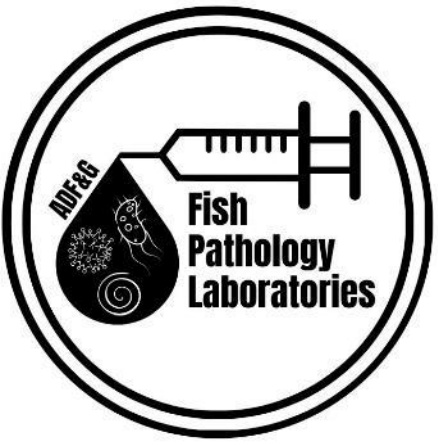
"Weak meat" in Alaska weathervane scallops due to the apicomplexan protist *Merocystis kathae*

Jayde A. Ferguson, Ph.D.

ADF&G Statewide Fish Pathology Program



Protecting Alaska's Finfish & Shellfish Resources from Diseases

Alaska Fish & Shellfish Health Program: Mission

- Monitor & control fish & shellfish diseases statewide
  - Title 16 Alaska Statutes
- Conduct diagnostic examinations
- Develop disease policies
- Advise ADF&G Commissioner & other state & federal authorities on fish disease issues

Protecting Alaska's Finfish & Shellfish Resources from Diseases

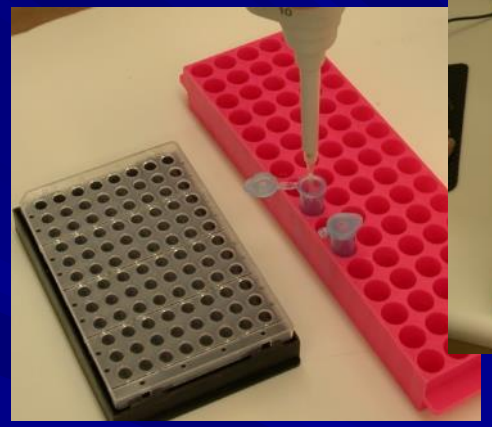
Facilities and Staff

- Diagnostic labs in Anchorage and Juneau
- 2 fish pathologists, 3 microbiologists
- Staff experienced & trained in microbiology, fish & shellfish health & veterinary medicine
- Fish Pathologists certified by the AFS-FHS

Functions

- Diagnostic testing
- Hatchery support
- Fish & shellfish disease management
  - Title 16, Alaska Statute
- Research
- Public education

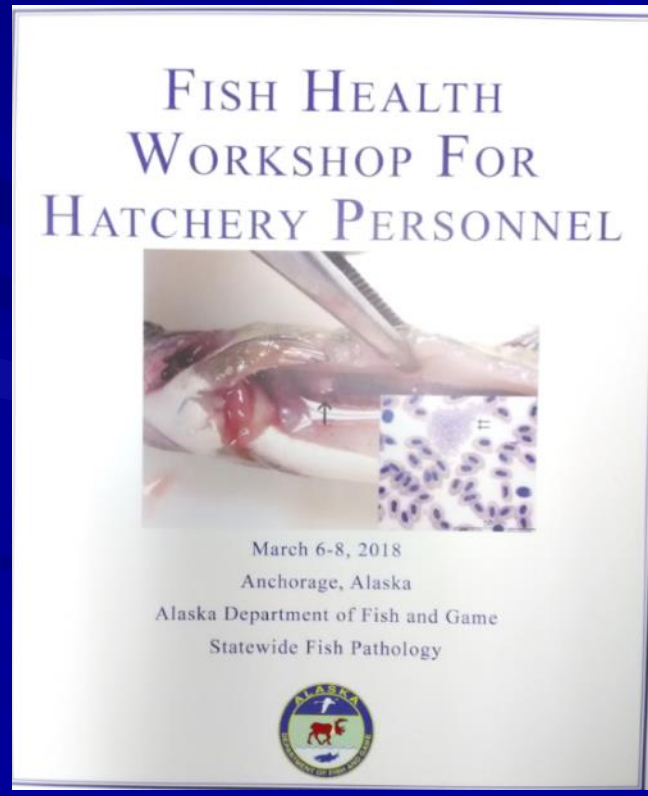
Diagnostic Testing



- Diagnostic services- wild & hatchery fish & shellfish for all user groups
- Perform examinations for infectious and non-infectious diseases
- Evaluate mortality and recommend treatments

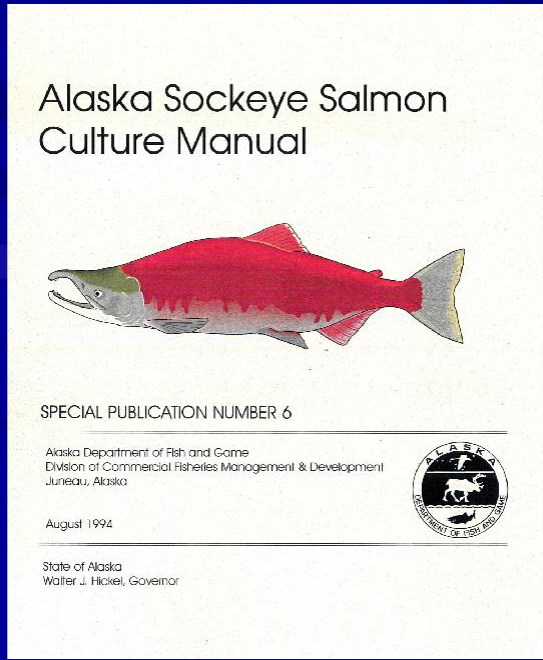
Hatchery Support

- Supervise fish health activities at 30 fish & 2 shellfish hatcheries
- Conduct hatchery inspections
- Diagnose fish diseases, recommend preventive measures & treatments
- Assist in field sampling
- Conduct workshops & training for hatchery personnel



Disease Management

- Compile statewide disease history database
- Review finfish and shellfish transport permits
- Conduct disease screening of parent fish used in hatchery programs
- Develop finfish & shellfish disease policies
  - E.g., sockeye culture policy for IHN
- Disease certification Pacific oyster stocks for importation into Alaska



Research

- Disease transmission studies using on-site wetlab facilities
- Determine susceptibility of fish to different pathogens
- Describe and characterize new disease agents
- Evaluate new techniques for the detection of disease organisms
- Distribution surveys of disease agents in finfish and shellfish stocks statewide

Education & Outreach

- Provide info on fish & shellfish abnormalities to fishers & general public
- Conduct laboratory tours to elementary through college-level students
- Support local schools with science fair activities
- Publish research results in peer review journals

Alaska Scallop Fishery

- Weathervane scallops – biggest species
  - Northern California to Bering Sea
- Commercial fishery – only Alaska
  - ⬆1960's E. US vessels due to declines sea scallops
  - 1970's overharvest = better regulation 1980's
  - Stabilized, but general decline in landings

Alaska Scallop Fishery

- State & federal managed –
  - limit entry, area/season quotas, gear/crew restrict, bycatch limit, observer program, & area close
- Well managed, but declines- unknown cause
  - Kamishak Bay 2002 ⬇ catch/unit effort & ⬆ "cluckers"
  - Fisherman report "weak meats"

What are “weak meat” scallops?

