A review of Alaska king crab stock enhancement

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North Pacific Fisheries Management Council

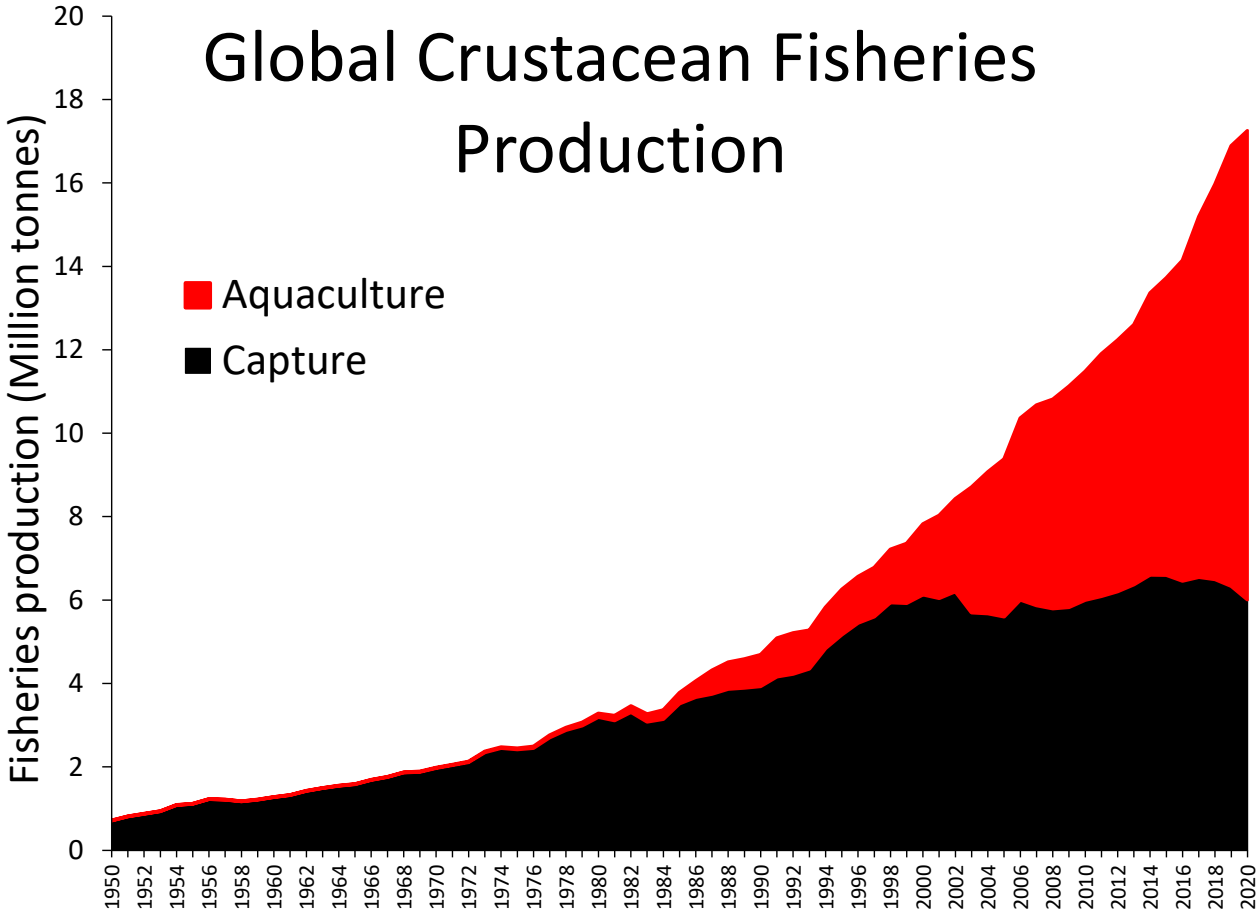
Crab Plan Team meeting

Anchorage, January 10-12, 2024

What is stock enhancement?

The release of cultured juveniles into the wild with the goal to rebuild natural populations by overcoming recruitment limitation and bolstering the spawning stock.

A growing need for enhancement



- Continued aquaculture development needed for global food security
- Most aquaculture production used for direct food consumption
- Improved culture technology enables expansion of fisheries enhancement through the release of cultured juveniles to augment wild populations

Data source: FAO https://www.fao.org/fishery/statistics-query; live weight

Marine crustaceans as candidates for enhancement activities

- High commercial value
- Often recruitment limited
- Accessible to harvest: slow moving, shallow
- High fecundity allows large scale hatchery production
- Low larval survival in wild
  - Bypass some sources of natural mortality via hatchery culture

Stock enhancement advancements and challenges

- The “Responsible Approach” to stock enhancement highlights key components to optimize and help guide developing programs
- Improved culture technology
- Better understanding of ecological competence
  - Plasticity and epigenetics

- Challenges: evaluating success/impacts, addressing genetic consequences, **identifying recruitment limitation**, integrated management

Blankenship, H. L., and Leber, K. M. 1995. A responsible approach to marine stock enhancement. In American Fisheries Society Symposium, American Fisheries Society, Bethesda, Maryland, USA, pp. 167–175.

