A Scenario Approach to Forecast Potential Impacts of Climate Change on Red King Crabs in the Eastern Bering Sea

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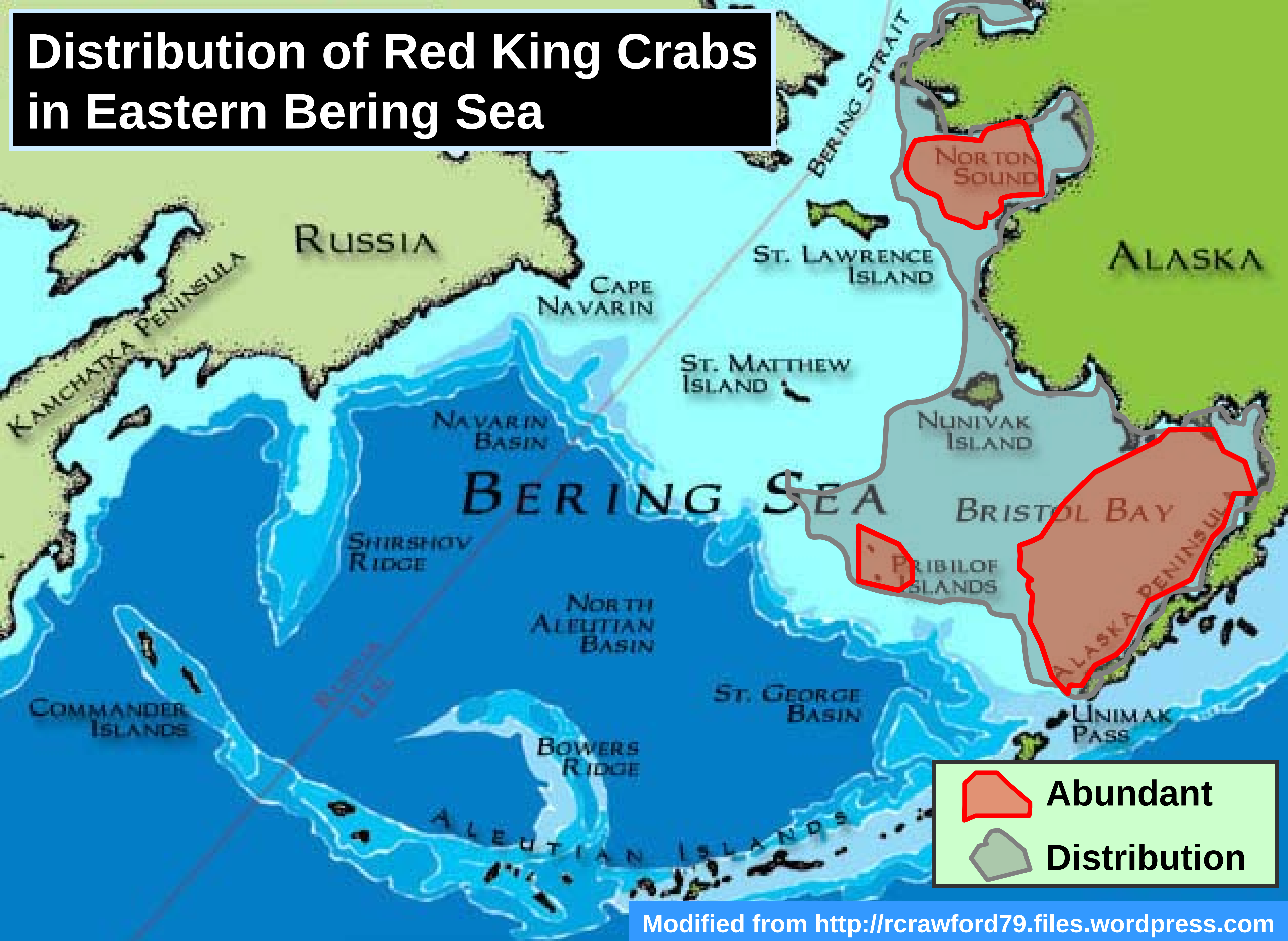
Project Goal

- Provide rapid assessment based on reasoned expert judgment on impacts of climate change on red king crab biomass and harvest in the eastern Bering Sea through 2030 and 2050

Approach

- Identify bio-physical mechanisms likely to affect king crab productivity via workshop of experts
- Use central case climate scenario for key atmospheric/oceanographic driving variables, based on 4th Assessment Review by IPCC (primarily A1B Scenario – "medium" emissions)
- Develop central, low, and high crab biomass estimates based on expected relative response of each mechanism, from "---" to "0" to "+++"
- Scale cumulative effects from all mechanisms to levels of historical variability of biomass
- Apply harvest control rules to biomass estimates to estimate commercial catches

