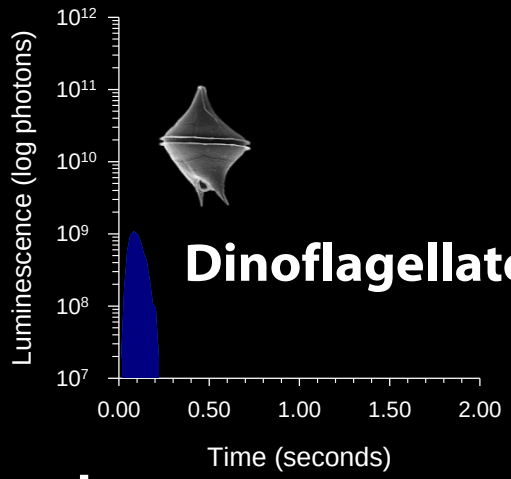
Can be deployment from:

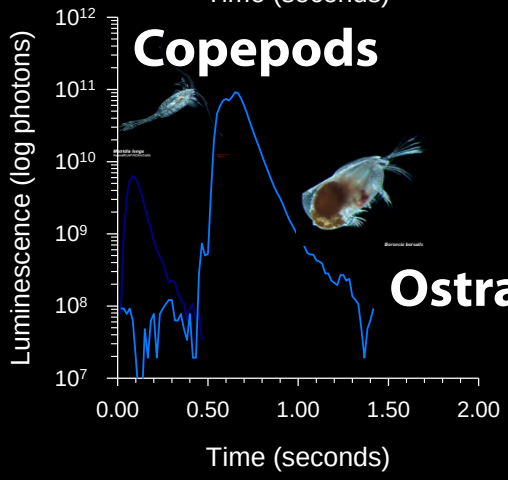
- fixed platform
- profiling cage
- REMUS AUV











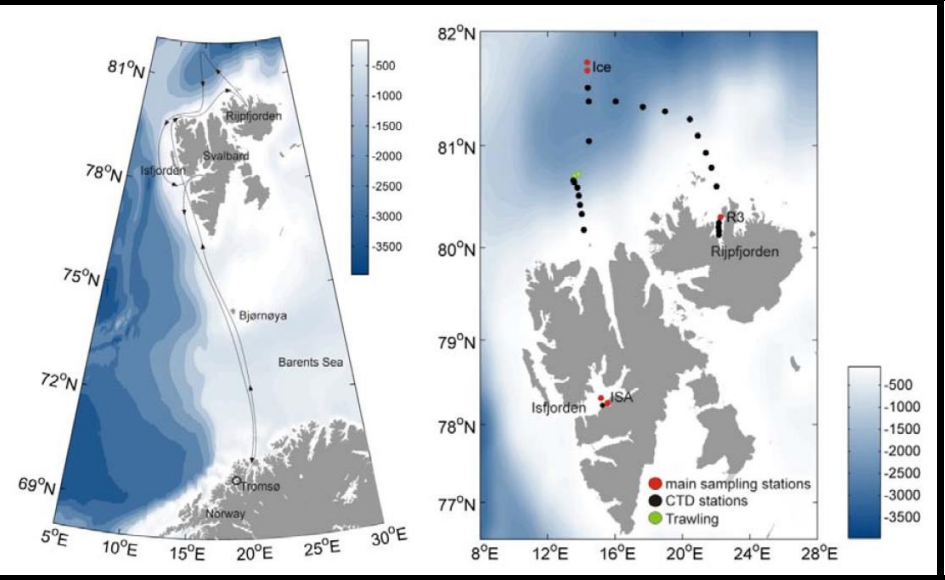
Flash kinetics of luminescent plankton sampled by the UBAT represent taxon-specific signatures