- Muscle brownish coloration, stringy texture

- Slip off shell with viscera/tear when shucked

Ripped Meats

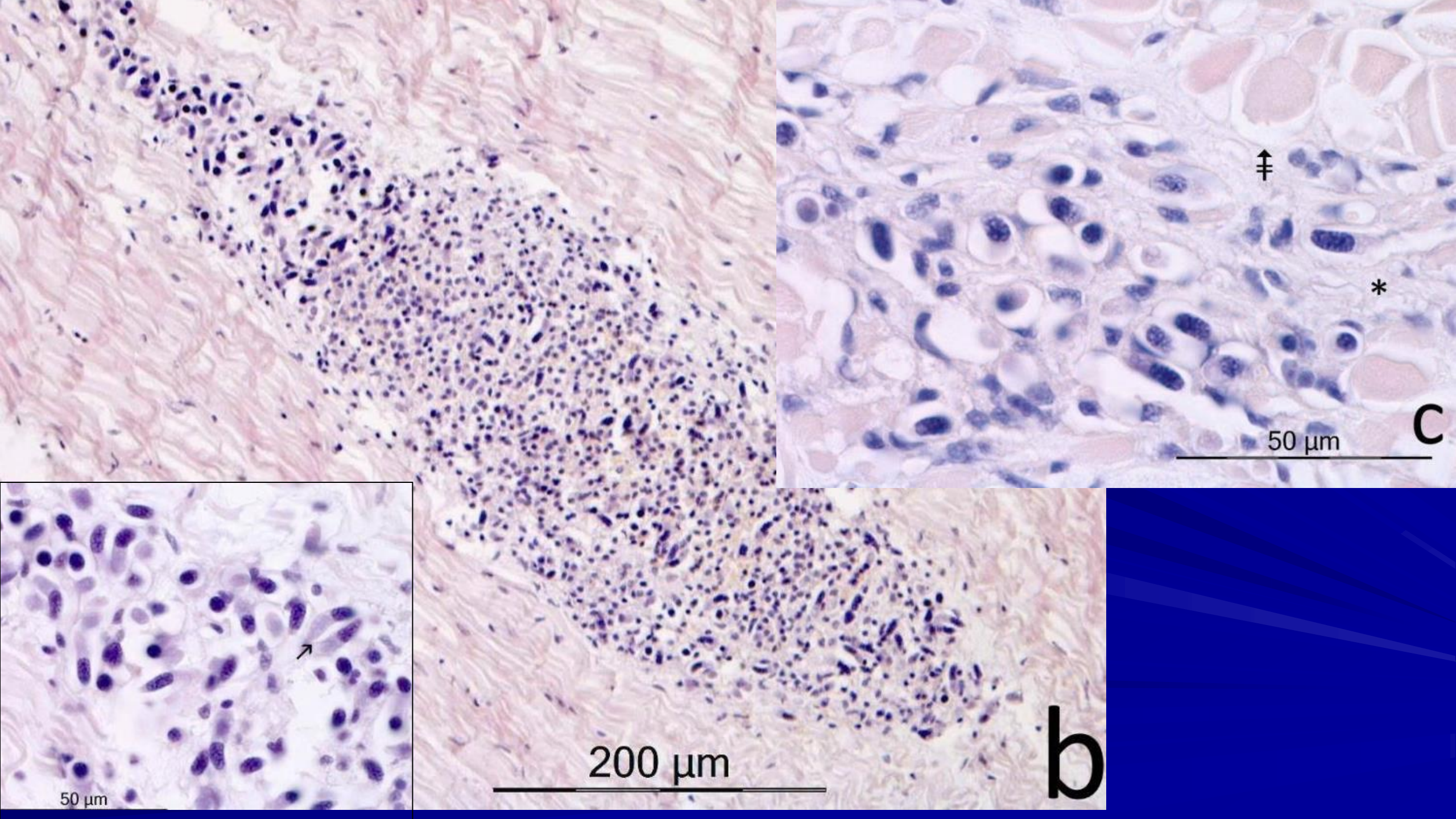
Viscera Meats

Previous “weak meat” investigations

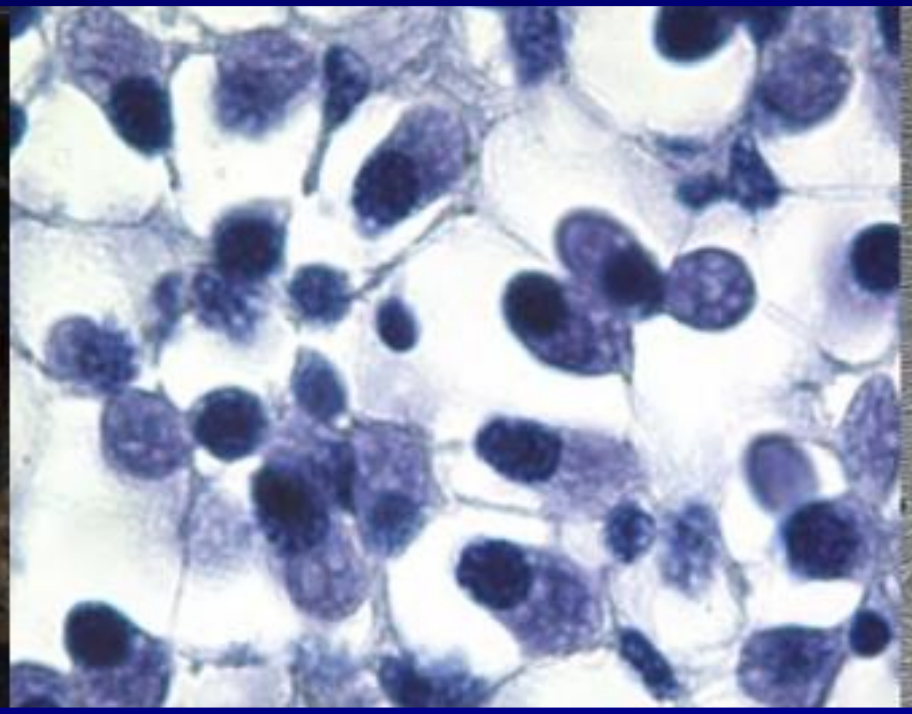
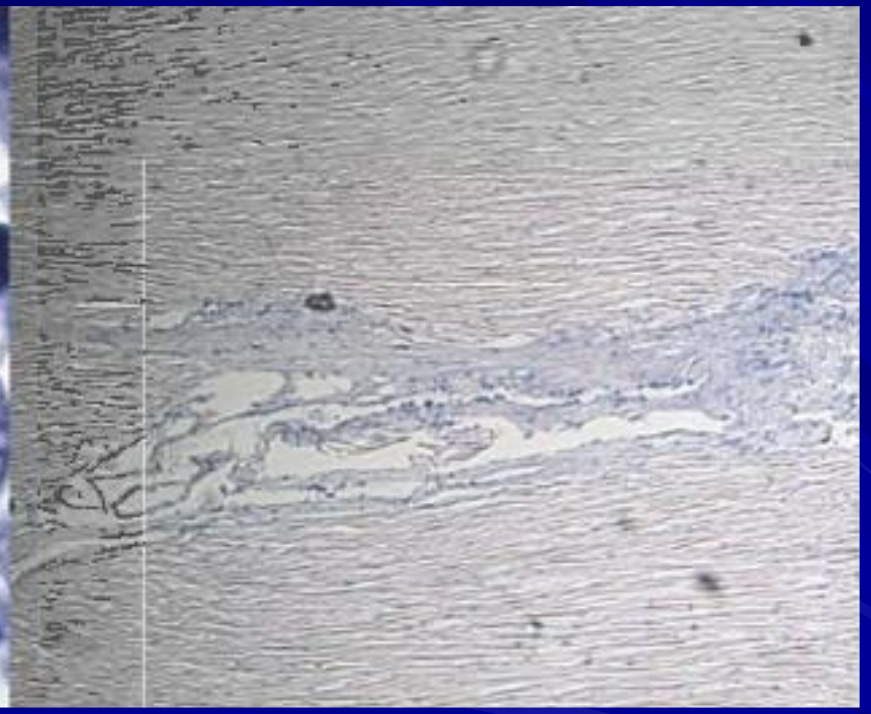
- Food quality tests, nutrition stress (Brenner et al. 2012)
- Similar syndrome “gray meat” E. US & Canada
  - 1st Bay of Fundy, 1936; senescence (Stevenson 1936)
  - Parasite burden
    - Chronic boring sponge (*Clinoa*) infest (Medcof 1949)
    - Rickettsia-like-organism = RLO (Gulka et al. 1983)
    - Synergy shell borer, RLO, senescence (Stokesbury et al. 2007)

Case study

- Jan. 2015 fisherman Bering Sea “weak meat”
- Live & formalin fixed samples submitted
- Full necropsy, histopath, & virology
- Results
  - Negative for virus, ciliates in gill wet mounts, muscle squashes unremarkable
  - Massive, disseminated apicomplexan infection and severe tissue changes