Distribution of Red King Crabs in Eastern Bering Sea

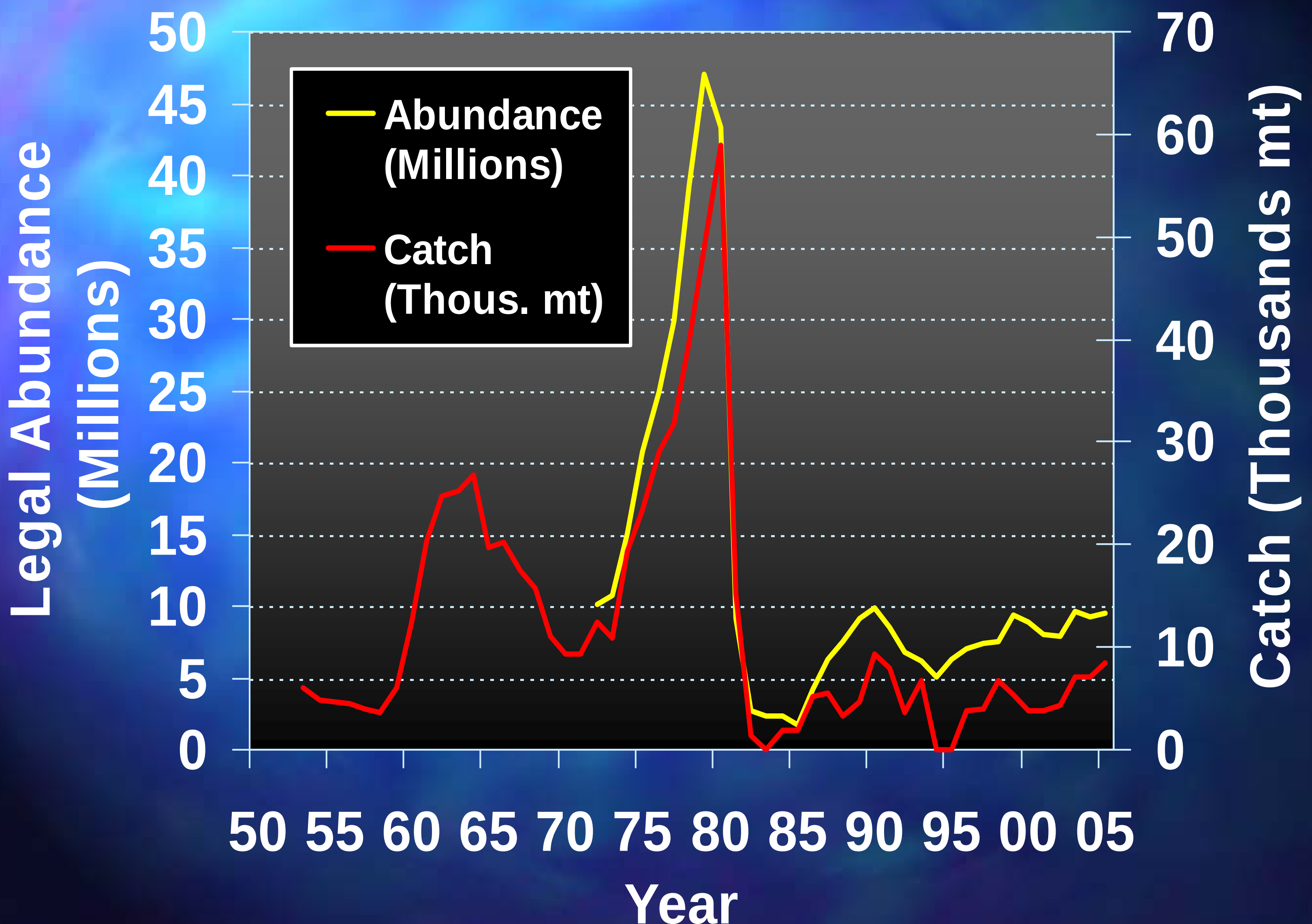


Modified from http://rcrawford79.files.wordpress.com

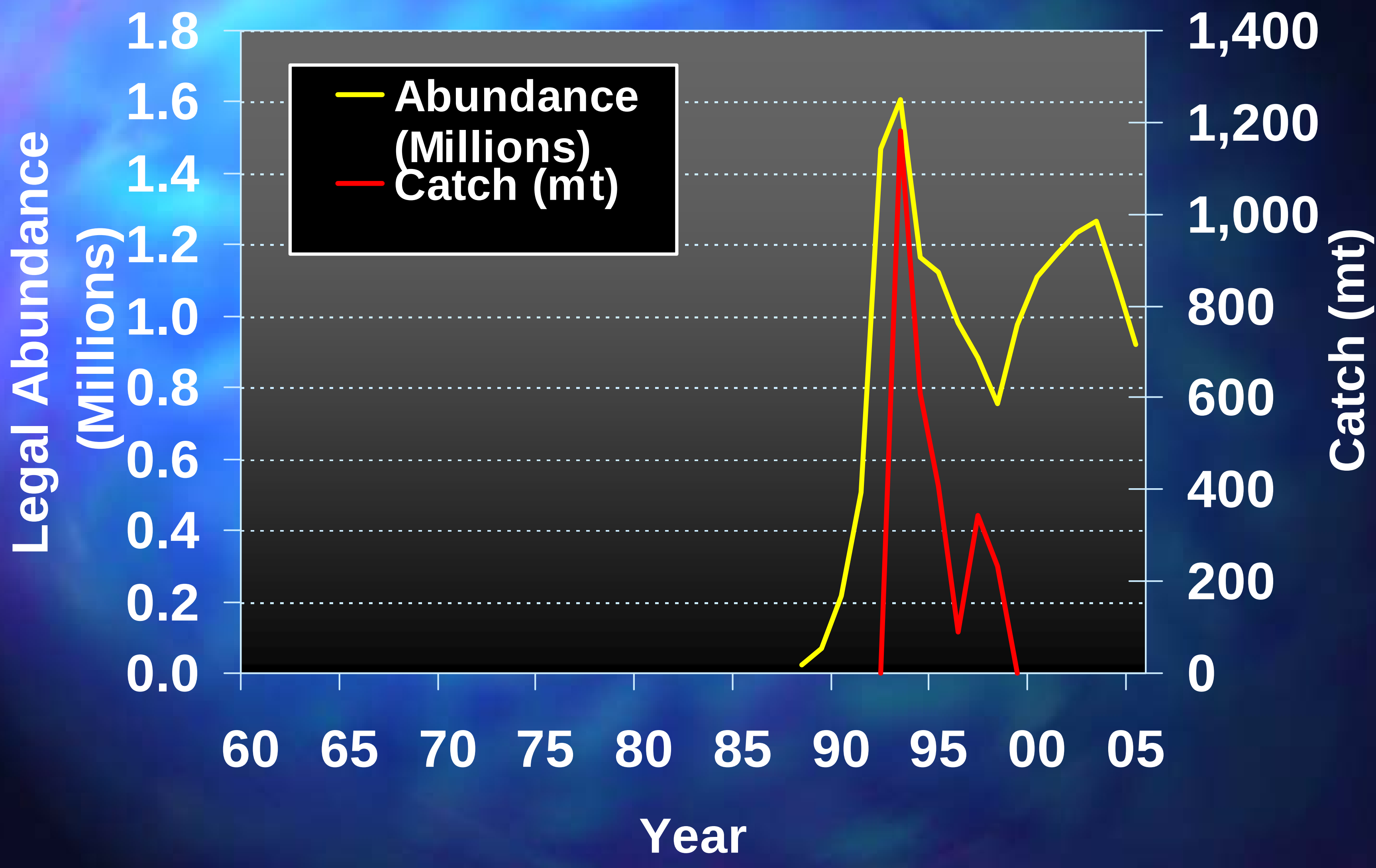
Overview of Fishery Management

- 3-S (Size-Sex-Season) Management
  - Sex – Only males are legal for harvest
  - Size – Minimum legal size
  - Season – No fishing during spring molting & mating periods
- Target harvest rate:
  - Bristol Bay: 10-15% of mature males
  - Norton Sound: 5-10% of legal males
  - Pribilof Islands: harvest depends on blue king crab abundance