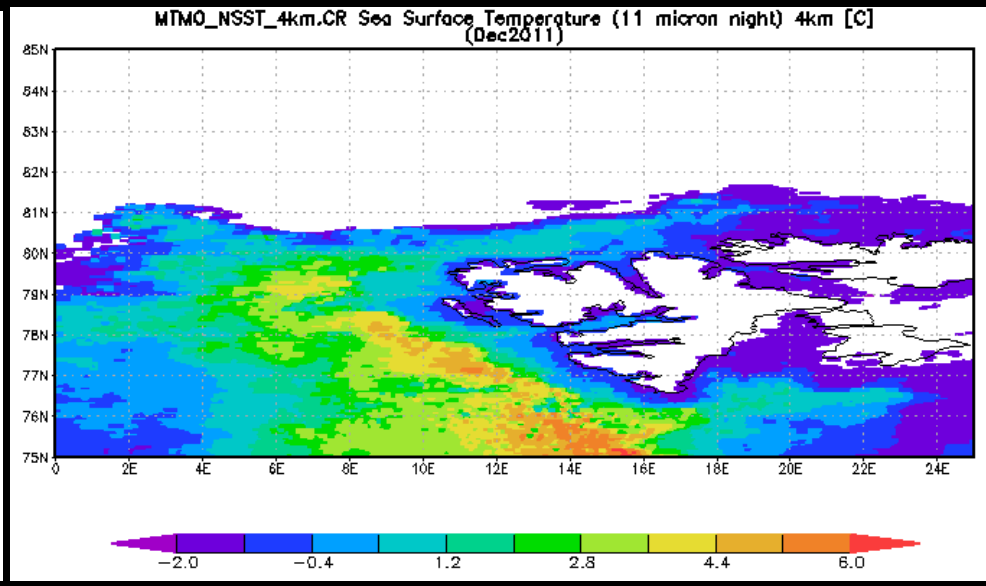
Using a library of flashes obtained through lab experiments, UBAT sampling can be used to quantify luminescent taxa in field deployments

Johnsen et al. (2014)
Cronin et al. (in prep)

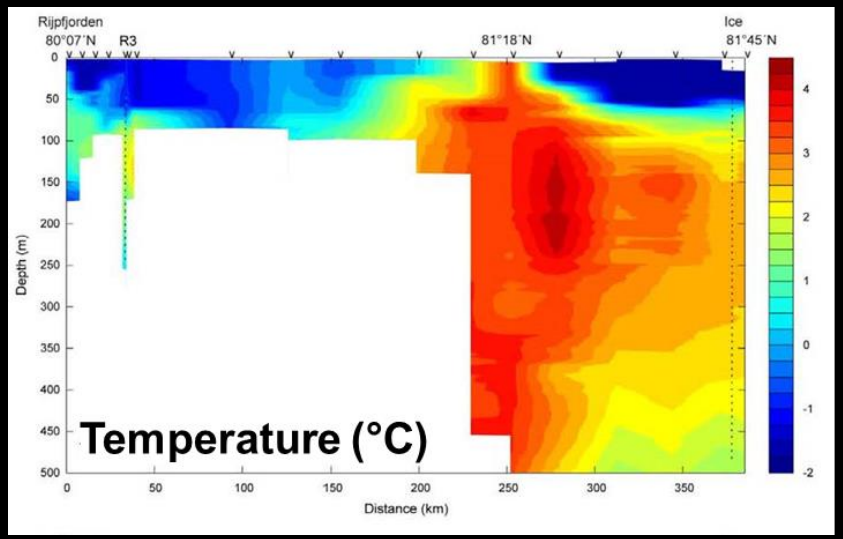
Images: G. Johnsen, R. Hopcroft (ArcOD)

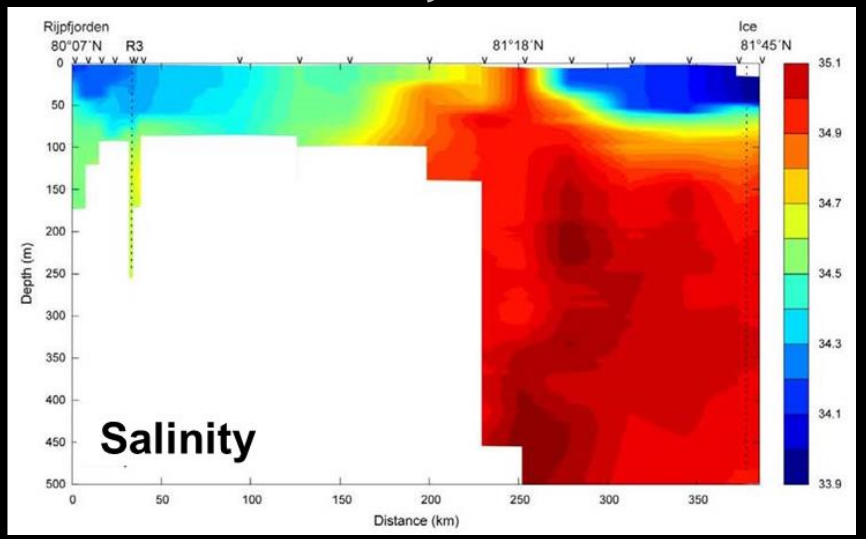
Vertical distribution of luminescence in the Arctic Ocean north of Svalbard during January 2012