50 µm
c
200 µm
b
50 µm

Looked familiar – Intl. Symp. Aquat. Anim. Health 2014

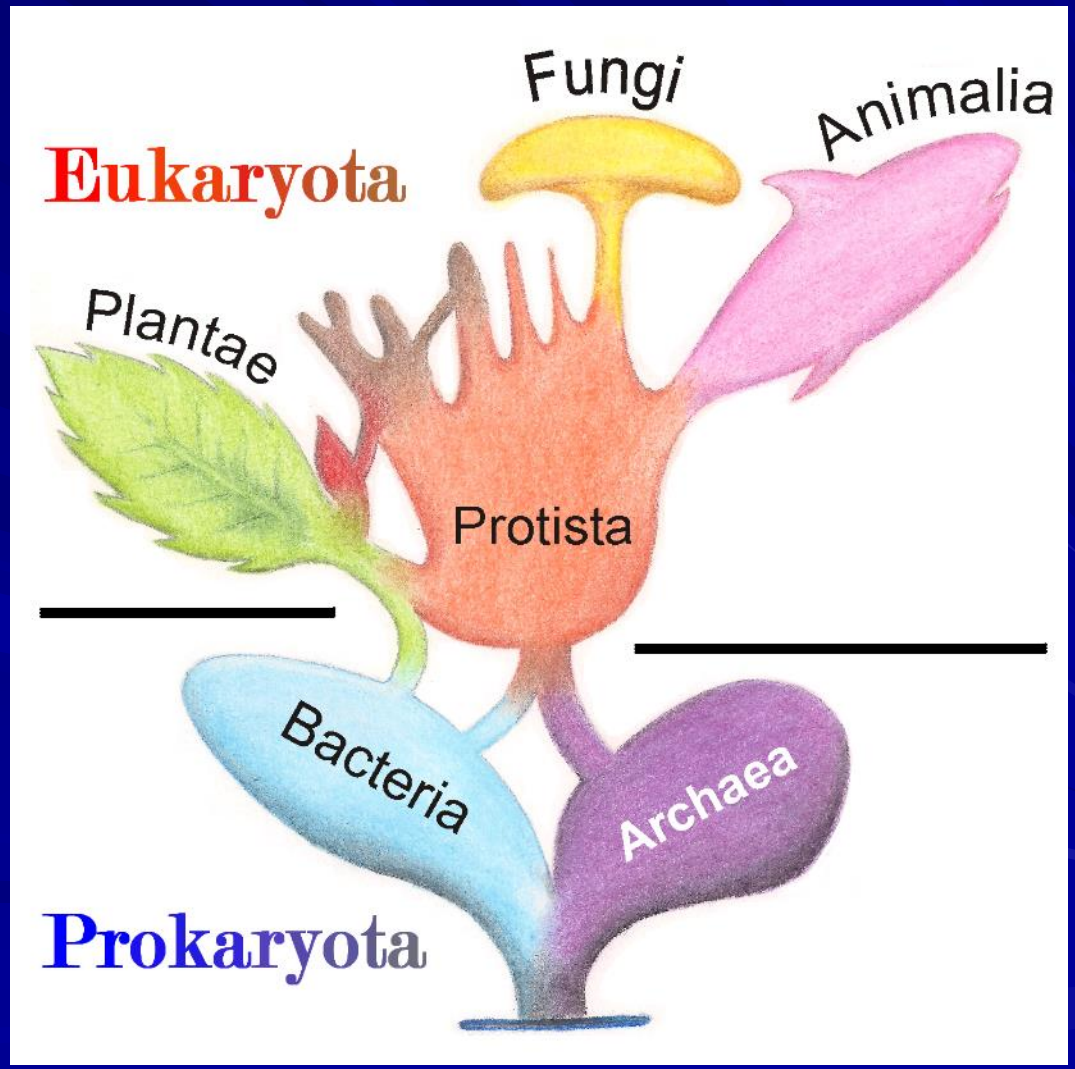




Apicomplexan infection of Atlantic sea scallop

Kristmundsson, Inglis, Stokesbury, Freeman

Merocystis kathae - protist

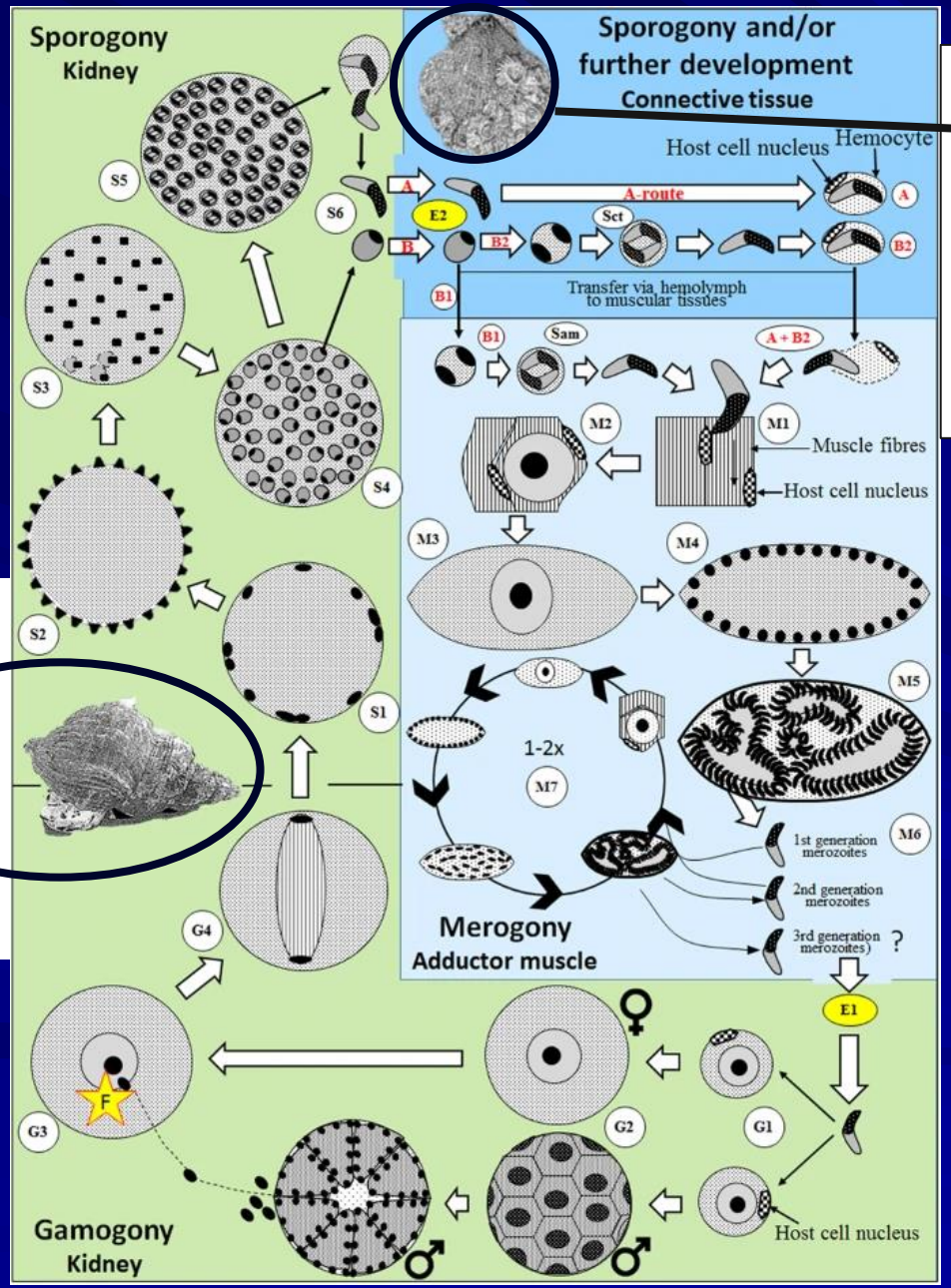
