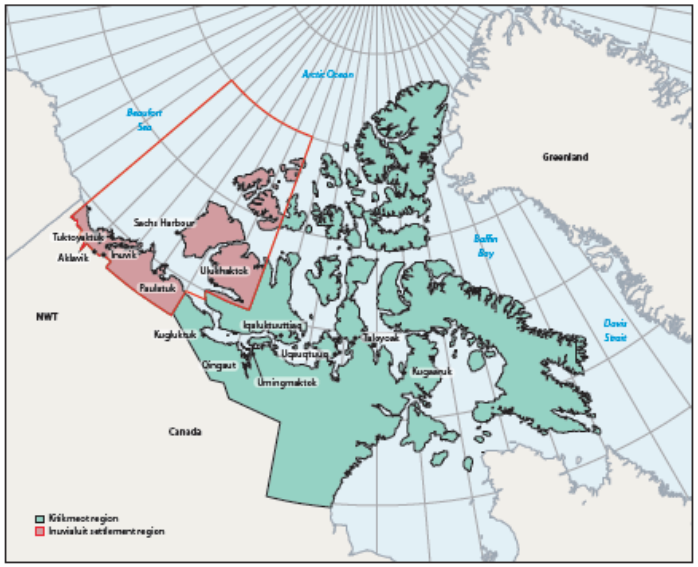
Changing oceans – Arctic

- Define vulnerable areas and impacts due to changing oceans
  - Physical, ecological, social, economic, governance

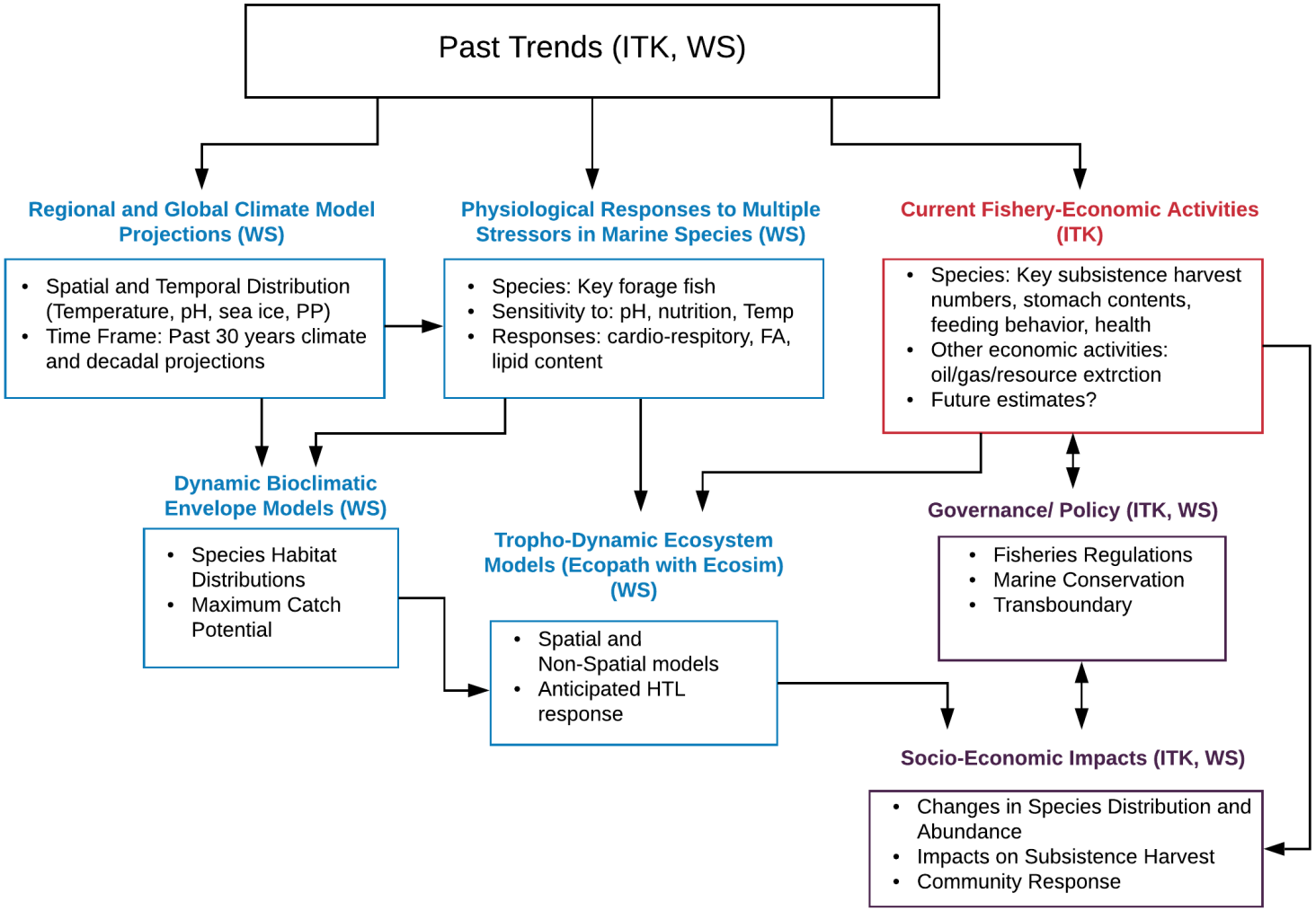
- Current working projects and analyses
  - AMAP report
  - Canada's current and future Arctic fisheries