Evidence for Intrusion of North Atlantic Water (warm, salty) into Arctic Ocean





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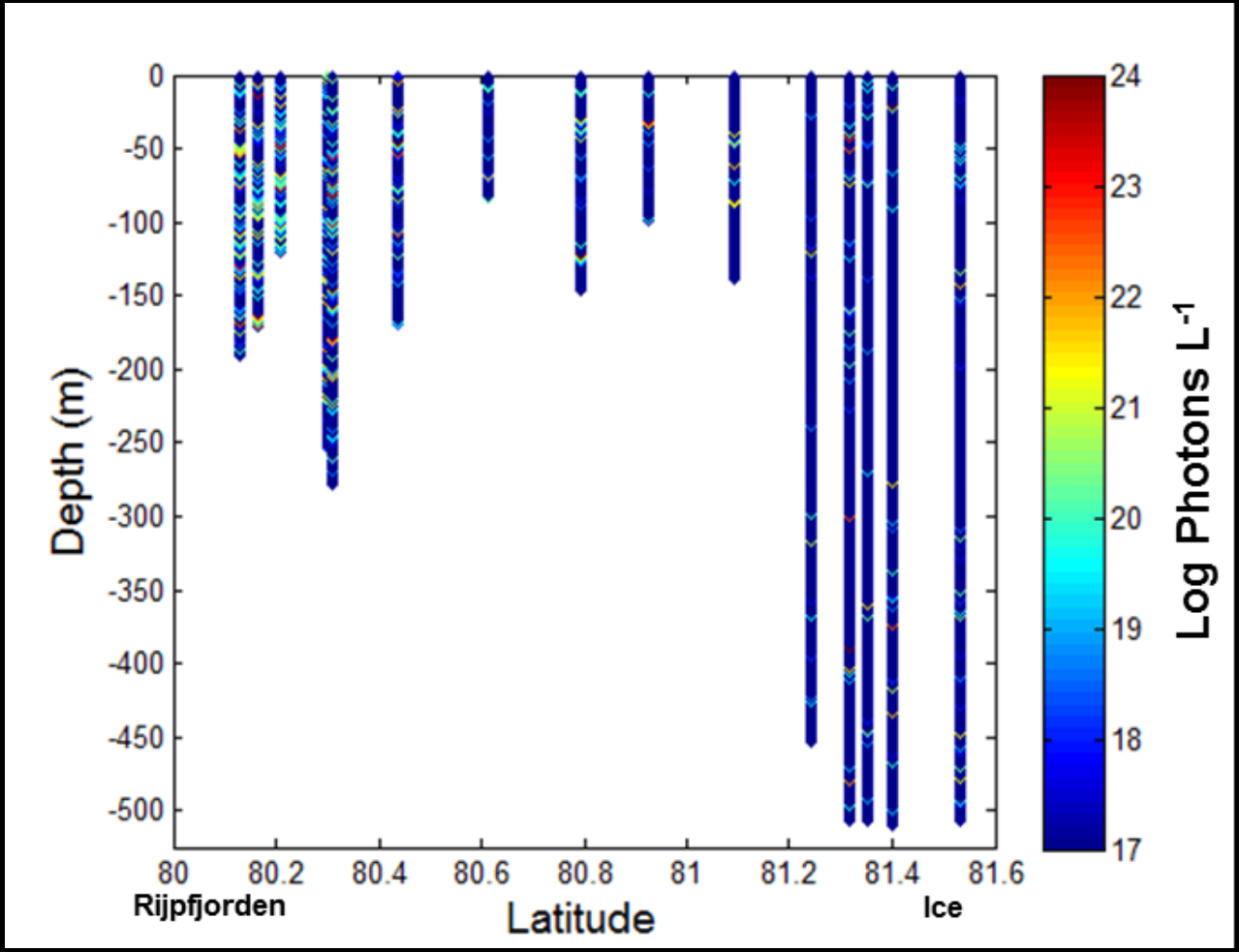
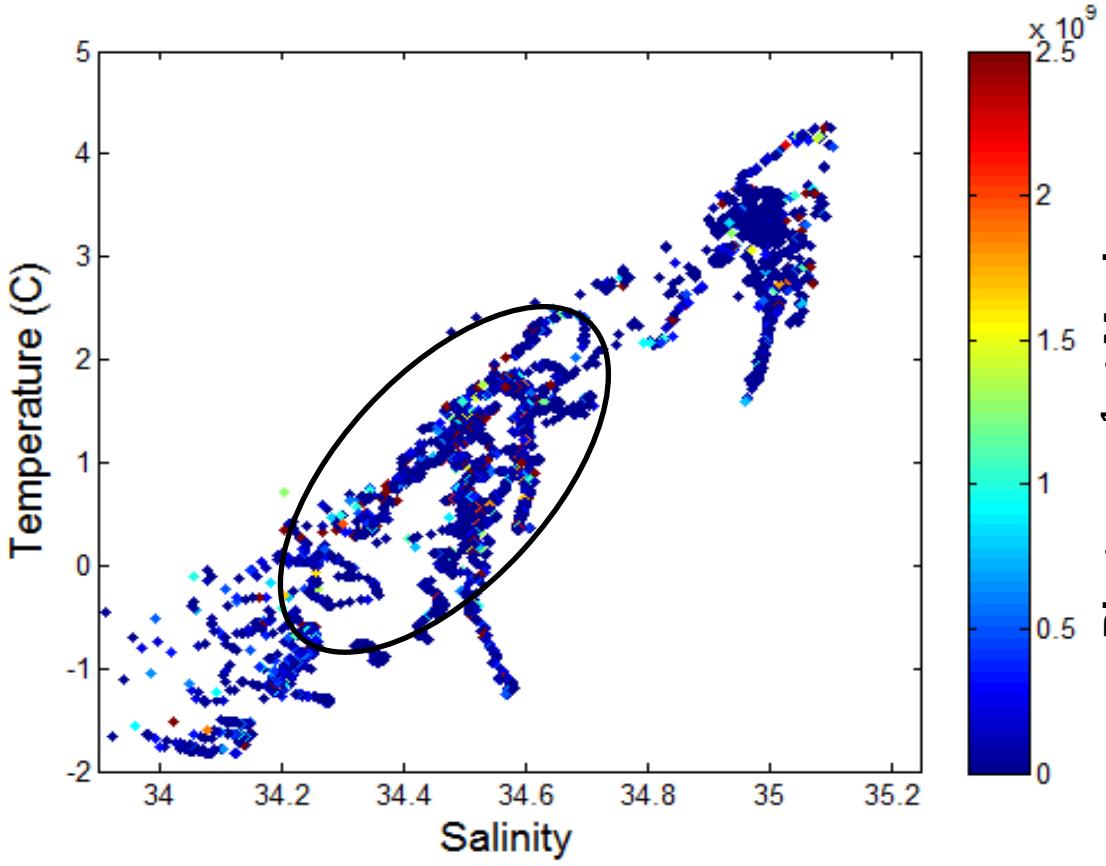