- ***Prot***ists:
  - ***Proto*** = original or primitive
  - Not animals, plants, or fungi but may share characteristics



Merocystis kathae - lifecycle

Scallop (intermediate host = asexual reproduction)

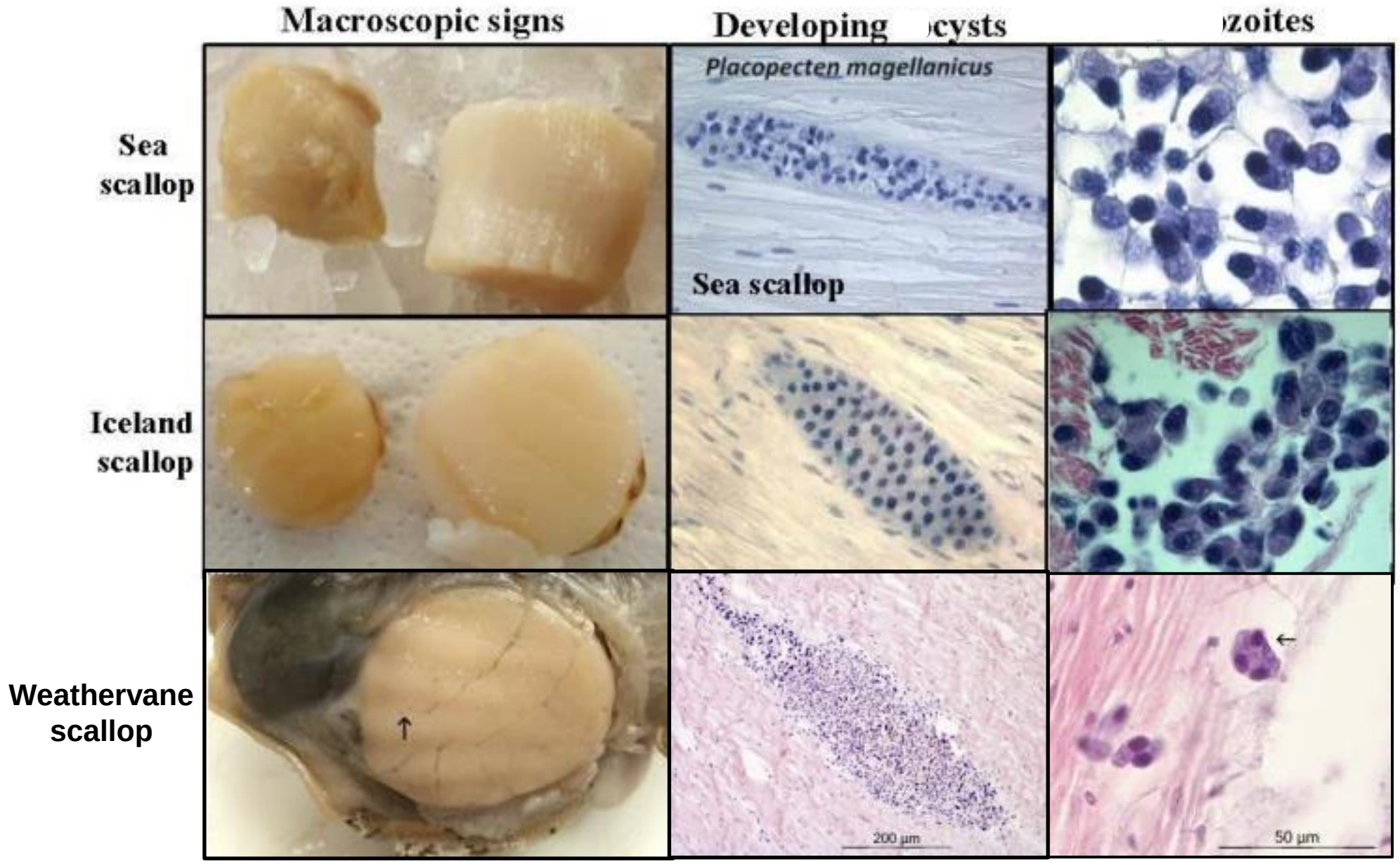
Whelk (definitive host = sexual reproduction)