AMAP report

- Arctic Monitoring and Assessment Programme
- Linking climate model projections to subsistence fisheries
- Beaufort Sea focus
- Arctic cod case study



Integrated framework



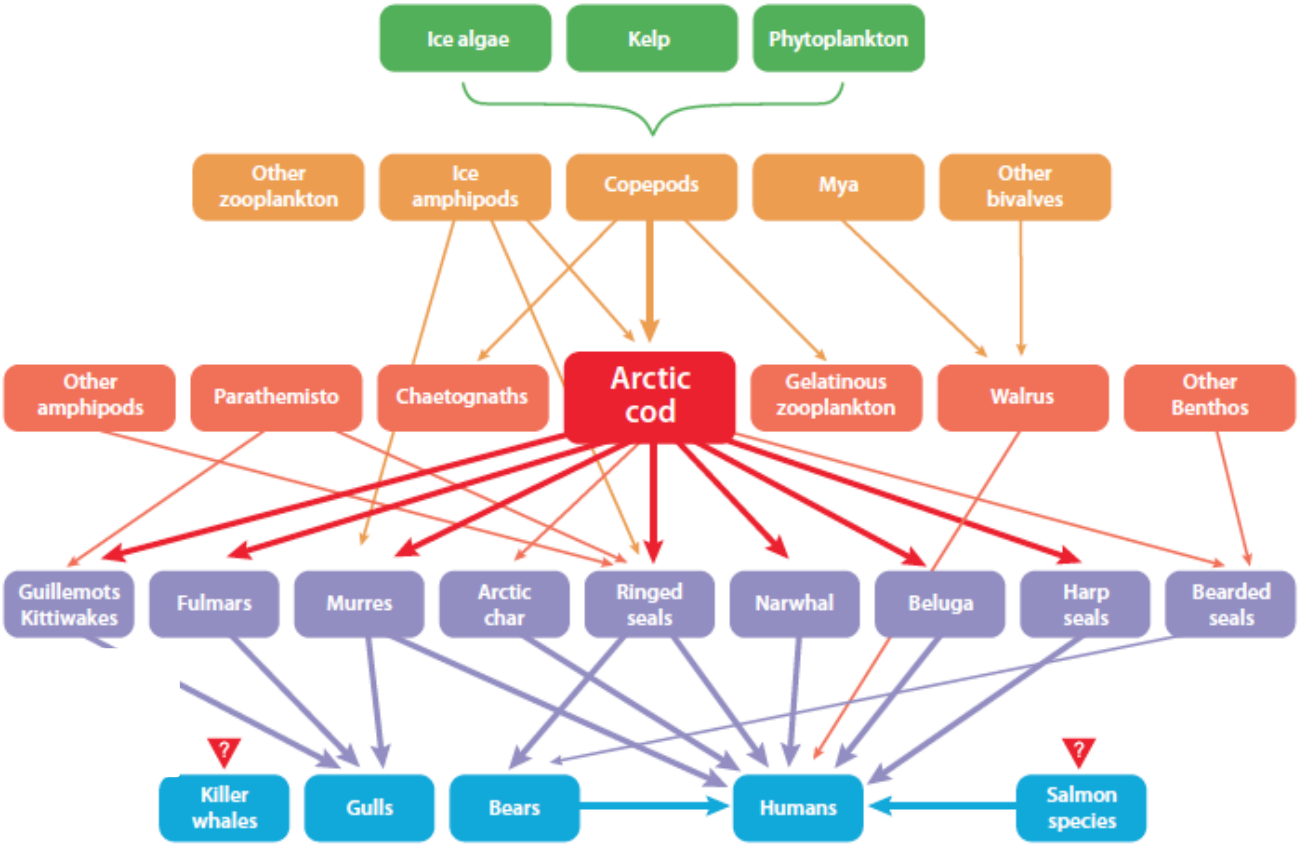
Taking stock

- Physiological responses to temperature and pH

Species common name:	Temperature limits (°C)				pH
	Critical lower	Lower pejus	Upper pejus	Critical upper	Critical/Pejus/Optimum
Pacific herring		Adults = 4.7C		Spawning = 10C Larvae= 13.3C (at 25ppm)	
Spot prawn	Adults = 3C	Adults = 5C	Eggs = 13-15C	Adults = 21C Larvae = 15.2C	
Arctic cod	-1.4C	Adults = 0.2C	Spawning = 3.5C Adult heart rate (T_{max}) = 10.8C	Adult Loss of equilibrium (LOE) = 14.9C	No difference in proton leak and ATP production efficiency between groups acclimated at 400 µatm vs. 1170 µatm of CO_2
Arctic char	0C	Eggs < 3C	Adults = 16C Adults Growth freshwater = 15.1C T_{max} (heart rate) = 23C	larvae feeding = 22C Alevins, fry and parr (acclimation 5C) = 23-3, 25-1 and 25-7C	Pejus = CO_2 <10 mg/L optimum 10-20 mg/L
Capelin	-1.5C	0C	Juveniles= 10C Adults= 14C		
Calanus glacialis (copepod)			Stage IV = 10C or = 5C with 3000 µatm added stress		Hatching delay: 6.9 pH Copepodites stage IV: 7.87 pH
Limacina helicina (pteropod)	Adults = -1.9C	Adults = -0.4	Adults = 7C		Adult: 28% decrease in calcification at 760 µatm. Ω ~ 0.8 = severe damage