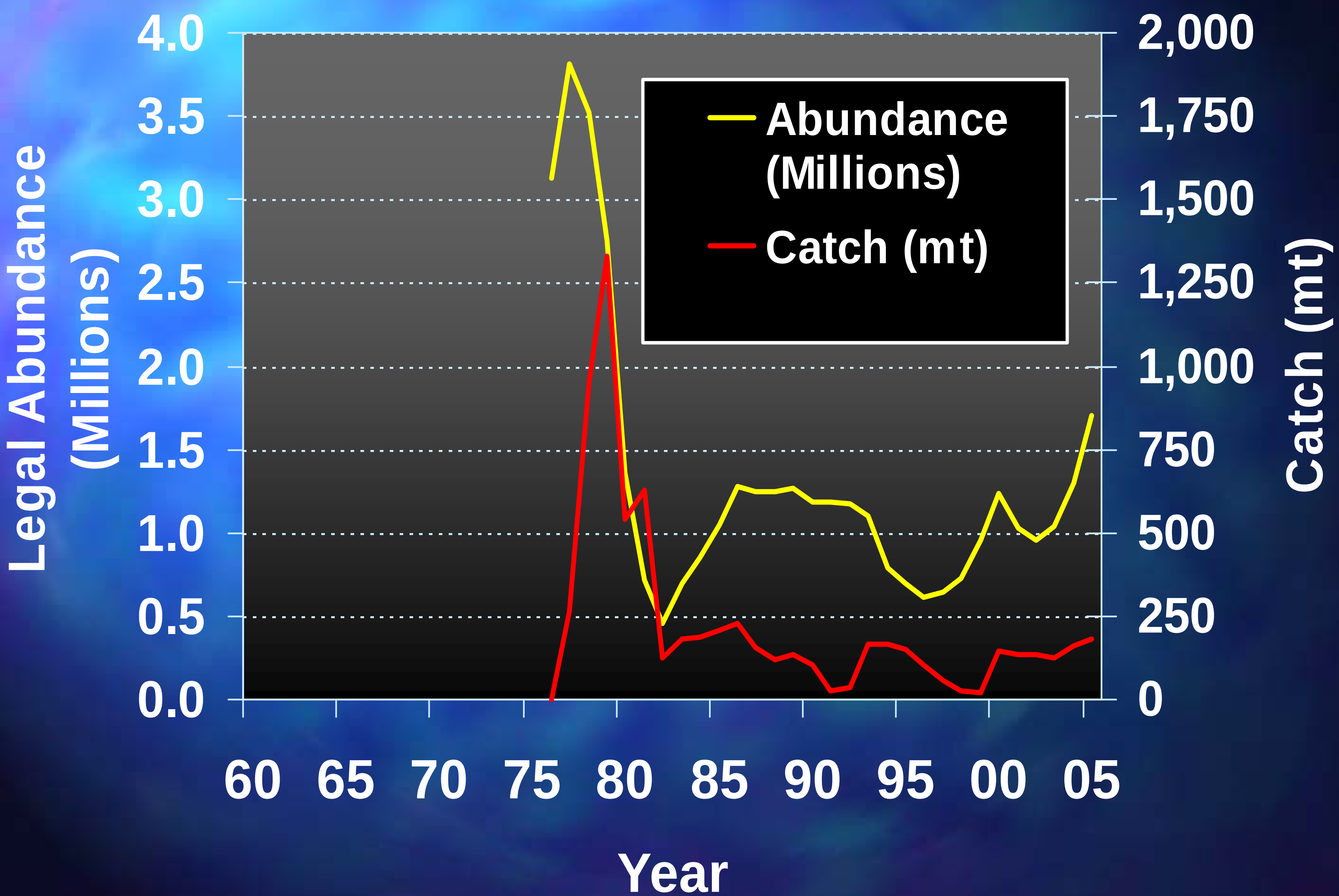
Abundance & Catch: Bristol Bay



Abundance & Catch: Pribilof Islands

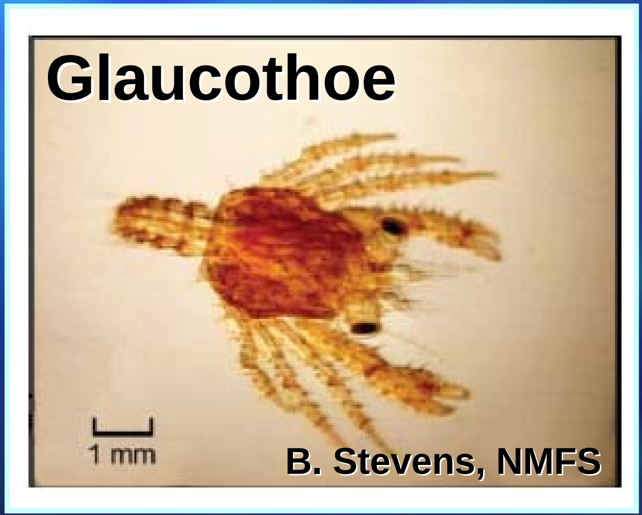


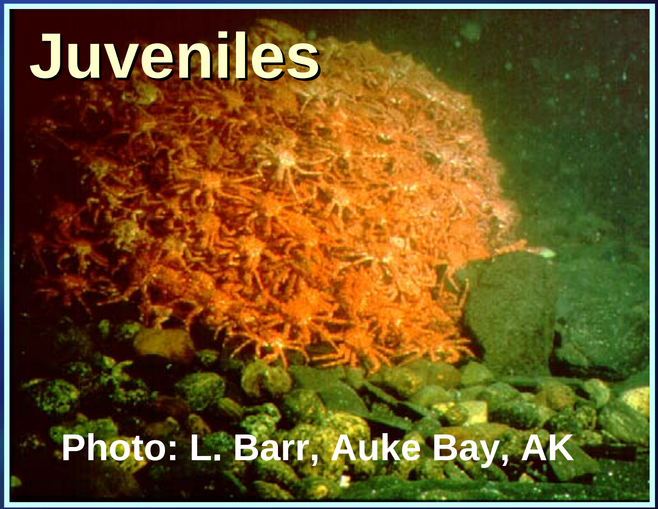
Abundance & Catch: Norton Sound



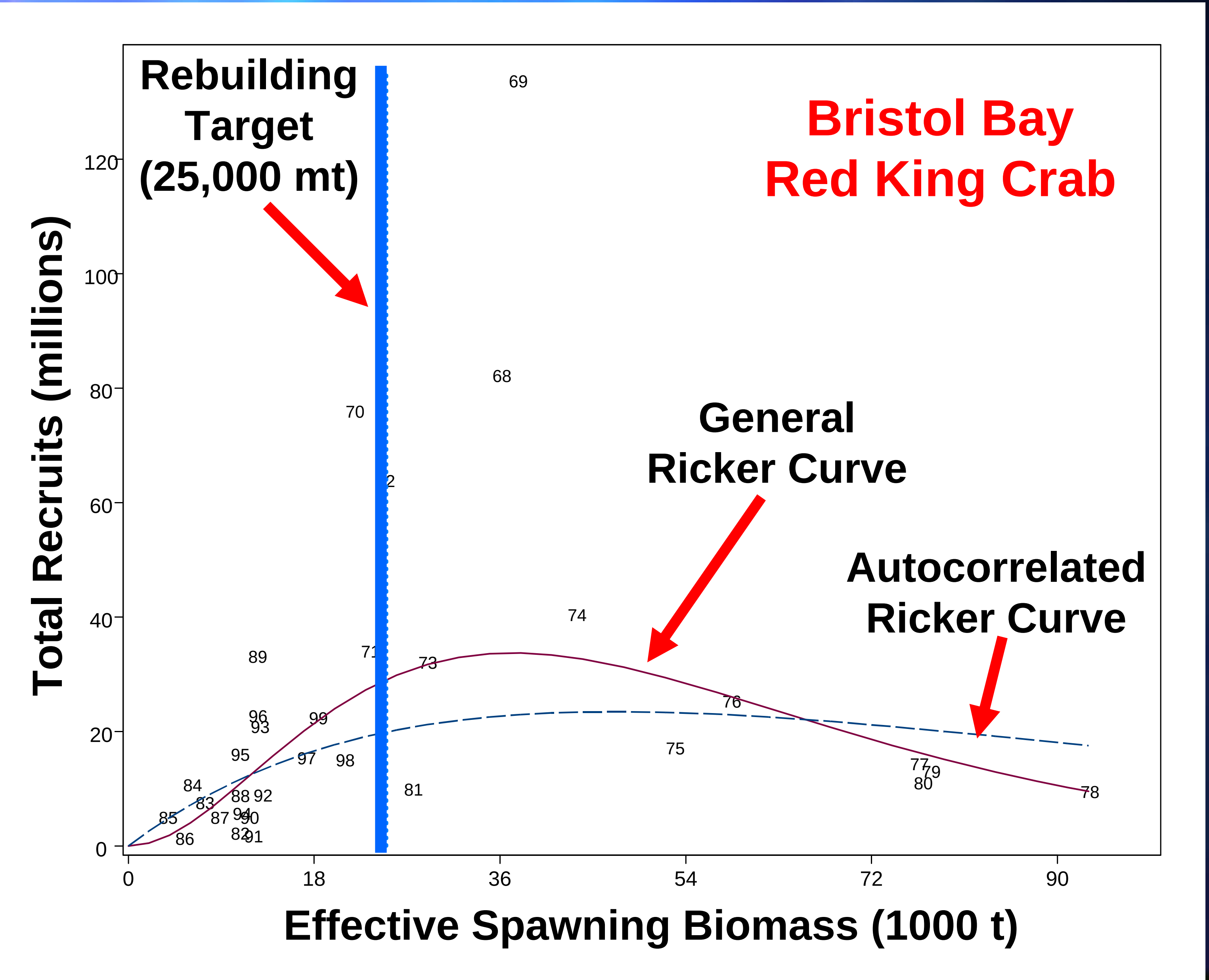
5 Mechanisms for RKC Recruitment

1. Spawning biomass
2. Larval prey timing
3. Larval advection
4. Juvenile predation
5. Benthic energy flow

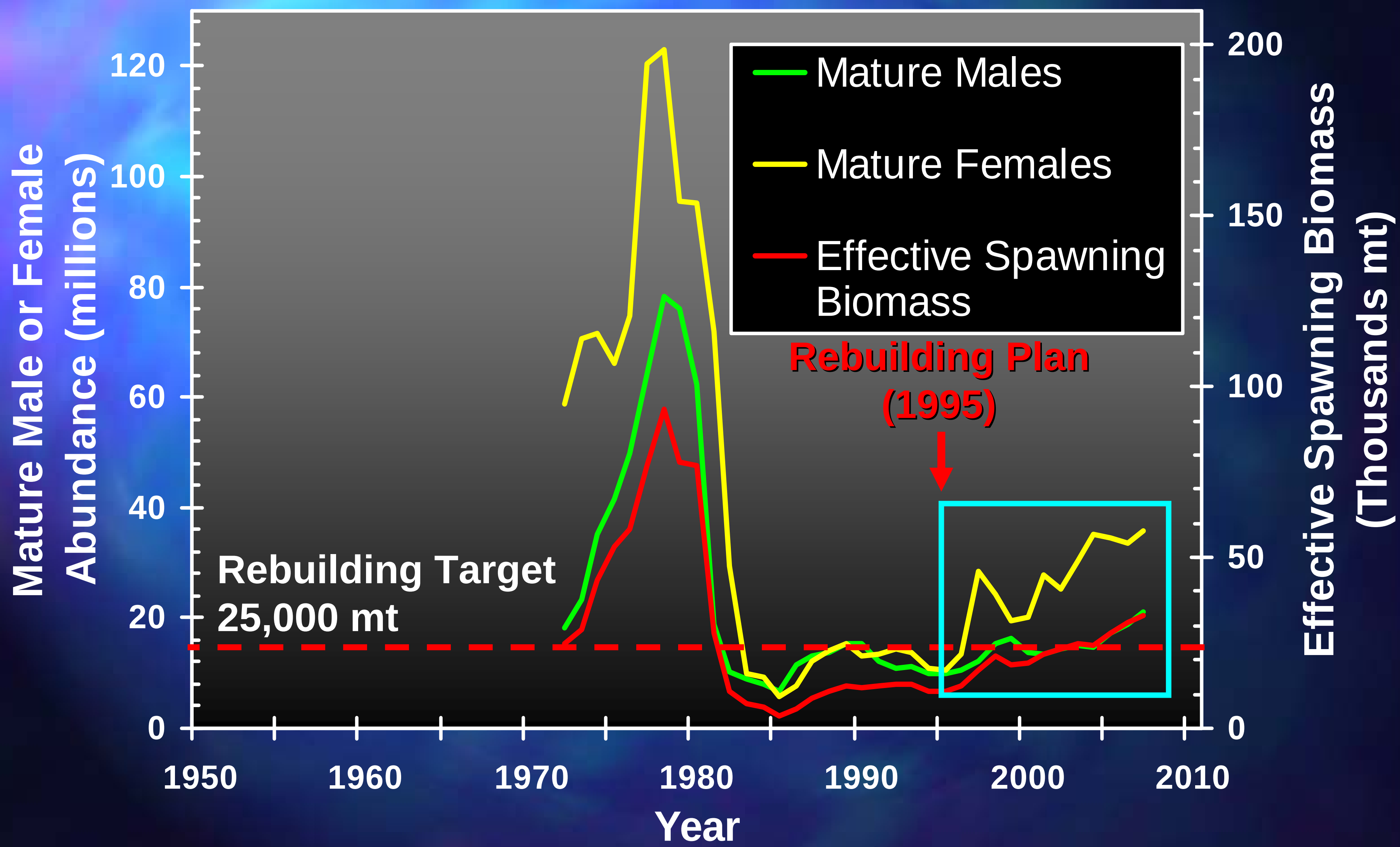




Role of Spawning Biomass on Recruits



Bristol Bay RKC Abundance/Biomass



Expected Management Effects

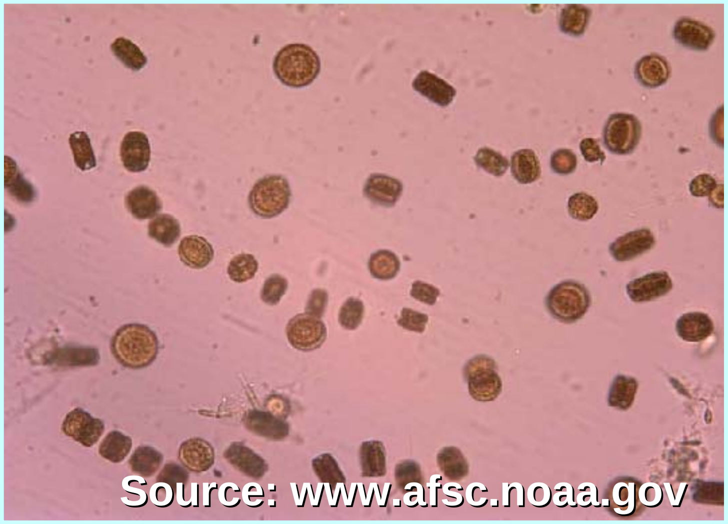
- Bristol Bay – benefits of rebuilding plan are expected to continue to accrue, as biomass has returned to moderate levels, increasing the probability of periodic good recruitments
- Pribilof Islands – no systematic change expected, as stock has been lightly fished
- Norton Sound – stock has been conservatively managed for 25 years, but some increase could occur, if the stock is still recovering from high harvests in the late 1970s