Bioluminescence is not uniform across latitude and depth

- More BL at coastal stations
- More BL in upper water column
  - Vertical migration (Berge et al. 2012)
  - Density dependence

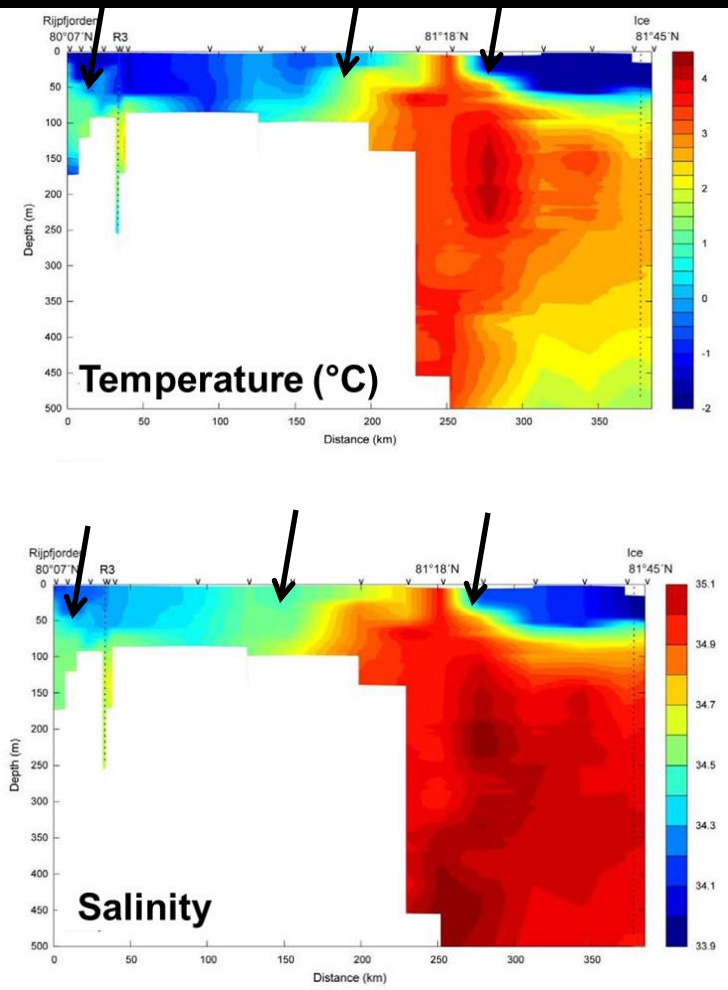
Vertical distribution of luminescence in the Arctic Ocean north of Svalbard during January 2012