Eastern Scallop Parasite Story

- "Gray meat" - like weak meat, but called gray
- Iceland scallops – gray meat & mass mortality associated with heavy pathogenic apicomplexan infection
  - Related to coccidian *Aggregata* (Kristmundsson 2015)
  - Parasite found in declining stock of gray meat sea scallops in E. US; confirmed DNA seq. (Inglis 2016)

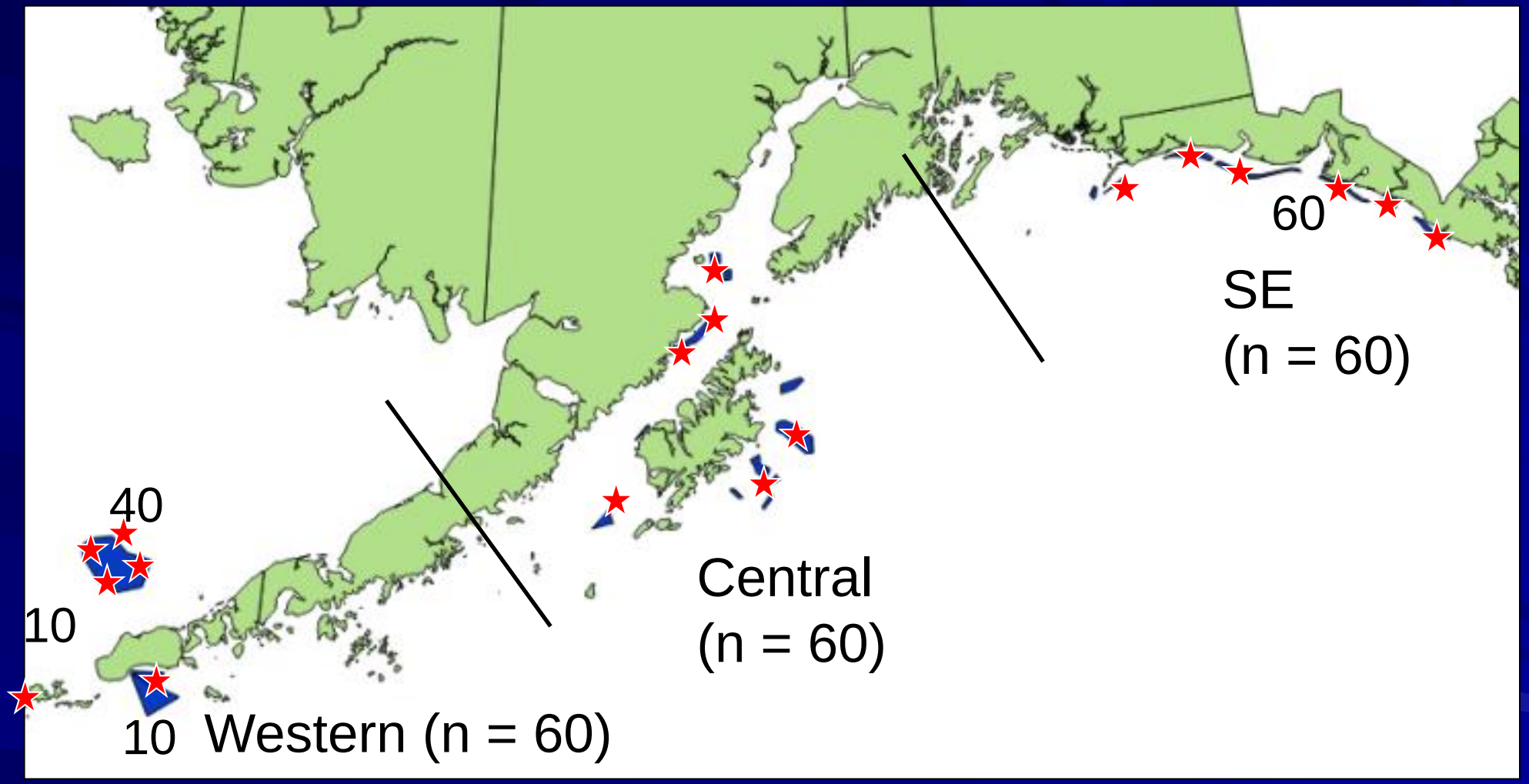
Similarities



Scallop Apicomplexan Survey

- Product quality issue- statewide surveillance
  - prevalence & geographic distribution; 2015
- 180 scallops collected observer program
  - regions biologically differ currents & habitats
  - formalin fixed (histo) and ethanol (DNA testing)
- Data collected –
  - catch data, shell ht, sex, %/intensity infest *Polydora*, intensity parasite (foci/section)