Taking stock

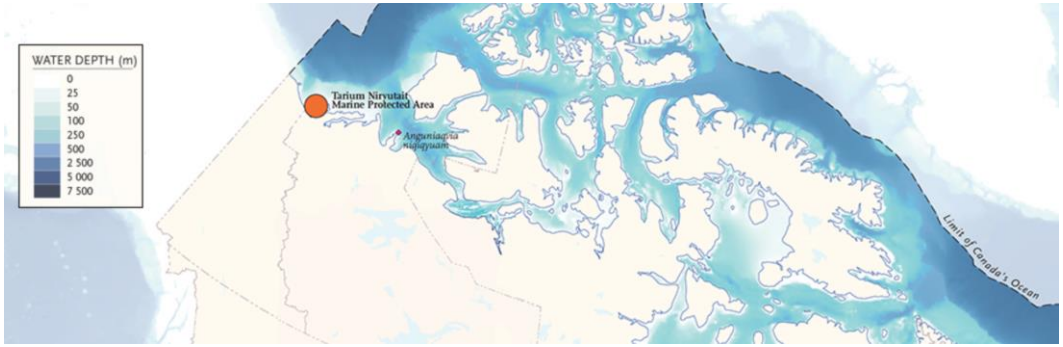
- Beaufort Sea ecosystem structure



Taking stock

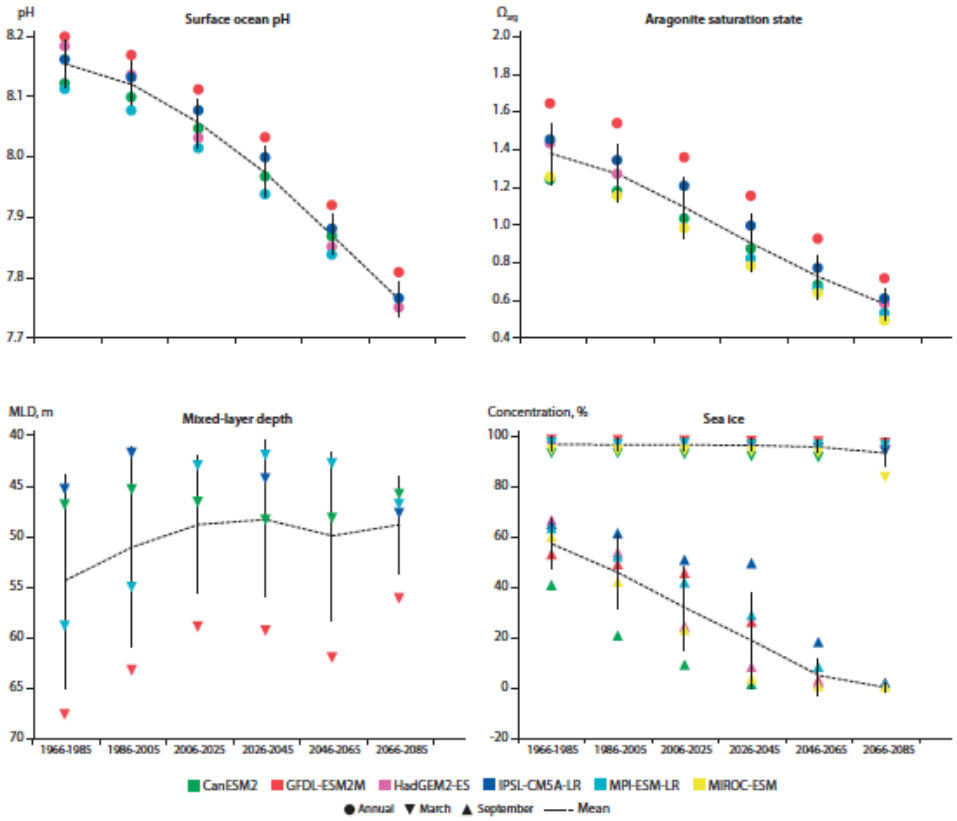
- Current fisheries catch and landed value
- MPA networks

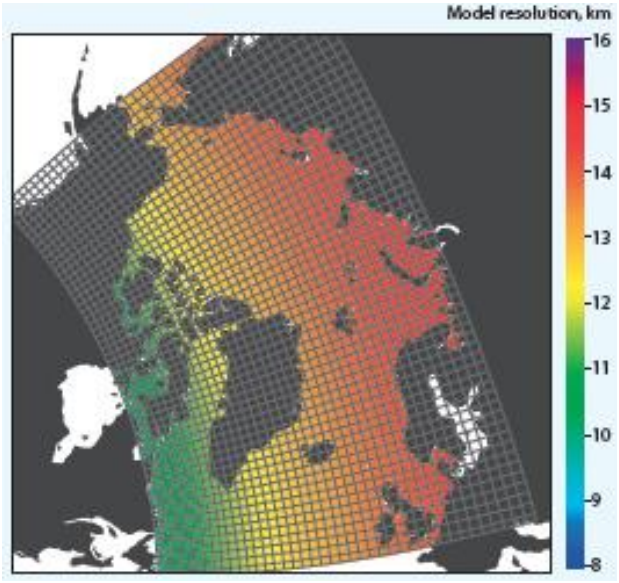
	Current (2001–2010)	
	Catch	Landed value
Arctic cod (*Boreogadus saida*)	4600	3240,000
	(2810 – 5800)	(1980,000 – 4090,000)
Capelin (*Mallotus villosus*)	4,310	1150,000
	(1260 – 6490)	(337,000 – 1740,000)
Navaga (*Eleginus nawaga*)	103	69,300
	(69.4 – 144)	(46,700 – 96,800)
Atlantic halibut (*Hippoglossus hippoglossus*)	10.5	77,700
	(1.90 – 16.4)	(14,100 -121,000)
Lemon sole (*Microstomus kitt*)	9.42	45,500
	(6.81 – 11.3)	(32,900 – 54,500)
Arctic char (*Salvelinus alpinus alpinus*)	3.50	13,200
	(1.17 – 5.39)	(4410 -20,300)
Greenland cod (*Gadus ogac*)	0.300	756
	(0 – 0.895)	(0 – 2290)
Total	**9029**	**4599,000**
	(4150 – 12,500)	(2410,000 – 6120,000)