Expected Management Effects

Area	2030 L	2030 C	2030 H	2050 L	2050 C	2050 H
Bristol Bay	0	+	++	0	+	++
Pribilof Islands	0	0	0	0	0	0
Norton Sound	0	0	+	0	0	+

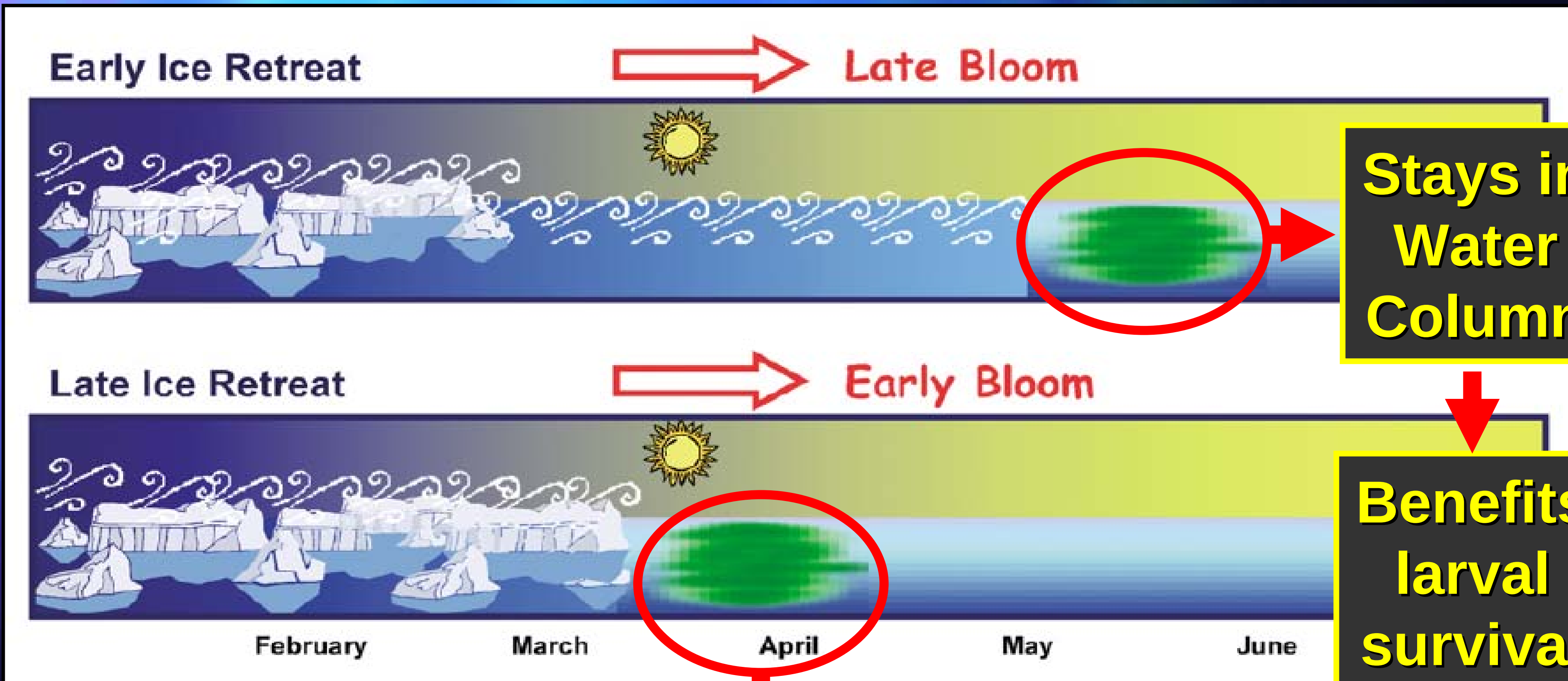
Expected Effects on Larval Prey Timing

- Red king crab larvae hatch in mid April to mid June
- Diatoms (e.g., *Thalassiosira* sp.) are preferred larval food



- Red king crab larvae must feed within 2-6 days of hatching in order to survive (Paul and Paul 1980)
- Larval growth is directly related to concentrations of *Thalassiosira* diatoms (Paul et al. 1989, 1990)

Expected Effects on Larval Prey Timing



Stays in Water Column

Benefits larval survival

(Hunt et al. 2002)

Benthos

Filter feeders Detritivores

Crab growth & reproduction

Expected Effects on Larval Prey Timing

Key Climate Parameter	**Description of Baseline**	**2030**	**2050**
Winter sea ice extent	1980-1999 mean winter sea ice extent 0.44×10^6 km^2	-0.16×10^6 km^2 -36.4%	-0.20×10^6 km^2 -45.5%