American lobster

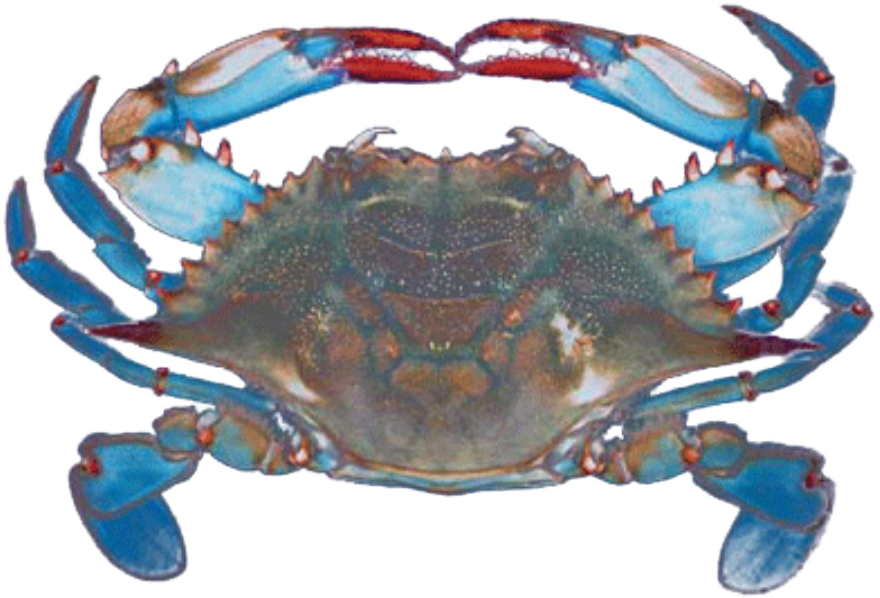
- Hatcheries throughout New England in late 1800s though the mid 1900s
  - Sporadic releases of larvae and juveniles
  - Early 1900s: 200,000–1,000,000 larvae annually
- No evidence to show that enhancement impacted fishery landings
- Uncertainty in recent high commercial landings sparked renewed interest in exploring stock enhancement

Photo credit: Derek Keats

- Recent work on ocean-based nursery grow-out to produce larger juveniles

Chesapeake blue crab

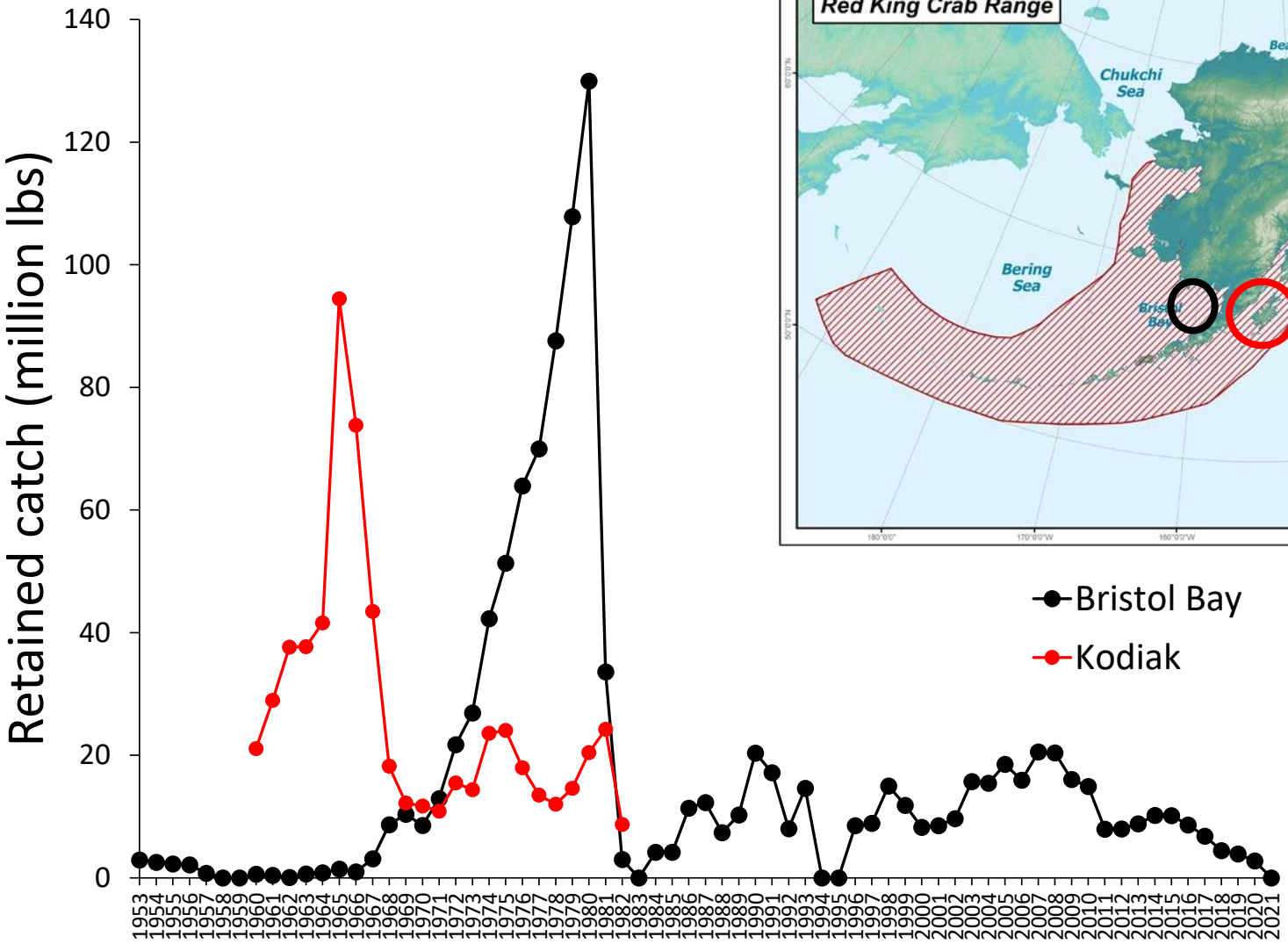
- Dramatic pop. declines starting in 1990s
- Evidence for recruitment limitation
- Blue Crab Advanced Research Consortium (BCARC): aquaculture and hatchery experts, crustacean endocrinologists and pathobiologists, geneticists, and benthic and fishery ecologists
- Multi-year program to assess potential of stock enhancement
- 290,000 cultured juveniles released during 2002-2006