Scallop Apicomplexan Survey

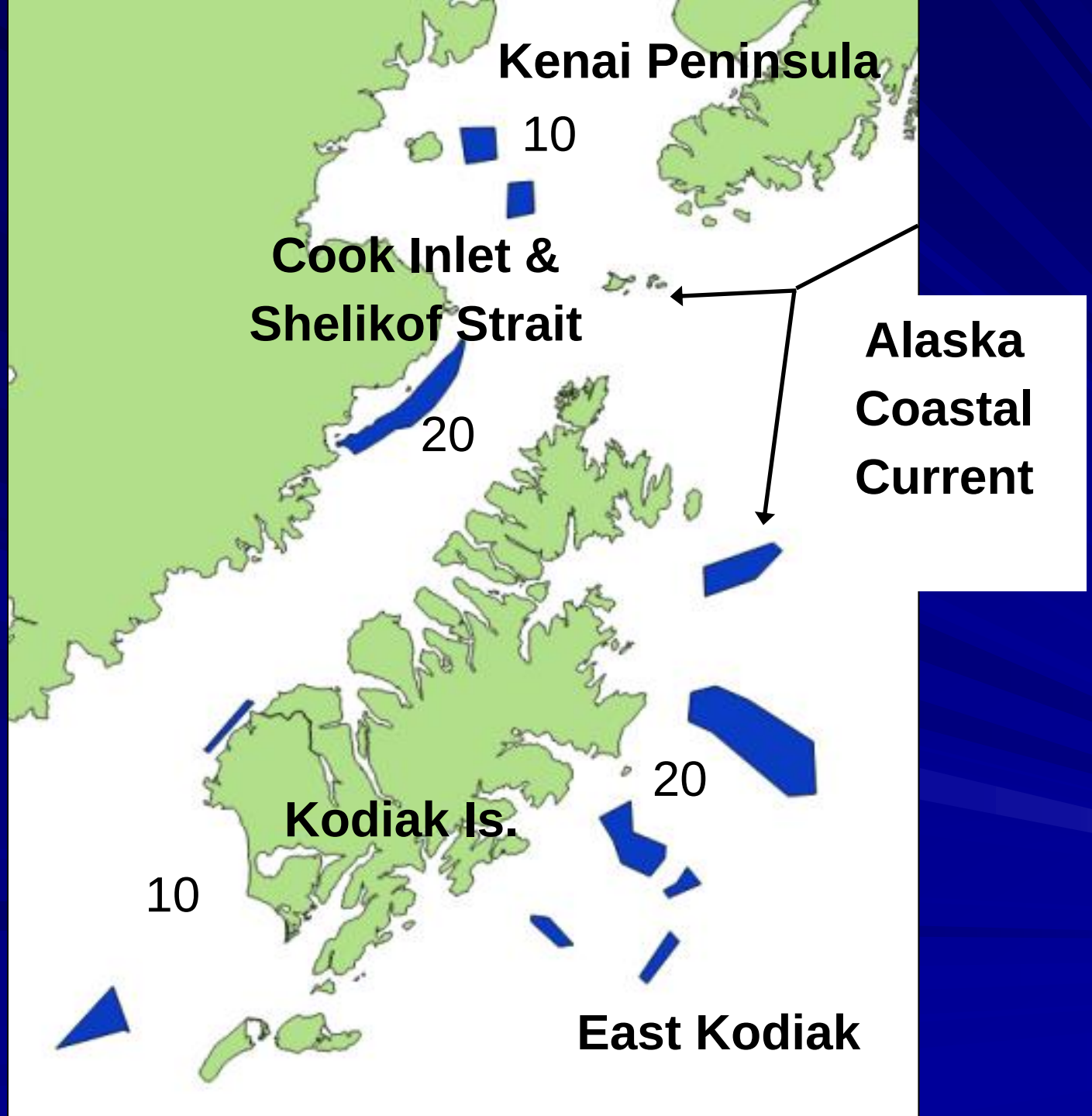


Large area; subsampled regions with beds unlikely to be biologically connected- currents, habitats

Cook/Shelikof & E. Kodiak –

unlikely biologically connected

1) AK Coastal Current splits
2) Different habitats



Scallop Apicomplexan Survey

- Clinical signs
  - 2 “weak meat” coloration (Kamishak Bay)
  - 1 Slipped off shell with viscera (Bering Sea)