Expected Effects on Larval Prey Timing

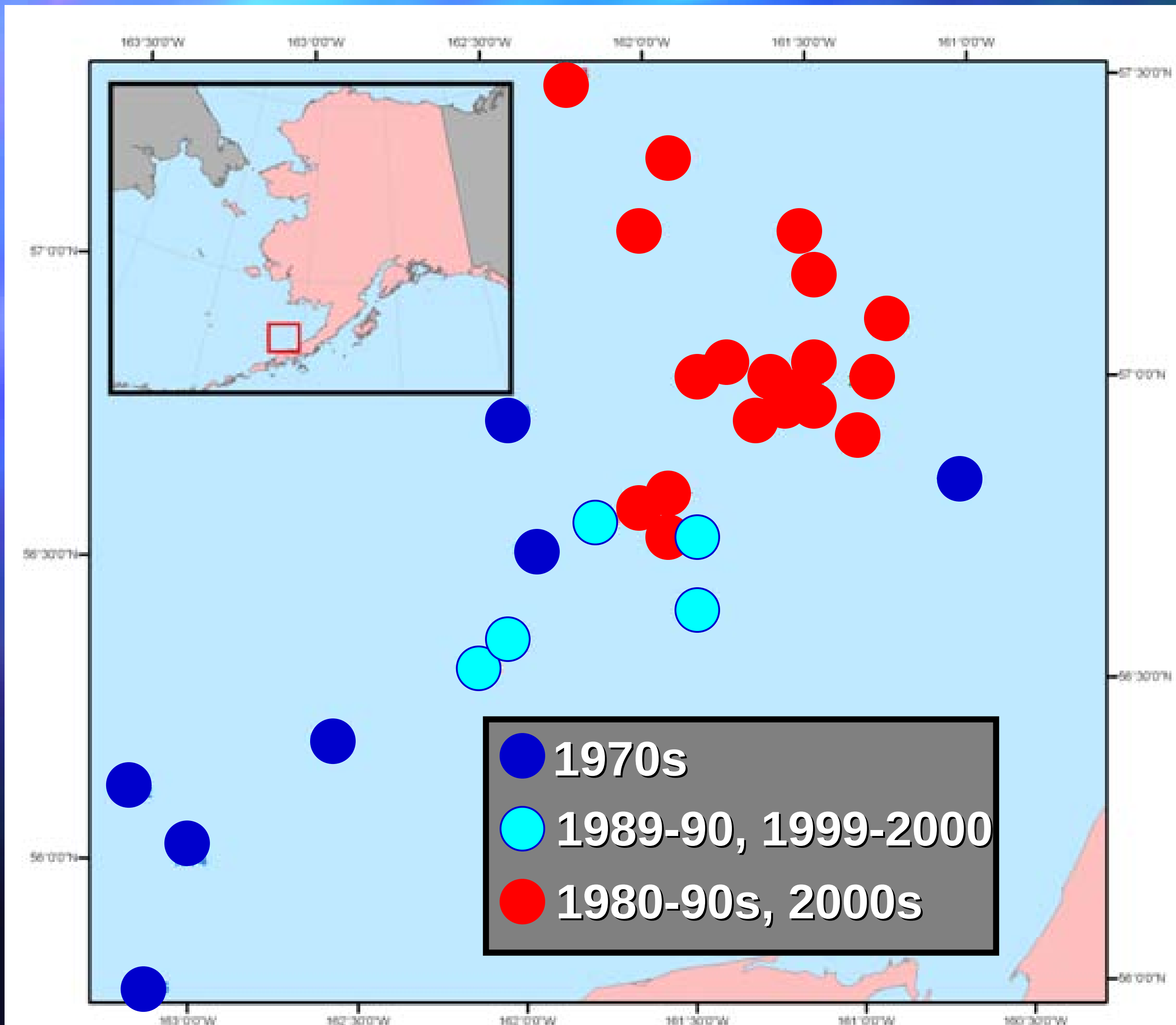
	2030			2050		
Area	L	C	H	L	C	H
Bristol Bay	0	+	++	+	+	++
Pribilof Islands	0	+	++	+	+	++
Norton Sound	0	+	++	+	+	++

Expected Effects on Larval Advection

Two Temperature Effects:

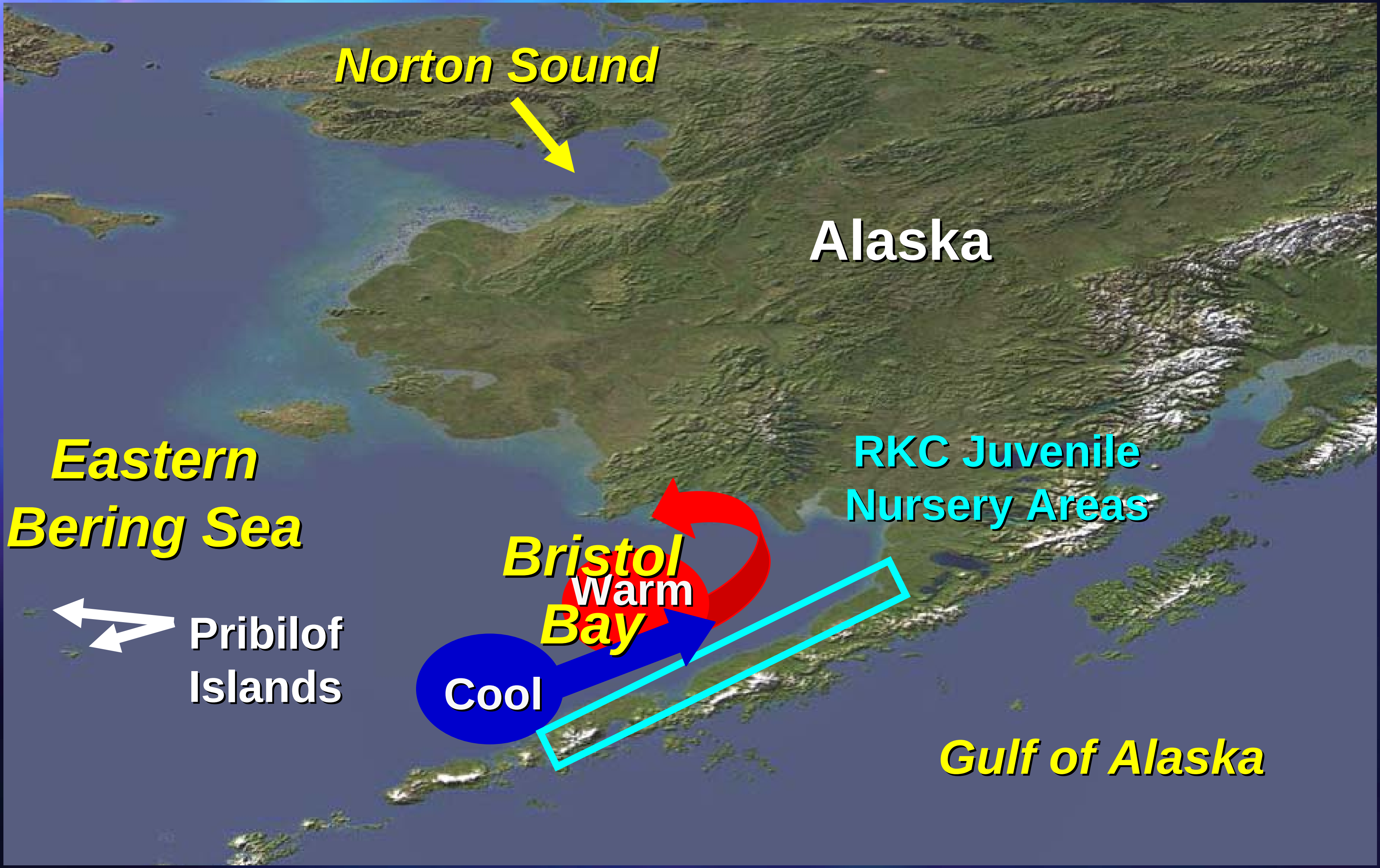
- Distribution of adults also depends on temperature (Hsu 1987, Loher & Armstrong (2005, Zheng & Kruse, in review)
- Duration of four pelagic, zoeal stages is 325 degree-days (B. Stevens, NMFS, pers. comm.)