- Evaluated survival, growth, mating success, migration, foraging, predator defense
- Results encouraging for stock enhancement potential

Photo credit: https://dnr.maryland.gov/fisheries/

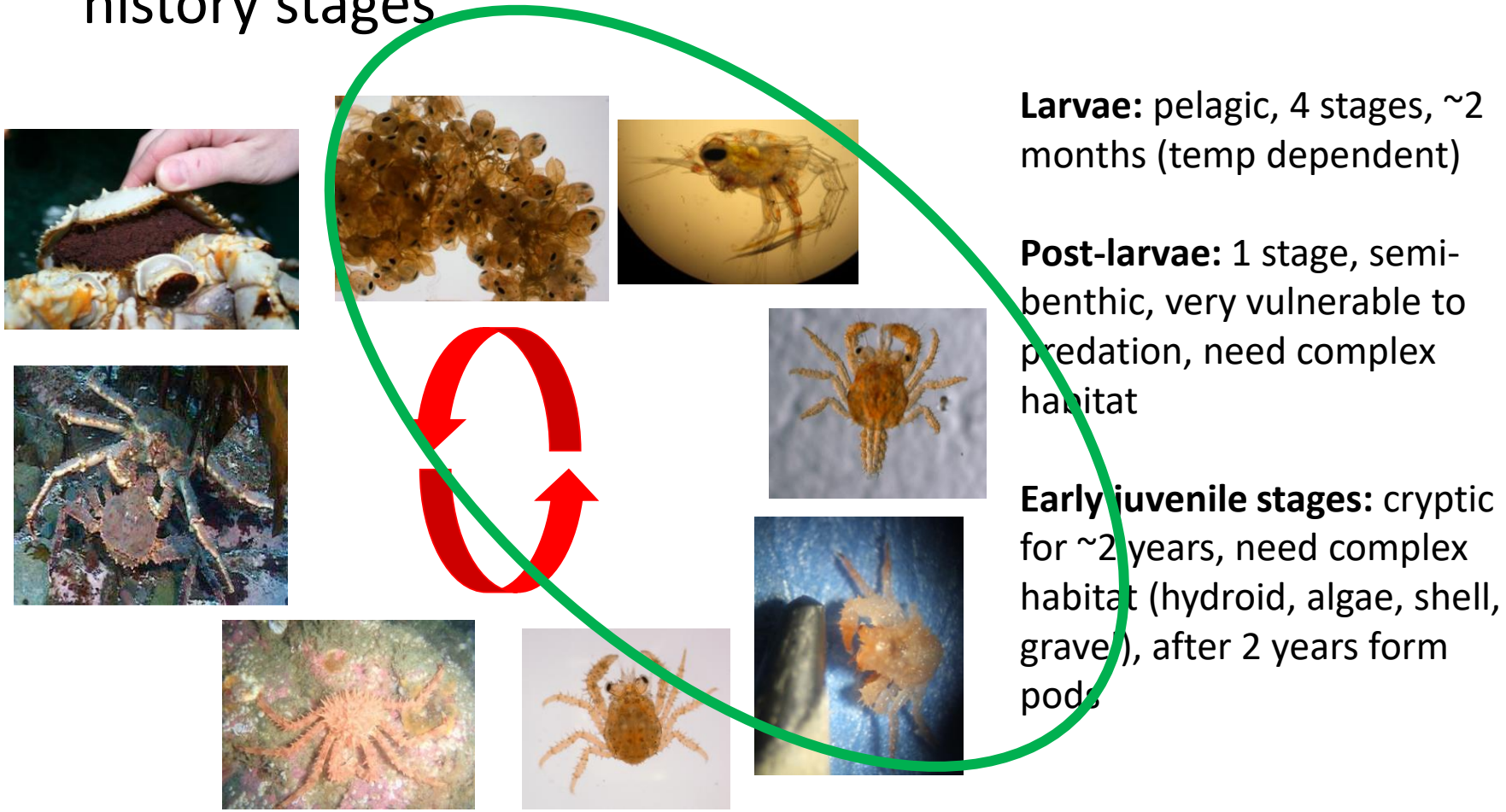
Alaska red king crab*



* blue king crab also candidate

Alaska red king crab

- Thought to be recruitment limited
- Population bottleneck thought to occur in early life history stages



Larvae: pelagic, 4 stages, ~2 months (temp dependent)

Post-larvae: 1 stage, semi-benthic, very vulnerable to predation, need complex habitat

Early juvenile stages: cryptic for ~2 years, need complex habitat (hydroid, algae, shell, gravel), after 2 years form pods