Future scenarios

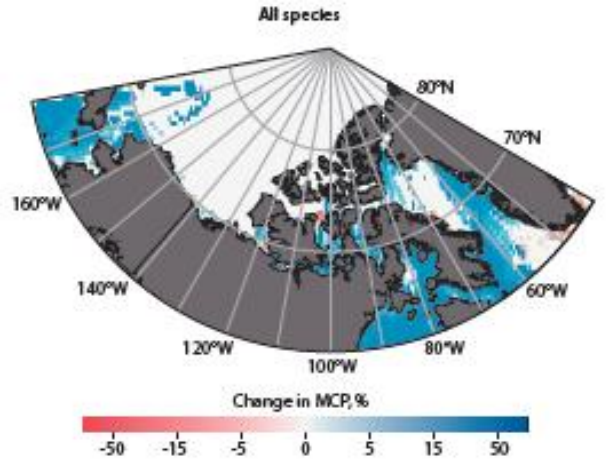
- Regional and global climate model projections
- High climate change scenario (RCP 8.5)

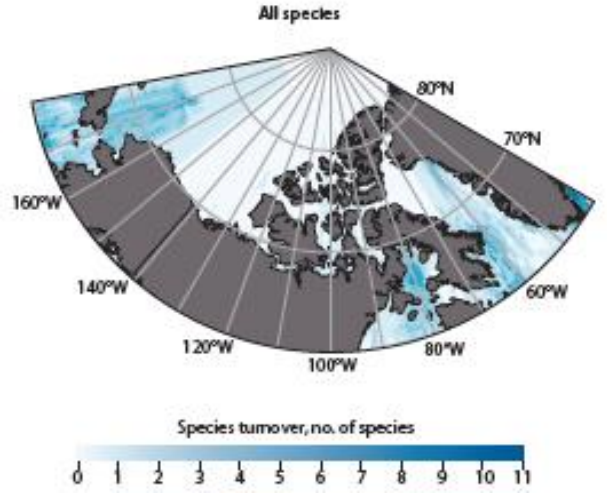




Future scenarios

- Dynamic bioclimate envelope model
  - High climate change (RCP 8.5)
  - Distribution and catch potential
  - Species turnover
- Tropho-dynamic ecosystem model
  - Ecopath with Ecosim (EwE)
- Economic impacts
  - Prices and to determine potential fisheries value



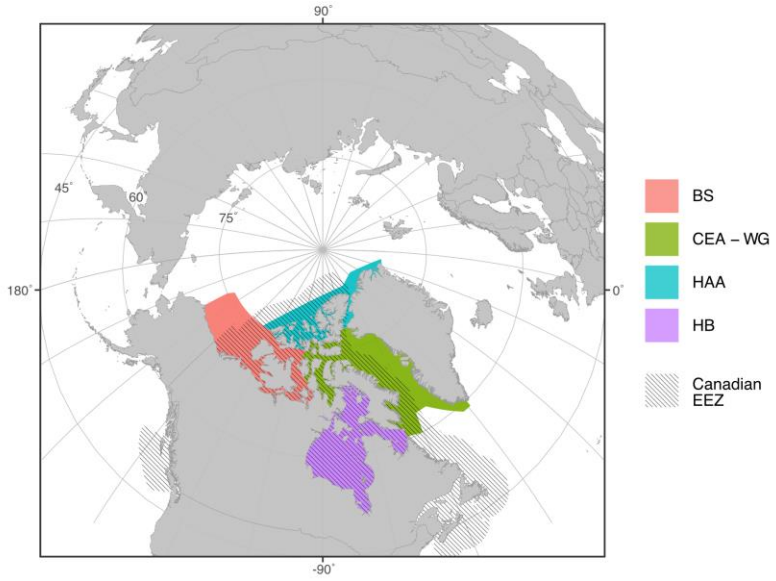


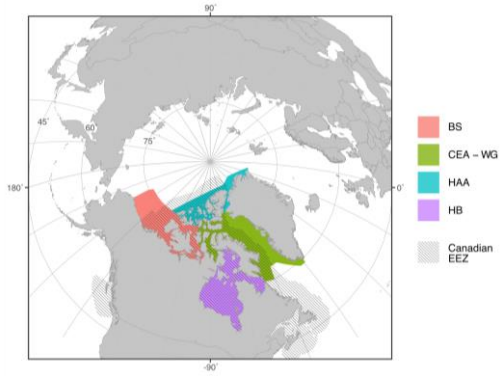
Next steps

- Governance and policy implications
  - Adaptation strategies to cope with change
  - National and pan-Arctic MPA networks are needed
  - Caution with possible opening of commercial fisheries