Extracted BL Flashes in T-S space



BL occurs in coastal and frontal regions

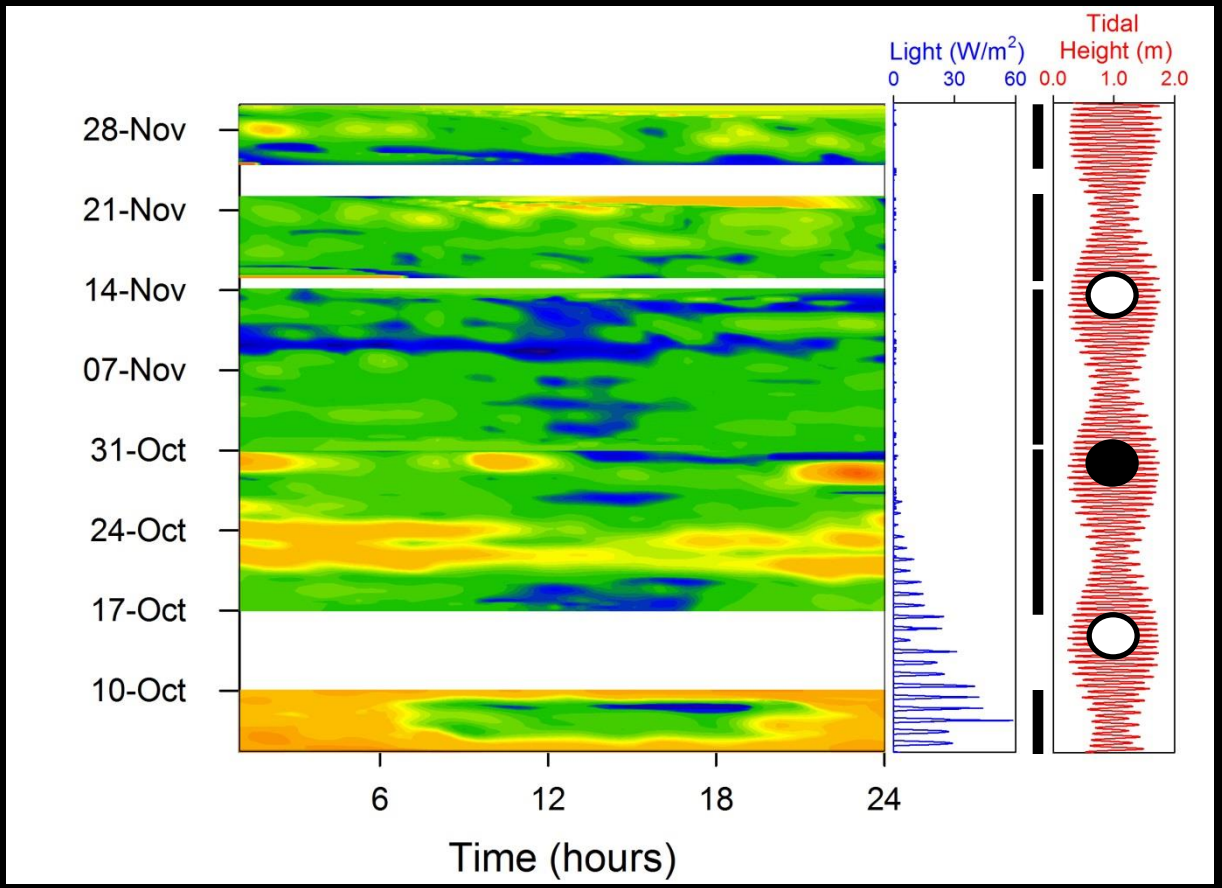
Photons s^{-1} at Maximum



At lower latitudes, luminescence often is controlled endogenously, occurring only during the nocturnal period

Is this also the case at high latitudes?

- Two month dock deployment (Oct-Nov 2011) in Adventfjord
- Some equipment failures during the time series, so examined five separate sections during autumn as L:D cycle decays



	Period (h)	
Tides	L:D	UBAT
12.2	N/A	N/A
12.6	N/A	N/A
12.4	21.4	23.8
12.4	23.7/25.3	23.8
12.6	23.8	23.6

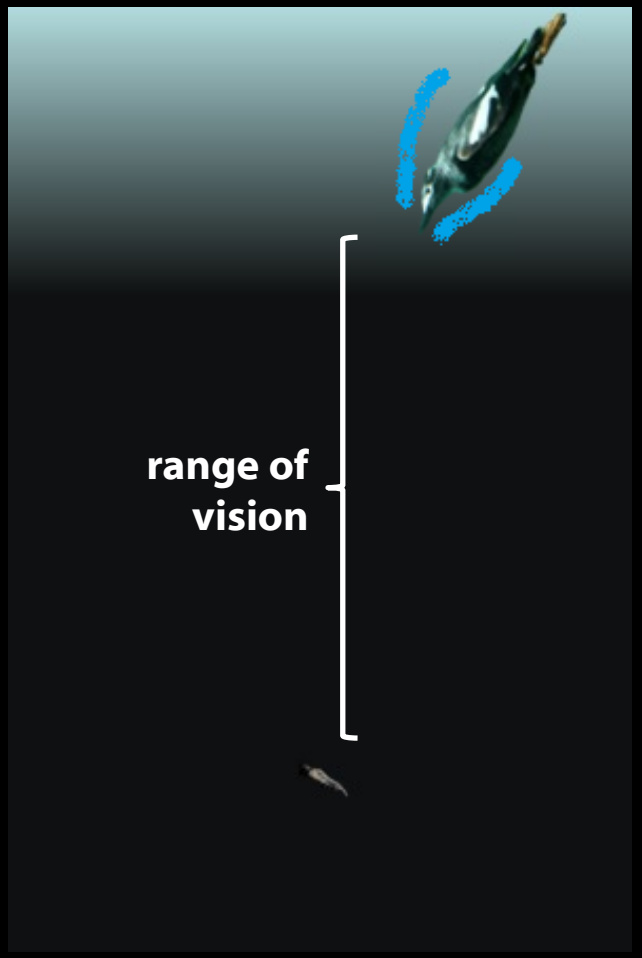
A luminescent burglar alarm for krill?

- Winter foraging on Arctic zooplankton occurs (Kraft et al. 2013, Rosing-Asvid et al. 2013)

- Diving predators may appear as silhouettes to the zooplankton eye
  - How far away is a seabird silhouette visible to a krill?
  - Does luminescence in the water column affect this?