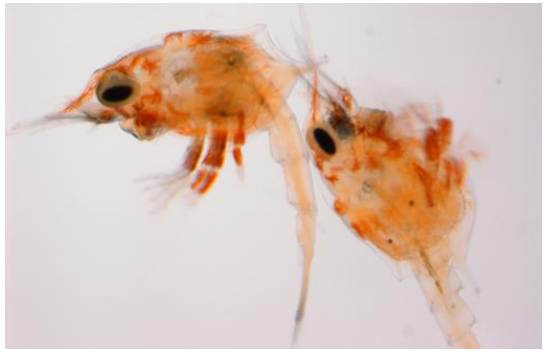
AKCRRAB Program

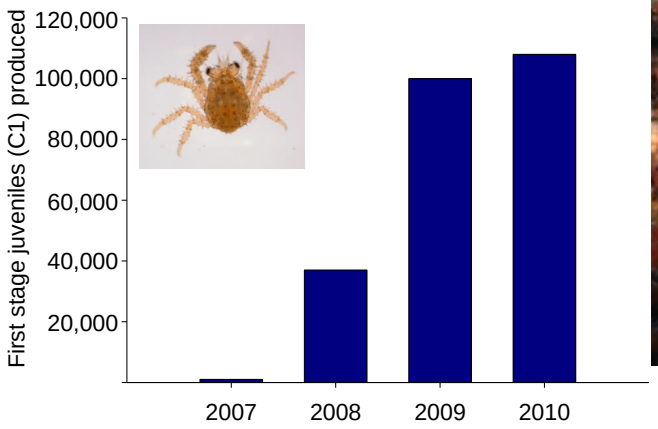
Alaska **K**ing **C**rab **R**esearch **R**ehabilitation and **B**iology

Created in 2006: begin to assess the *feasibility* of stock enhancement for king crabs in Alaska

Hatchery culture:

- Focus on large-scale culture techniques
  - Diets, density, temperature, etc
- ~50% survival from hatch to settling post-larval stage





Swingle et al., 2013. Aquaculture.

Sea Grant ALASKA Research

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Alaska King Crab Research, Rehabilitation and Biology Program (AKCRRAB)

Initiative summary

The Alaska King Crab Research, Rehabilitation and Biology (AKCRRAB) Program is an Alaska Sea Grant partnership with regional fishermen's groups, coastal communities, NOAA Fisheries, the Alutiiq Pride Shellfish Hatchery and Chugach Regional Resources Commission, and the University of Alaska Fairbanks, School of Fisheries and Ocean Sciences, to conduct a research program aimed at hatching and rearing wild red and blue king crabs in a large-scale hatchery setting. This coalition of state, federal, and stakeholder groups views the effort as important to the region's long-term economic development and sustainability.

Mission

To understand the large-scale culturing needs of wild red and blue king crab stocks, and to perfect strategies for hatching and rearing king crab to a stage where they can be released into the wild and contribute to reversing low wild stock abundance in Alaska. Acquiring this knowledge base will aid policymakers in making informed decisions about whether to one day pursue active rehabilitation of depressed wild king crab stocks through hatchery enhancement.

AKCRRAB links

Partners and supporters

Committees

Information

News Flash

News

Graduate students

Presentations, posters, and fact sheets

Photo gallery

Audio and video clips

Links and resources

Research

Scientific publications

Science plans

Strategic plan, 2015–2019 [PDF; 1.6 MB]

Related projects

Archives

News Flash archives

News archives

Science plan archives

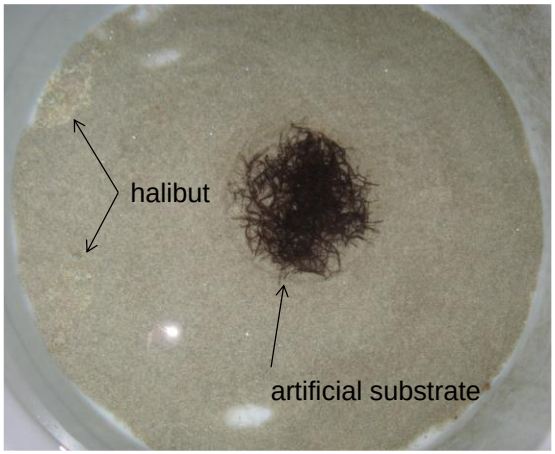
Milestones

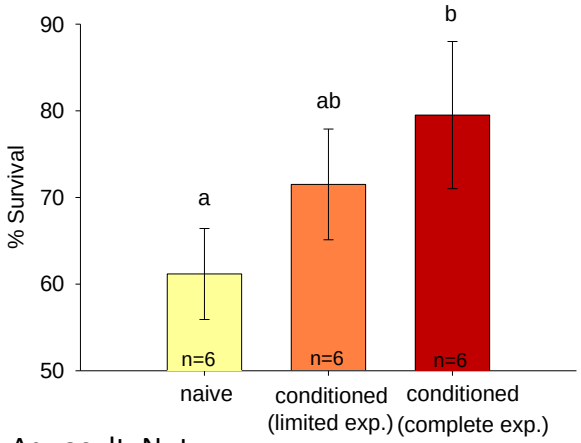
https://seagrant.uaf.edu/research/projects/kingcrab/general/