Canada's Arctic fisheries

- Estimates of current and future fisheries catch and value potential
- Canada's 4 major Arctic Large Marine Ecosystems
- Historical catch comparisons





Canada's Arctic fisheries

Historical (2005-2014)

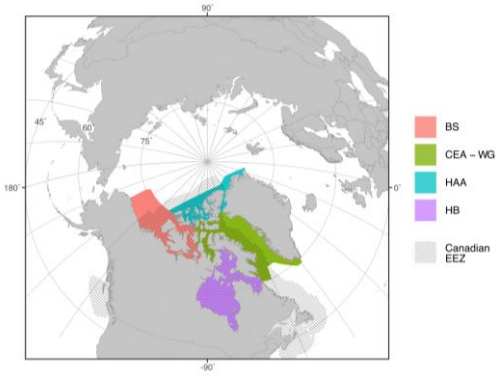
- 189,000 tonnes
- $560 M dollars

- More high value species
  - E.g. northern prawn

Current potential (modelled)

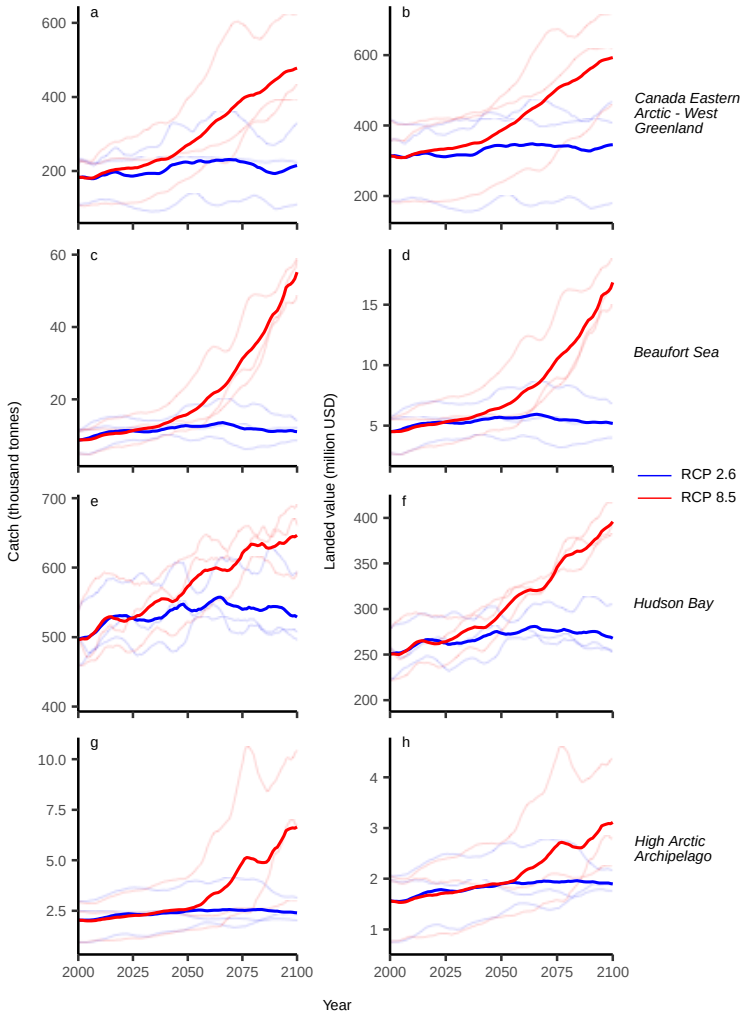
- 710,000 tonnes
- $578 M dollars

- More low value species
  - E.g. capelin



Canada's Arctic fisheries

- Significant increases in catch and value with increased CO_2
- Trends are largely the same across all earth system models



Integrated framework