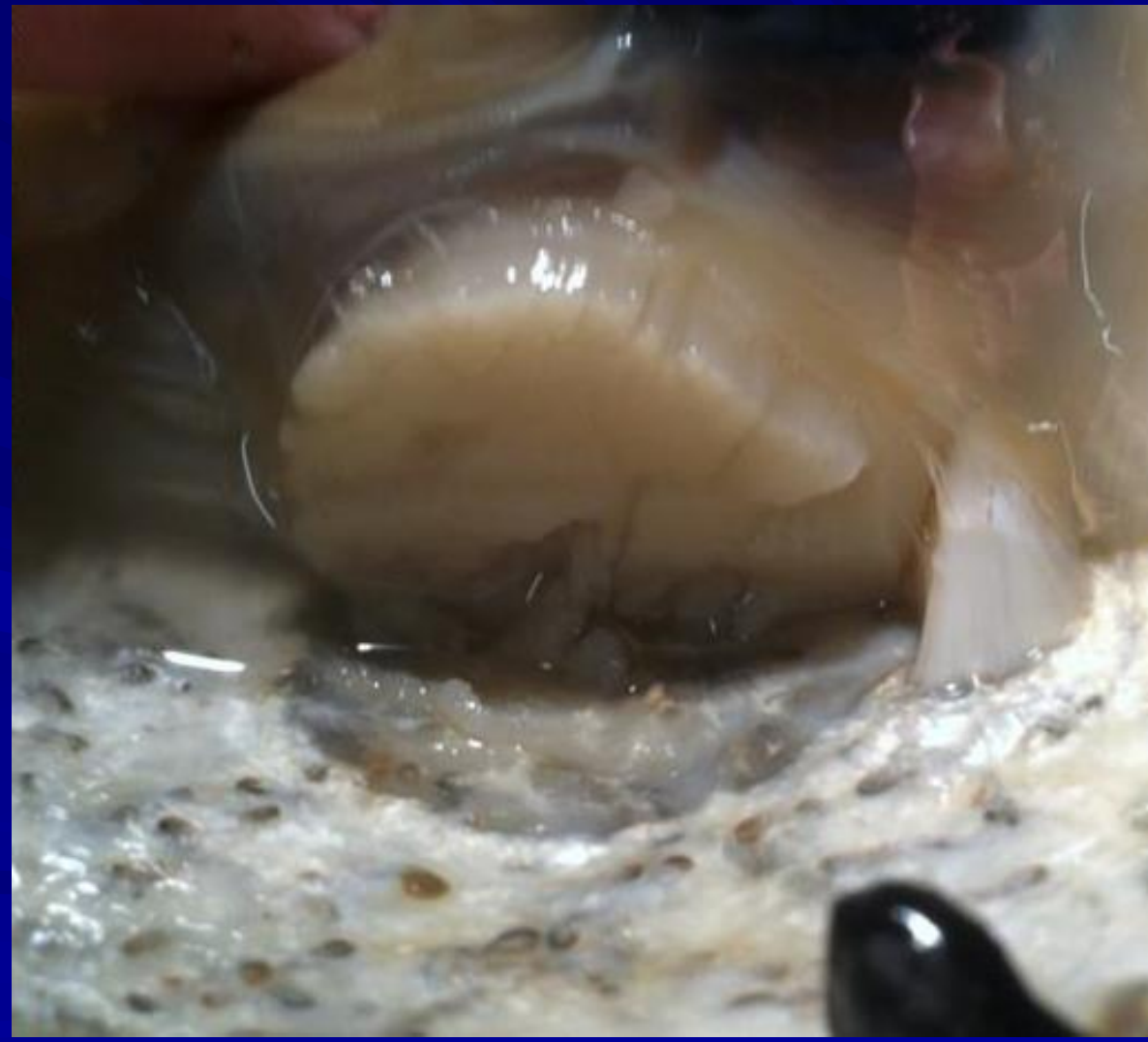
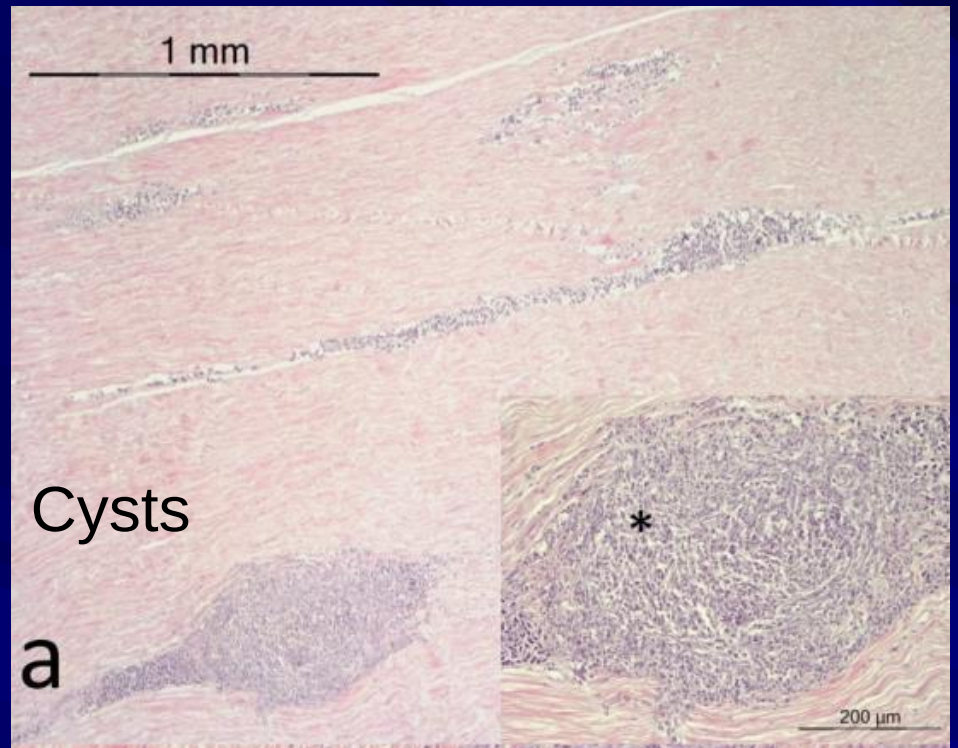
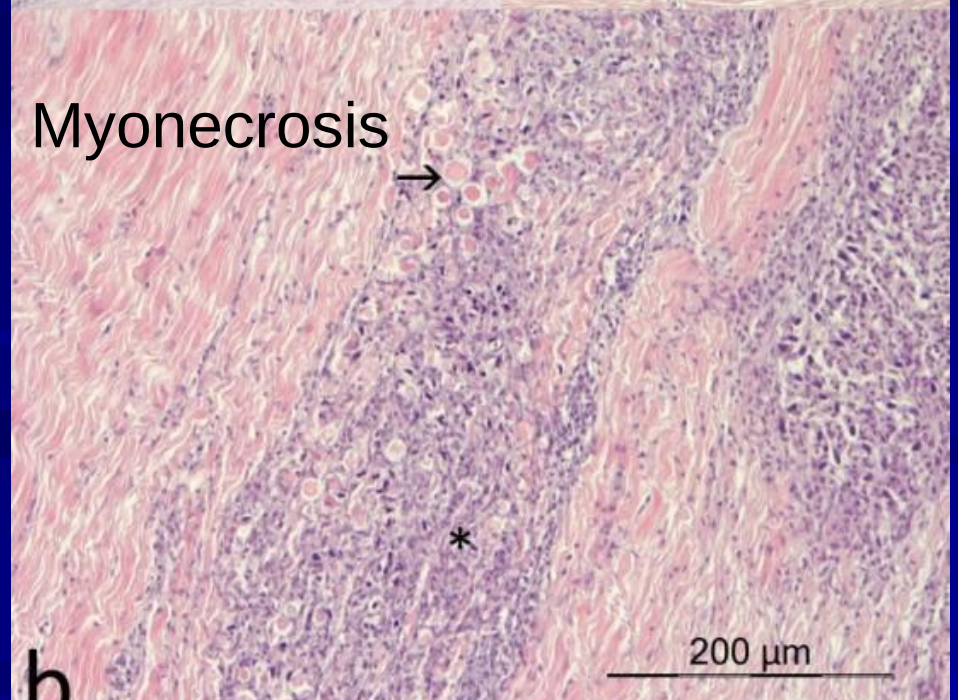