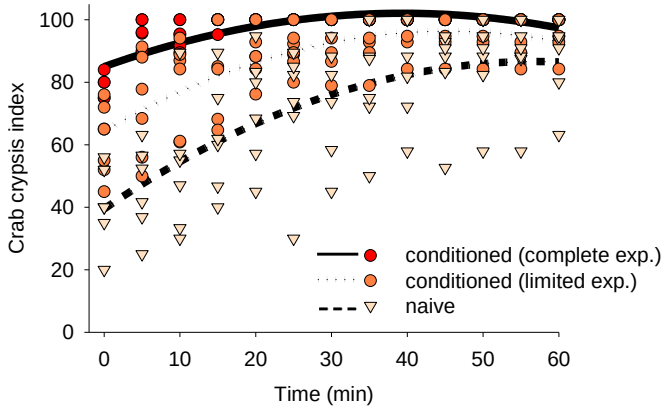
King crab hatchery culture: juveniles

- How can we reduce cannibalism?
  - Substrate, size grading, stocking density, diet, indiv holding
- How can we optimize ecological competence?
  - Demonstrate conditioning potential (predator exposure)

- Dietary supplements (astaxanthin) improves shell coloration



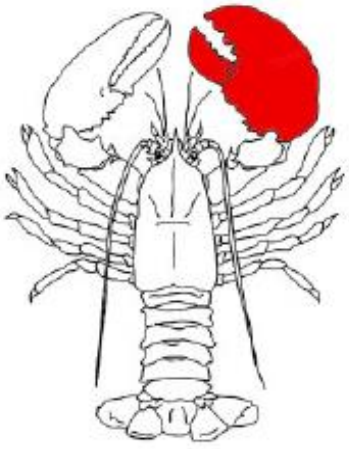




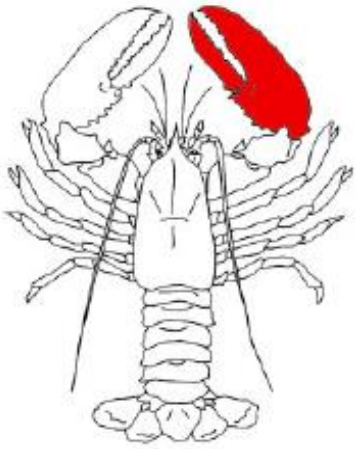
Daly et al., 2009, Aquaculture 2012, JEMBE, 2013 Aquacult. Nut.

Hatchery vs wild

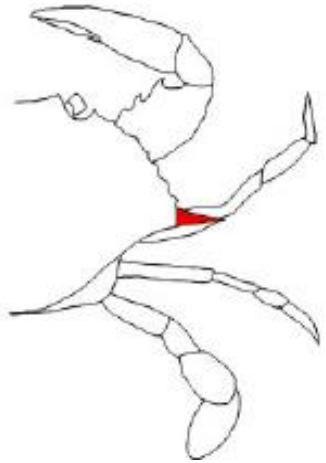
- Hatchery culture seeks to optimize production
  - Often occurs via artificial rearing conditions
  - Trade-off between release size and extended rearing
- How does an unnatural rearing environment impact survival in wild after release?
  - Behavior: predator avoidance, habitat selection, aggression, foraging, migration
  - Morphology: spine/claw size/shape, coloration, growth



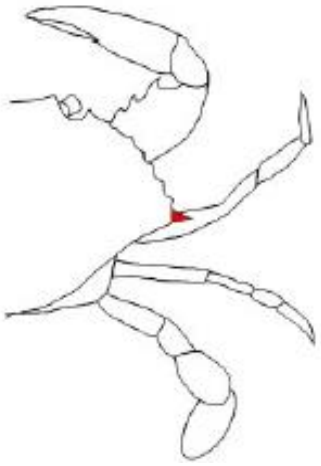
Wild



Cultured



Wild



Cultured

ICES Journal of Marine Science

ICES Journal of Marine Science (2021), 78(1), 421–434. doi:10.1093/icesjms/fsaa043

Contribution to the Themed Section: '*Marine aquaculture in the Anthropocene*'

Food for Thought

Moulding the ideal crab: implications of phenotypic plasticity for crustacean stock enhancement

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Daly, B. J., Eckert, G. L., and Long, W. C. Moulding the ideal crab: implications of phenotypic plasticity for crustacean stock enhancement. – ICES Journal of Marine Science, 78: 421–434.

Received 12 December 2019; revised 20 February 2020; accepted 21 February 2020; advance access publication 10 April 2020.

Numerous examples of behavioural and morphological differences between hatchery-cultured and wild individuals exist for a range of crustacean species; however, we submit that these variances are not deficiencies, but rather are adaptive responses to an unnatural rearing environment that may be detrimental in the natural environment. This phenotypic plasticity could be beneficial for stock enhancement because such plasticity suggests potential for change with adjustments to rearing protocols to achieve improved ecological competence. We examine how specific plastic responses can affect crustacean ecology through effects on predation, foraging, competition, and reproduction. For developing stock enhancement programmes, we recommend consideration of plastic phenotypic patterns before large-scale releases are initiated. Researchers can identify environmental factors that cue plasticity during hatchery rearing, determine if induced responses are ecologically influential after release into the wild, and examine the temporal scale on which phenotypic plasticity operates. Communal hatchery rearing at low-to-medium stocking densities with predator cues and natural substrates along with *in situ* conditioning, releases during periods of low predation risk, and coupled laboratory-field studies can contribute to improved ecological performance during stock enhancement. Finally, presentation of non-significant research results is needed to avoid bias towards hatchery–wild differences and help guide future conditioning programmes.