Expected Effects on Larval Advection

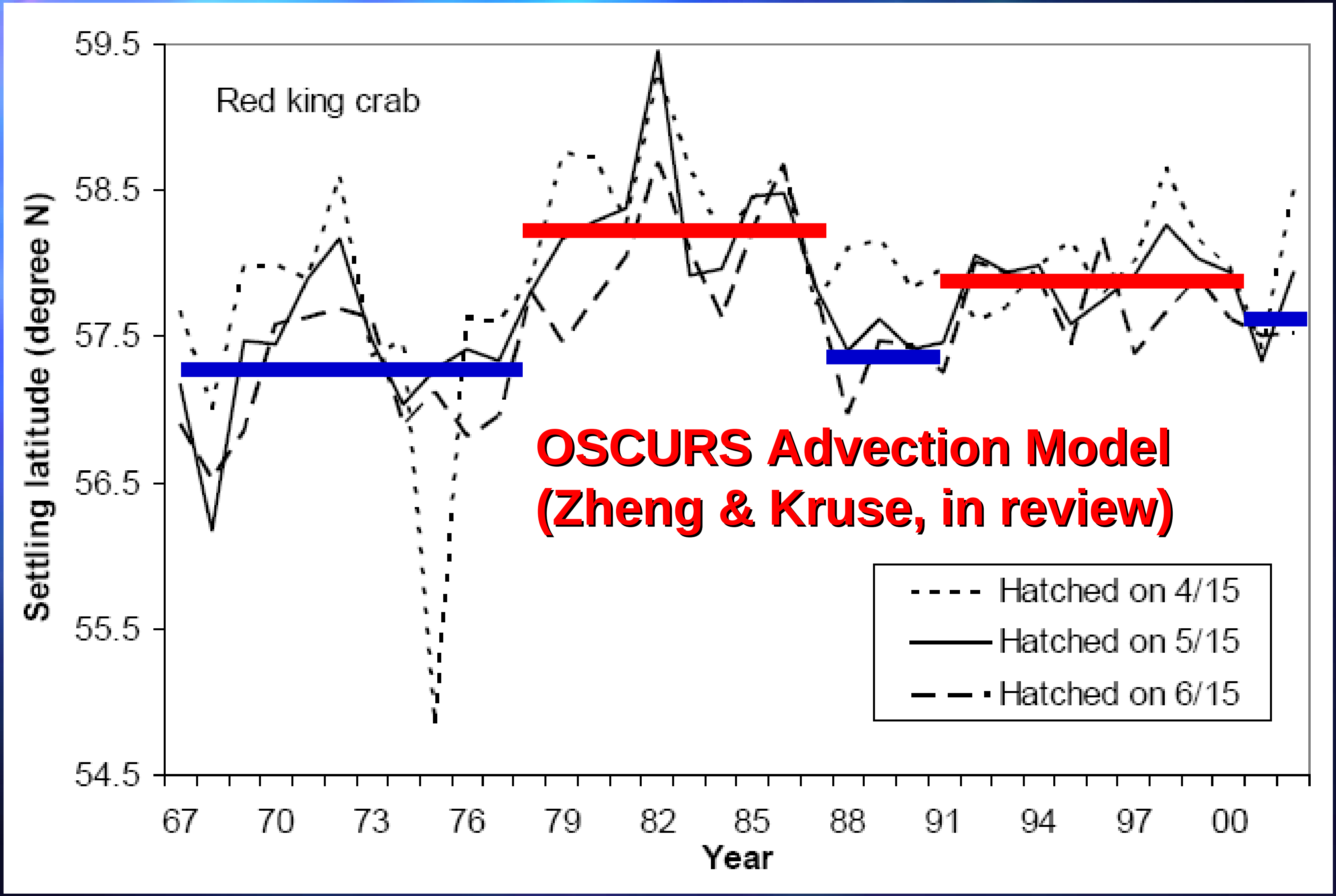


Centers of Distribution of mature female red king crabs in Bristol Bay (Zheng & Kruse 2006)

Expected Effects on Larval Advection



Expected Effects on Larval Advection



Expected Effects on Larval Advection

Key Climate Parameter	Description of Baseline	2030	2050
Sea surface temperature (SST)	1980-1999 mean SST	+1.0 C (Nov-Mar)	+1.5 C (Nov-Mar)

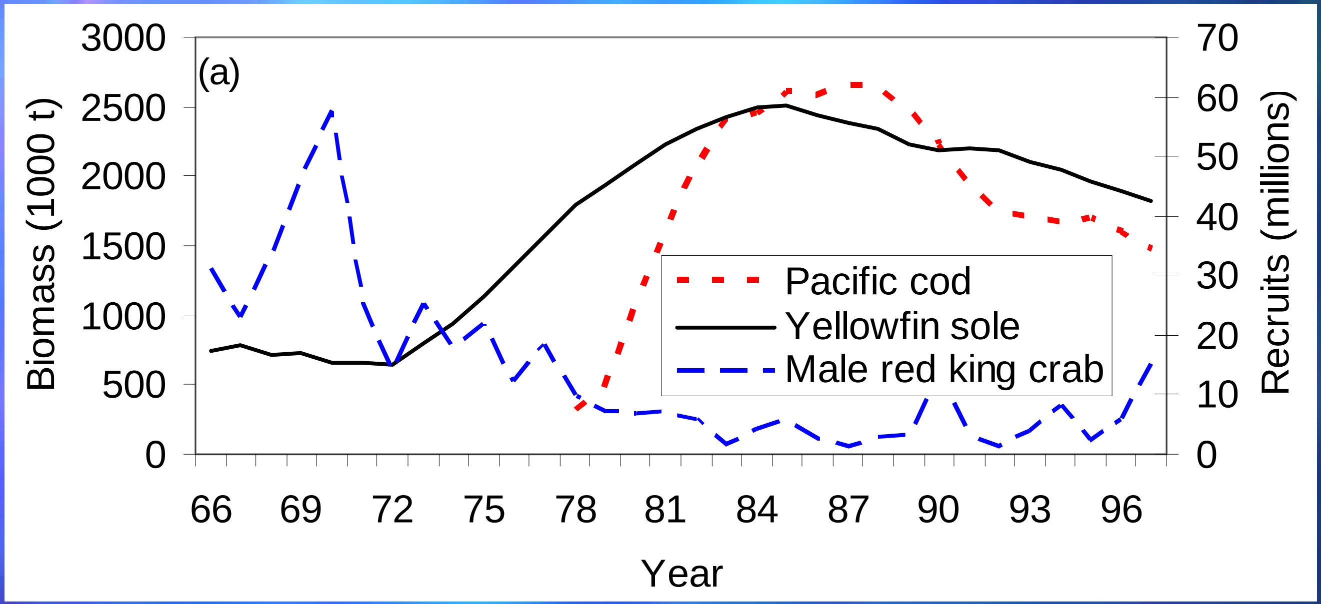
Expected Effects on Larval Advection

- <u>Advection</u> – Warmer temperatures make it difficult for red king crabs to supply the southern nursery areas with larvae in Bristol Bay, mainly due to northeastward shifts in adults
- <u>Retention</u> – Effects are likely quite different for Pribilof Islands (tidal fronts) and Norton Sound (gyre)

Expected Effects on Larval Advection

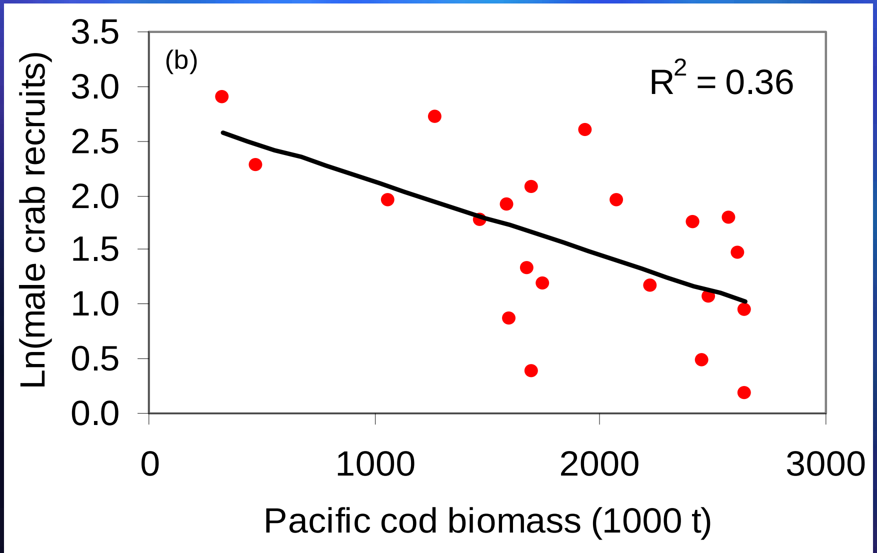
	2030			2050		
Area	L	C	H	L	C	H
Bristol Bay	--	-	0	--	-	0
Pribilof Islands	0	0	0	0	0	0
Norton Sound	0	0	0	0	0	0

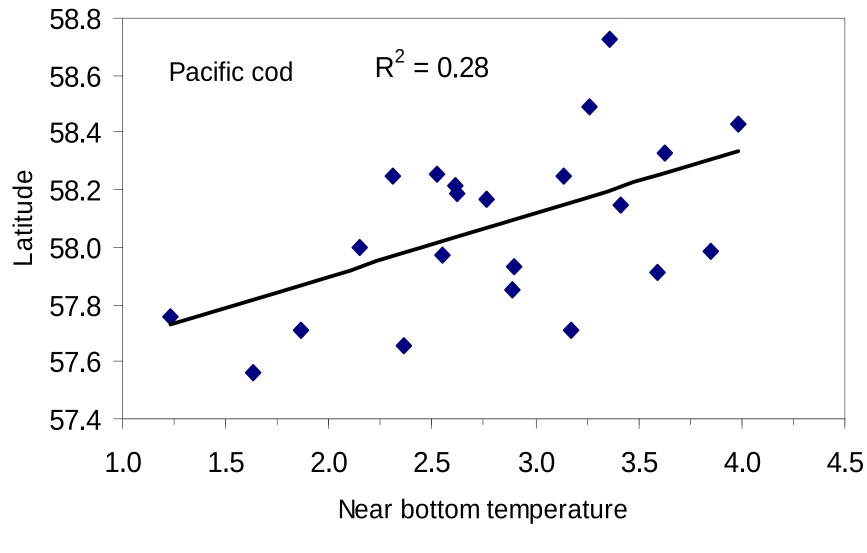
Expected Effects on Juvenile Predation



Years lagged to crab age 1

Zheng and Kruse (2006)