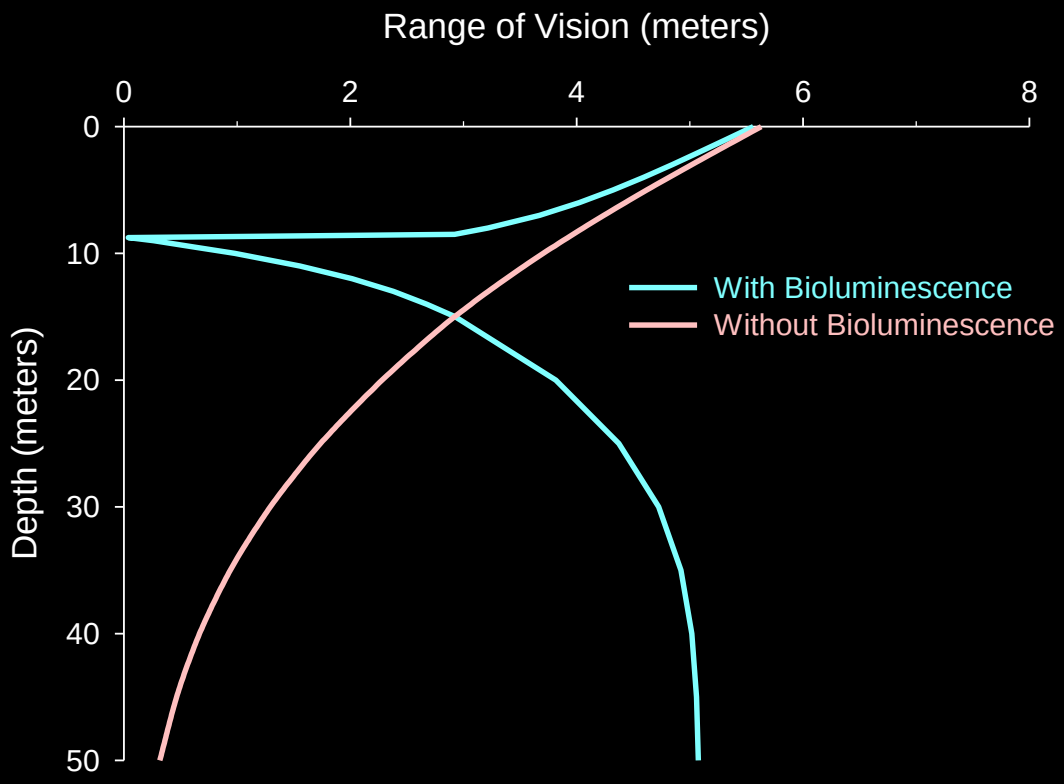
$$\left|N_{\boldsymbol{BL}} + N_{\boldsymbol{black}} - N_{space}\right| = R\sqrt{N_{\boldsymbol{BL}} + N_{\boldsymbol{black}} + N_{space} + 2X_{ch}}$$

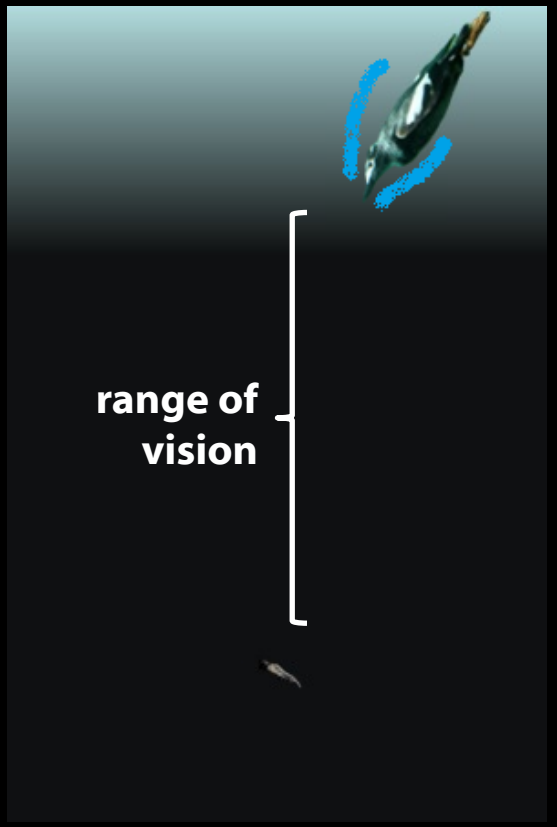
Nilsson et al. (2014)



A luminescent burglar alarm for krill?

- Without luminescence, silhouettes are harder to see at depth
- <10 m, luminescence "hides" dark silhouettes of predators
  - luminescence reduces contrast of silhouette against background light
- >10 m, luminescence helps to reveal a potential predator





Bioluminescence in the Polar Night

- Bioluminescence is a common feature in the Polar Night ocean
  - Coastal and frontal regions are "hot spots"
- Transition into and out of the Polar Night are interesting periods for BL because less periodicity is evident
- New instrumentation and analytical approaches has the potential to extract taxonomic detail of BL organisms
  - Coupled with data on species distributions and vertical migrations, this can help describe the role BL plays in ecology of the Polar Night
- Multi-frequency acoustics can be used to test hypotheses on BL role in predator-prey interactions derived from models