Keywords: conditioning, ecological competence, phenotypic plasticity, release strategy, stock enhancement

Crustacean phenotypic plasticity

- Are hatchery vs wild differences biologically meaningful?
  - Hatchery-wild differences demonstrates plastic responses to unnatural rearing environment, not inferiority
- For most species, hatchery cultured individuals are reasonably fit for life in the wild
  - Adapt quickly to overcome any detrimental adaptations to unnatural rearing environment
  - Research to determine conditioning needs for target species
- Plasticity implies conditioning potential
  - In captivity: environmental enrichment via natural substrates, diet, predator cues
  - *In situ*: Ocean-based nursery grow-out

Daly et al., 2020. ICES J. Mar. Sci. 78:421–434

Field experiments

- How do we optimize release success?
- Suite of field experiments to address predation risk, release density + timing, movement, habitat, recruitment

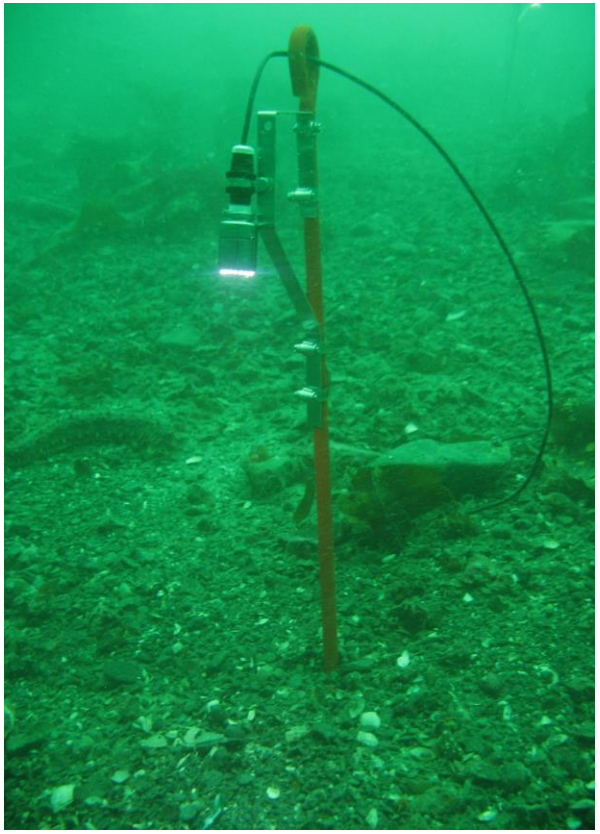
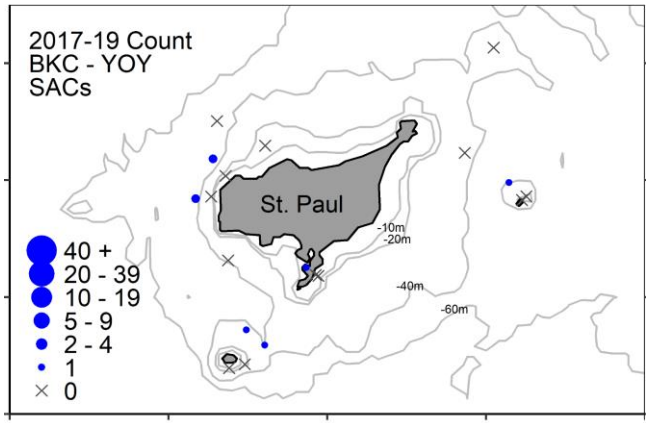


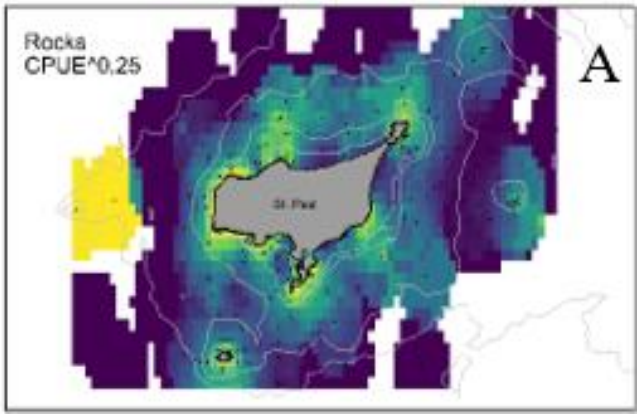
Photo credits: W.C. Long and B. Daly

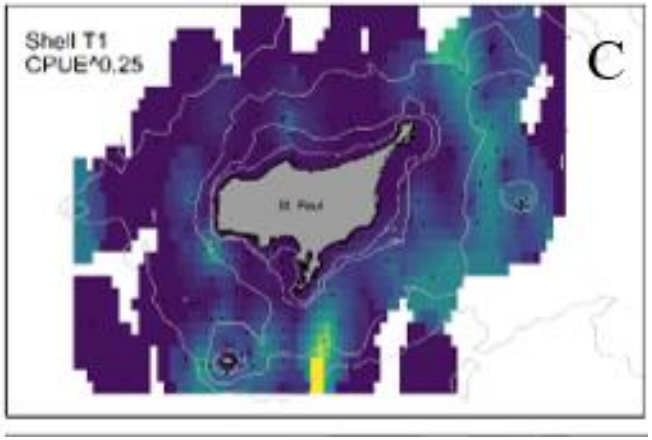
Field experiments[1]

Recruitment limitation

- Very low recently-settled juvenile king crab abundance despite available nursery habitat and low predation rates
- Habitat and predation do not appear to be limiting recruitment
- King crab likely limited by larval supply