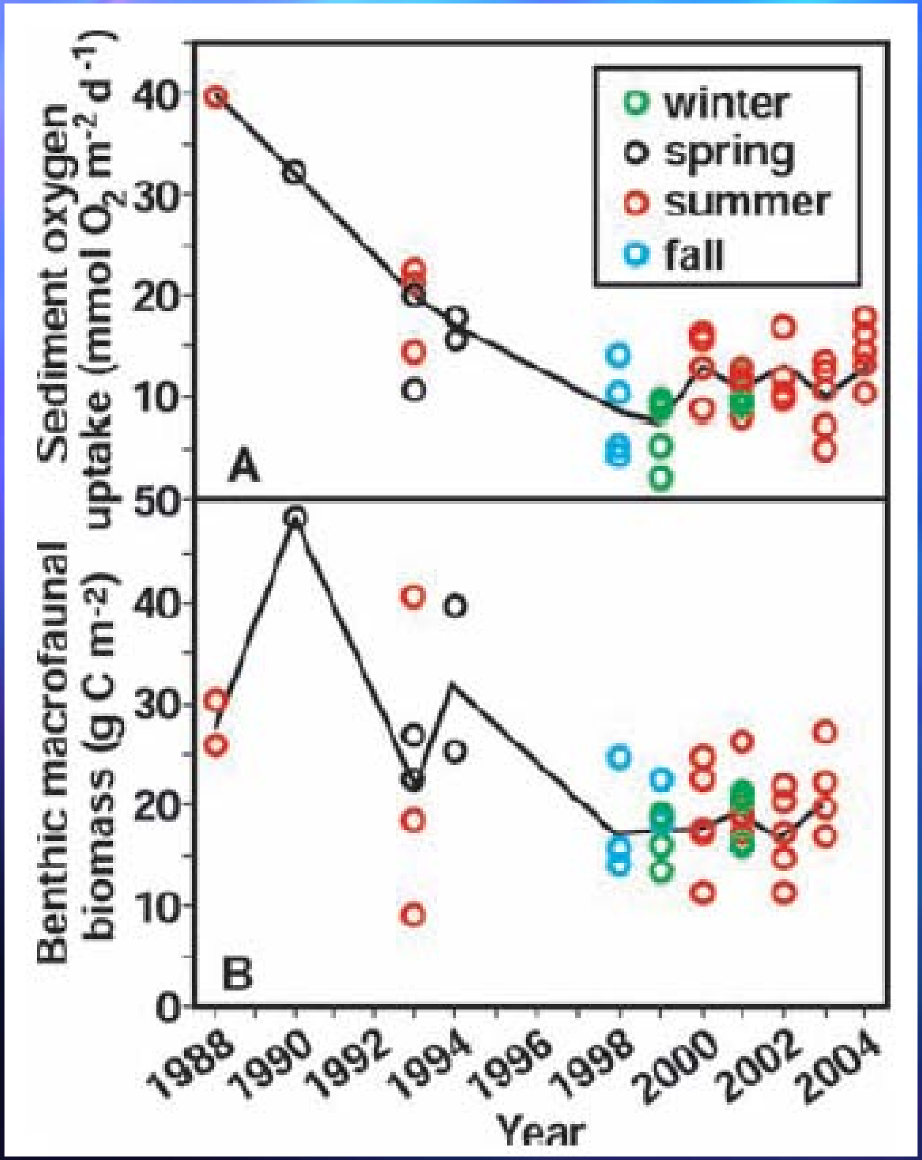




Expected Effects on Juvenile Predation

	2030			2050		
Area	L	C	H	L	C	H
Bristol Bay	--	-	0	---	--	-
Pribilof Islands	--	--	-	---	---	-
Norton Sound	--	-	-	---	---	---

Expected Effects on Benthic Energy Flow



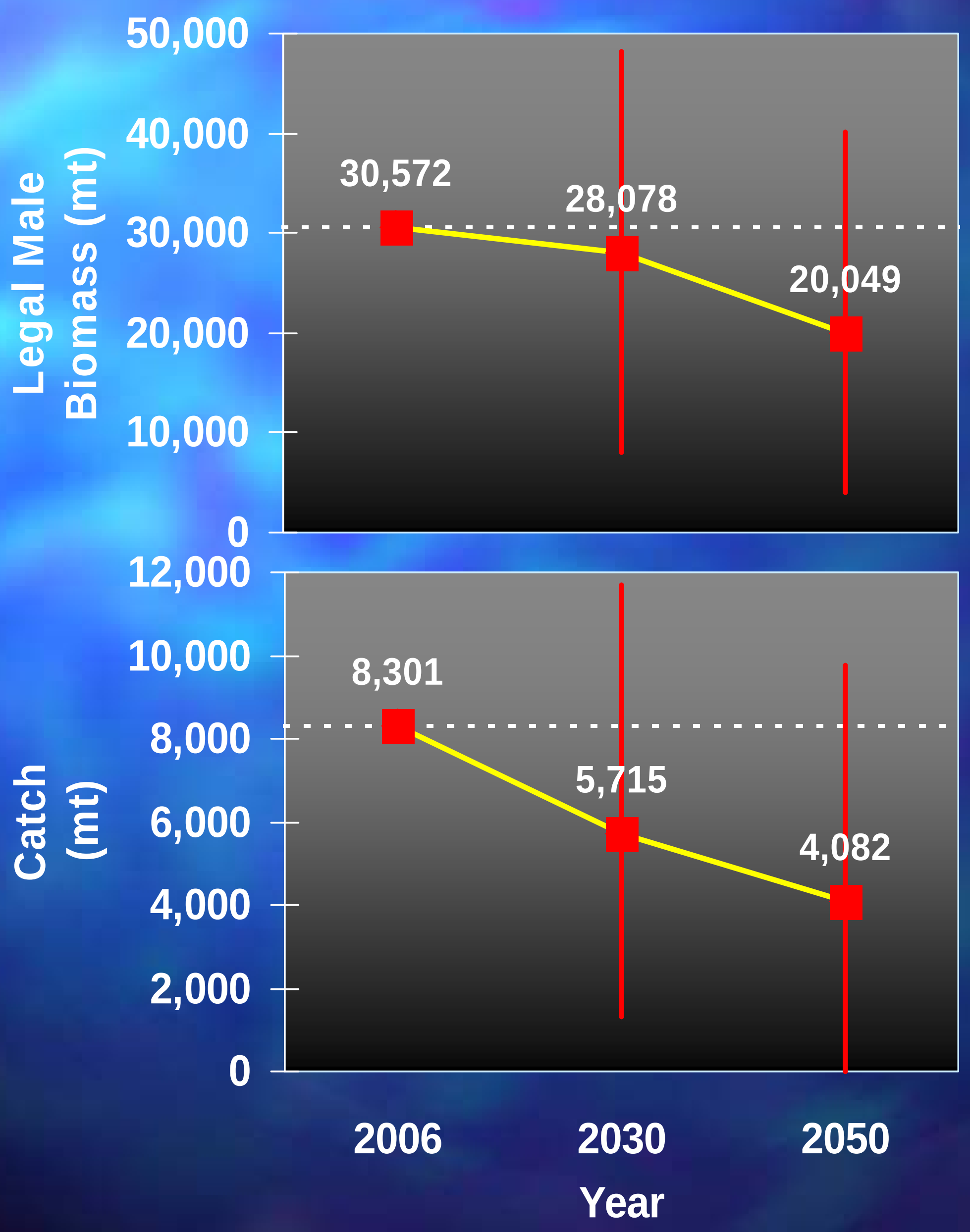
- Sediment oxygen uptake is an indicates carbon supply to the benthos
- Coincident decline in O_2 and benthic biomass in northern Bering Sea
- Decline in benthic biomass may adversely affect crab growth, reproduction and survival

Grebmeier et al. (2006)

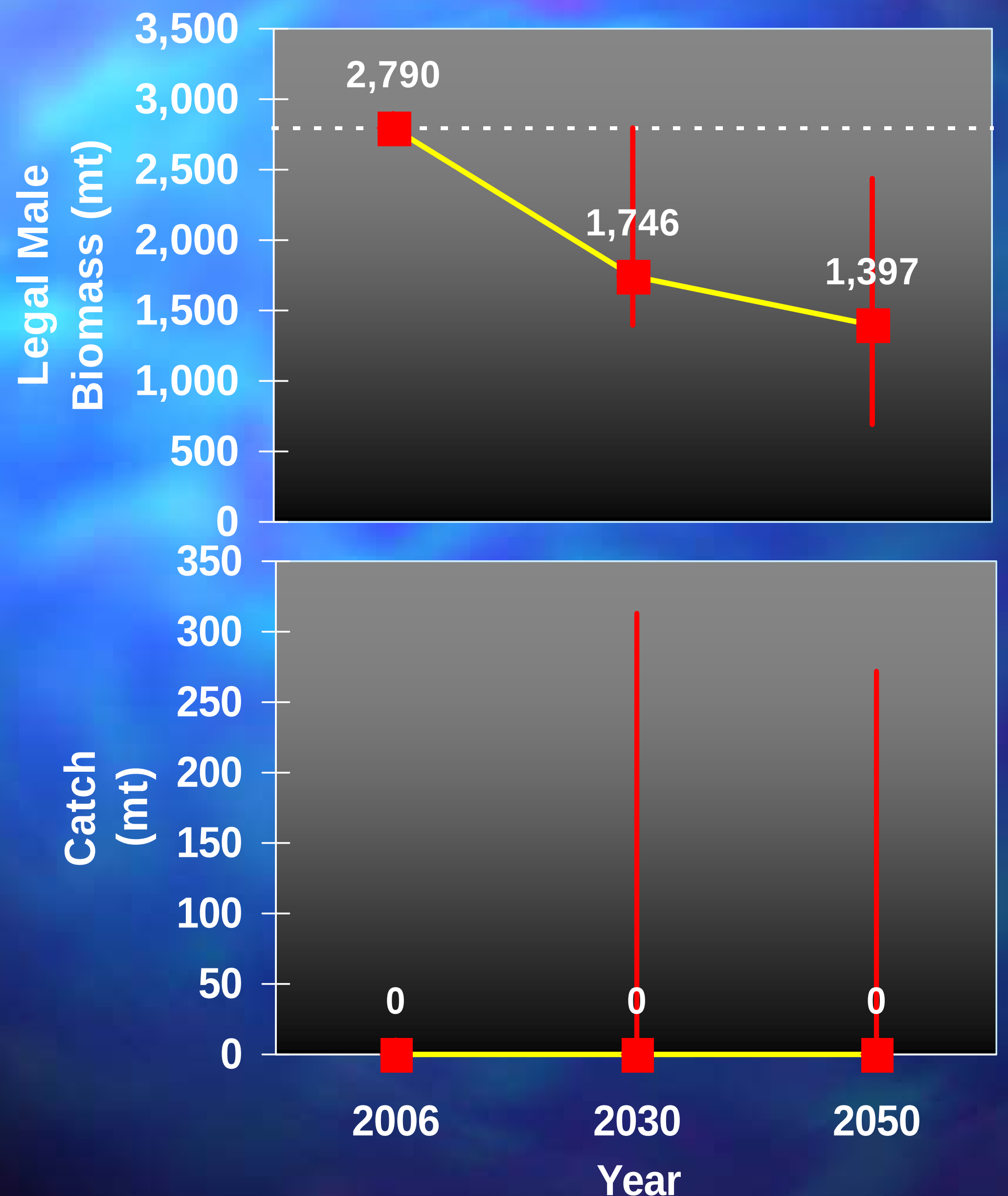
Expected Effects on Benthic Energy Flow

	2030			2050		
Area	L	C	H	L	C	H
Bristol Bay	--	-	0	--	--	-
Pribilof Islands	--	--	-	---	--	--
Norton Sound	--	-	-	---	--	--

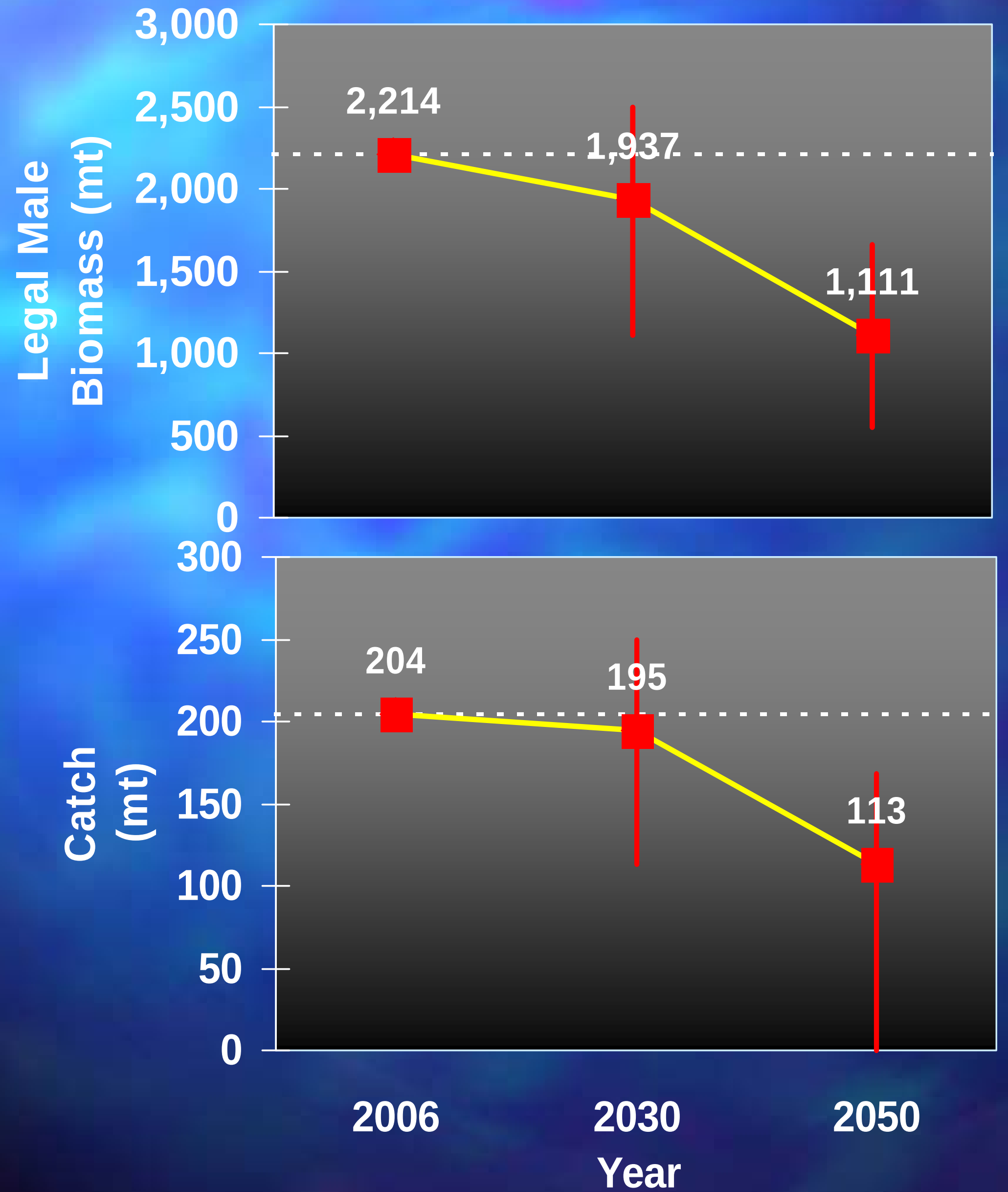
Bristol Bay: Biomass & Catch Projections



Pribilof Is.: Biomass & Catch Projections



Norton Sd.: Biomass & Catch Projections



Summary

- Positive benefits of conservative fishery management and improved match of larval hatch with prey may be overwhelmed by negative effects of adverse larval advection, increased juvenile predation and loss of benthic energy flow.
- Declines are projected for all three stocks, but large uncertainty exists.

Next Steps

- ***Field/laboratory studies and retrospective analyses*** **– to confirm bases for proposed mechanisms linking climate to red king crabs**
- ***Simulation modeling*** **– to quantify cumulative effects of various mechanisms on crab stocks**
- ***Management strategy evaluation*** **– to evaluate effects of climate change on future harvests using current and potential alternative management strategies**


Questions?