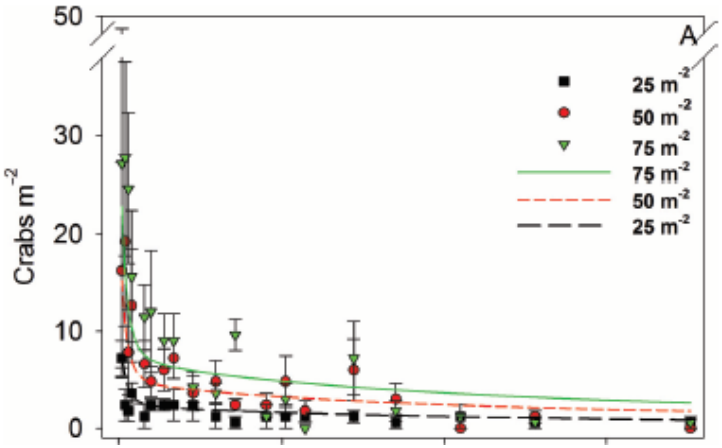


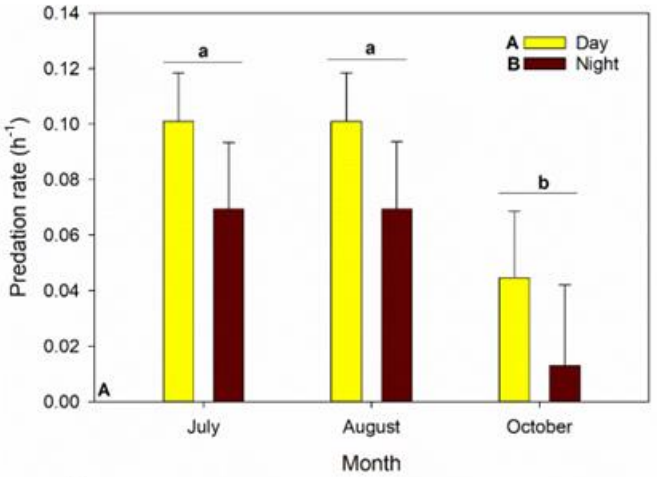


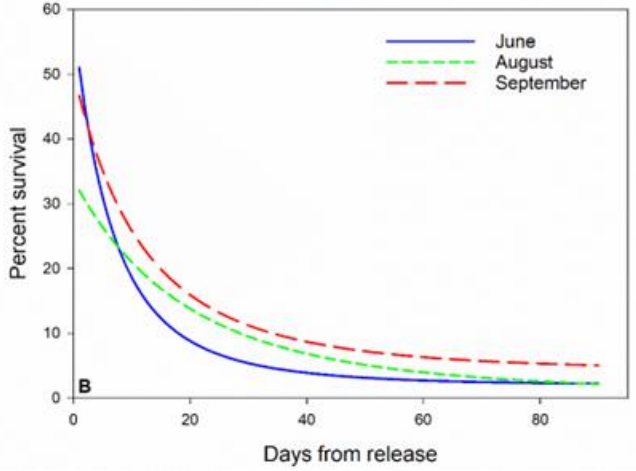
[1] Weems et al. 2020. Pribilof Islands blue king crab (*Paralithodes platypus*) recruitment limitation. NPRB Project 1608 Final Report. 40 pp.

Field experiments[1]

- High initial mortality (~50-70%)
- Lower mortality after
  - Better survival than wild crabs in SE AK[2]
- Crabs emigrate
- Releases can occur at high densities
- Better survival later in season
  - Likely due to larger crab size + improved cryptic behavior
  - Tradeoff: extended hatchery culture = high cannibalism
  - Release at C1 is likely best strategy
- Next steps: increase initial survival
  - Predator exclusion (cages/nets)
  - Improve ecological competence through conditioning







[1] Long et al., 2018. CJFAS. 75:1940-1948.

[2] Loher and Armstrong. 2000. JEMBE. 245:83-109.

Genetics work

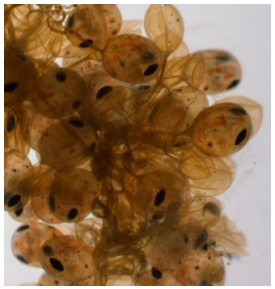
Scott Vulstek (RKC), Jen Stoutamore (BKC)

- **Stock structure**: geographic genetic divergence generally supports current management
  - Strong genetic differentiation within areas of SE AK
- **Mating system**: broods have single paternity
  - Unsurprising given female inability to store sperm and male mate-guarding
  - Implications for number broodstock needed for enhancement activities
    - More ovigerous females needed to achieve a given level of genetic variability than would be needed with multiple paternity

Integrated Management

- Programs must focus attention on development of supporting management in addition to large-scale production technology
  - E.g., Essential juvenile nursery habitat must be conserved for released individuals to survive and ultimately contribute to wild stocks

- Stakeholder involvement is needed





Crustacean stock enhancement potential

- Guided by science
- Understanding of basic biology, ecology, and life cycle of target species
- **Recruitment limitation must be the basis**
- Adoption of the responsible approach
- Ability to evaluate success
- Genetic considerations: local broodstock, wild mated, minimum number of parents, broodstock not re-used
- Integrated management strategies
- Economic feasibility of large-scale production

Recent State of Alaska legislation

House Bill 41 signed into law July 8, 2022

Creates a regulatory framework with which the Department of Fish and Game can manage shellfish enhancement projects, and outlines criteria for the issuance of permits. It sets out stringent safety standards to ensure sustainability and health of existing natural stocks. The Commissioner of Alaska Department of Fish and Game must also make a determination of substantial public benefit before a project can proceed.

House Bill 41

Chapter 12. Shellfish Enhancement Projects.

Sec. 16.12.010. Permits for shellfish enhancement projects. (a) Subject to the restrictions imposed by statute or regulation under this chapter, the commissioner may issue a permit to a nonprofit corporation organized under AS 10.20 for a project to

(1) augment the yield and harvest of shellfish indigenous to state water above naturally occurring levels by natural, artificial, or semiartificial production systems;

(2) rehabilitate a shellfish stock that is indigenous to state water by restoring it to its natural levels of productivity; or

(3) increase the area of productive natural shellfish habitat.

Senator Murkowski FY24 Appropriations Bill

FY24 Commerce, Justice, Science and Related Agencies (CJS) Appropriations Bill includes request for **$4 million** to the Alaska Fisheries Development Foundation to conduct **research on Bristol Bay red king crab enhancement**, including optimum rearing conditions, habitat, growth, and survival through rearing stages and post release.

Congress has not passed the budget: it could get removed during the budgeting process

- We don't know what will happen

Weems et al, NPRB project # 2308

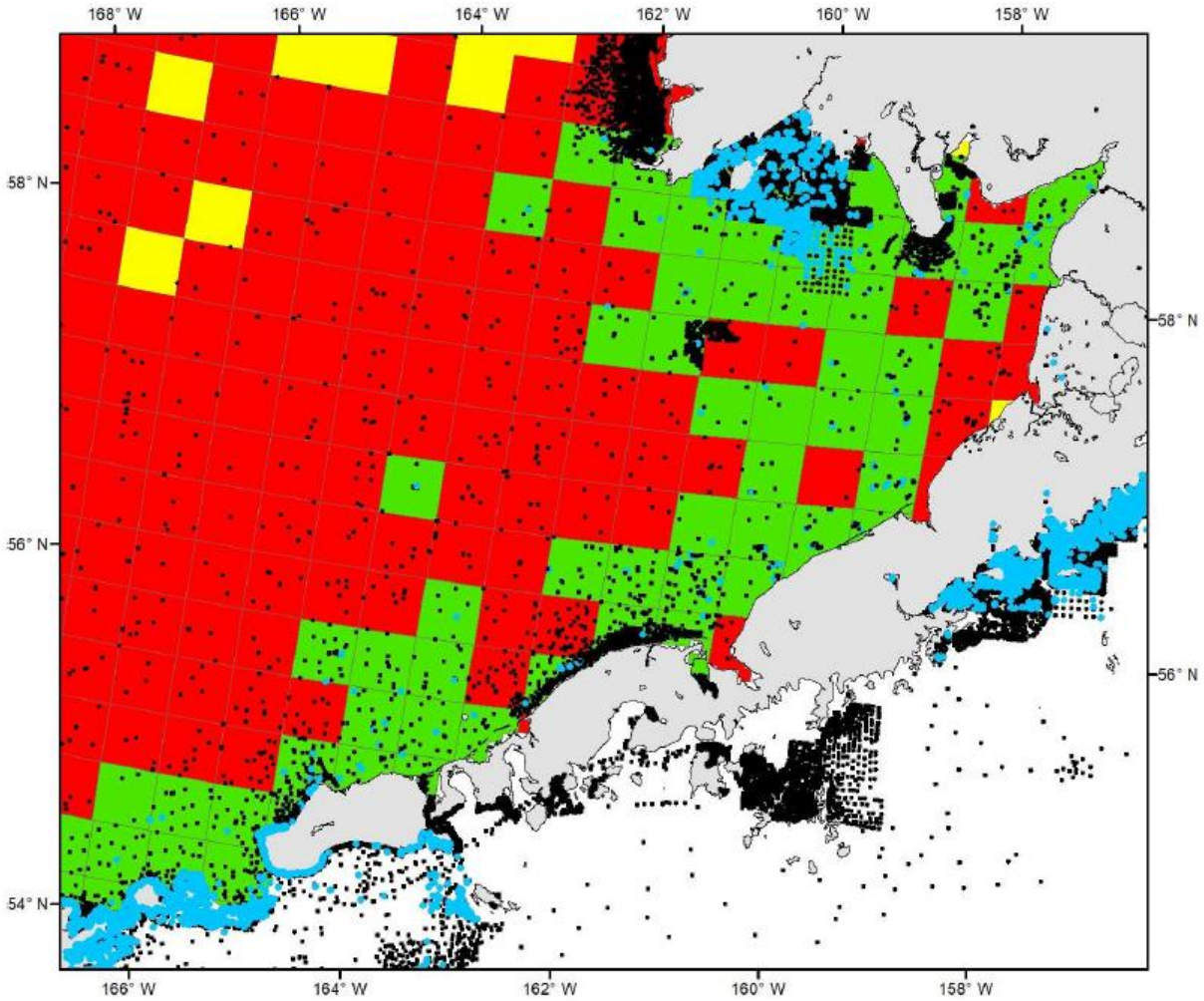
Title: "Bristol Bay red king crab post-larval settlement habitat and supply: understanding early life population bottlenecks"

Objective 1: Quantify the spatial extent of post-larval red king crab benthic habitat throughout Bristol Bay using high resolution benthic camera sled

Objective 2: Quantify red king crab post-larval supply throughout Bristol Bay using artificial collectors

Link to stock enhancement: will help determine if BBRKC is a good candidate for stock enhancement by informing whether recruitment is limited by larval supply

Settlement habitat and larval supply



Coarse-level understanding of good RKC settlement habitat

Larval supply in good habitat areas is unknown

This is a key aspect to characterizing recruitment limitation

Thank you!