Photo: S. Inglis


1 mm
Cysts
a
*
200 µm


Myonecrosis
*
200 µm
b

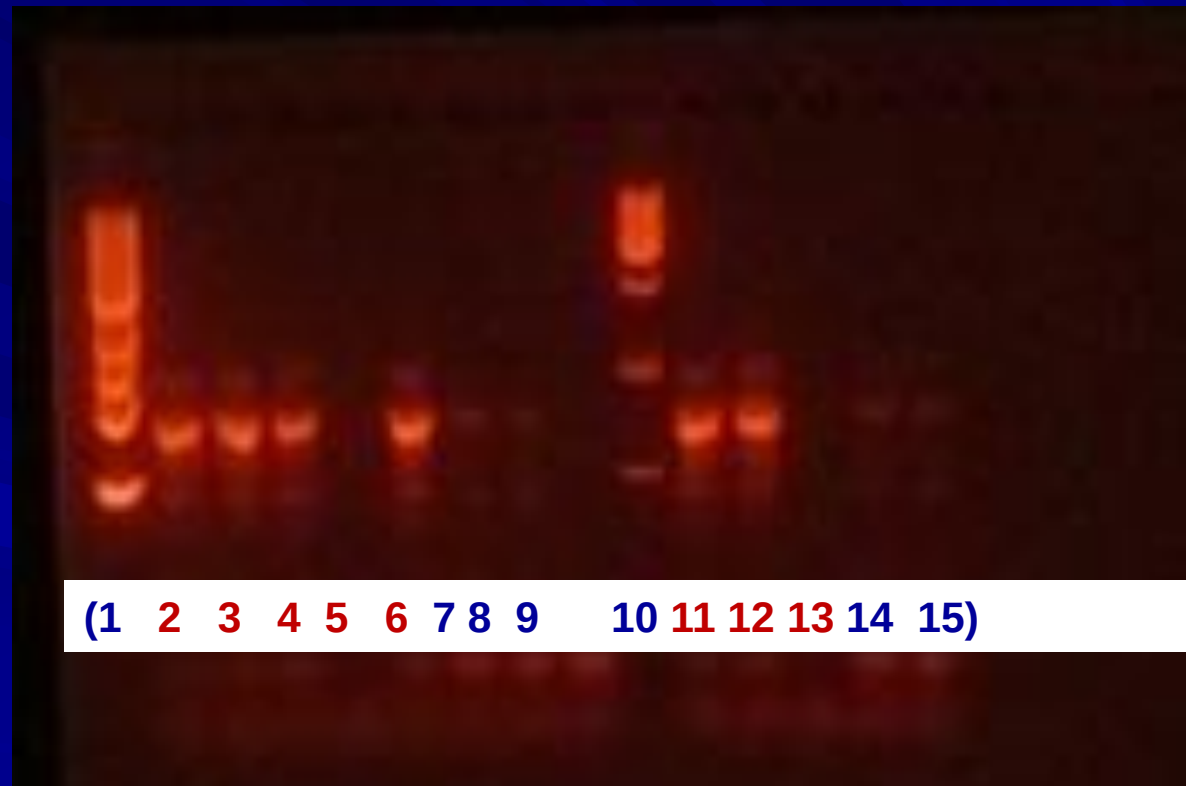

Zoites forming rosette
e
100 µm


f
Fibrosis
c
200 µm

District	%	$\bar{x}$ intensity (range)	Polydora % ($\bar{x}$intensity)	$\bar{x}$mm shell ht, (range)
Yakutat	68 %	6.8 (1-26)	51% (9.8)	124 (102-162)
NE Kodiak	80%	5.4 (1-16)	15% (11.7)	136 (100-155)
Kamishak B.	90%	6.2 (1-10)	100% (54.4)	158 (148-169)
Shelikof	100%	10.2 (1-30)	5% (2)	141 (106-177)
SW Kodiak	90%	22.6 (3-36)	20% (11.5)	154 (120-182)
Unimak Bight	80%	7.1 (1-16)	0	155 (127-173)
Dutch Harbor	100%	29.2 (12-64)	0	164 (152-181)
Bering Sea	86%	5.7 (1-14)	30% (4.5)	160 (121-181)

PCR/Seq Results

- PCR positive for same apicomplexan in the Atlantic !
  - Except #91 (quality issue)
- DNA sequencing confirm
  - 18S contig 100% match
  - 95% coverage



1kb , #33, #39, #74, #91, #78, PC1, PC2, Control, 10kb, #33, #39, #91, PC1, PC2

(1 2 3 4 5 6 7 8 9 10 11 12 13 14 15)

NOTE: PC =positive control (diluted)

Journal of Invertebrate Pathology 185 (2021) 107668

Contents lists available at ScienceDirect

Journal of Invertebrate Pathology

journal homepage: www.elsevier.com/locate/jip

A case report and statewide surveillance of "weak meat" condition of Alaska weathervane scallops, *Patinopecten caurinus*, linked to a recently identified pathogenic parasite, *Merocystis kathae* (Apicomplexa: Aggregatidae)

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ARTICLE INFO

Keywords:
Alaska weathervane scallops
Patinopecten caurinus
Parasite
Disease
Apicomplexan
Product Quality Issue

ABSTRACT

Weathervane scallop, *Patinopecten caurinus*, the largest scallop species in the world, is distributed from northern California, U.S.A., to the Bering Sea, and is only commercially harvested in Alaska. The fishery is considered well managed by the State of Alaska (U.S.A) Department of Fish and Game (ADF&G) and federal government, with many precautionary measures in place to avoid overharvest. There have been episodic declines in some management areas due to unknown causes. Fishermen also encounter scallops with abnormal adductor muscles, a condition colloquially termed "weak meat", characterized by the retention of muscle when shucked, an obvious darkened discoloration, and/or an abnormal texture making the product unacceptable for marketing. A similar syndrome in Atlantic sea scallops, *Placopecten magellanicus*, described as "gray meat", occurs in the eastern U.S. and Canada, and proposed causes include senescence, loss of bioenergetics due to chronic infestations, or a synergism of these factors. Recently a severe apicomplexan infection was found to cause a gray meat condition in Iceland scallops, *Chlamys islandica*, and the collapse of that stock. This parasite was subsequently detected in Atlantic sea scallops with the gray meat condition off the U.S. East Coast. Studies that followed identified the parasite as *Merocystis kathae*, previously described from the common whelk, *Buccinum undatum*, more than 100 years ago. In 2015 Bering Sea fishermen reported weak meat in their catch, so samples were submitted to ADF&G for diagnosis. Adductor muscles from all affected scallops had many large foci of an apicomplexan associated with necrosis, fibrosis, and muscular atrophy. Given the reduced quality, marketability, and possibly fitness of affected scallops, we performed a survey to estimate prevalence, intensity, and geographic distribution of this apicomplexan in Alaskan weathervane scallops. We sampled 180 scallops, from individual beds within each of the three major geographically broad scallop areas in Alaska. Overall prevalence was about 82%, ranging from 69 to 100% by district. Overall mean infection intensity, based on the number of parasite foci/section, was about 9 (range of 5–29, by location), with scallops from the Bering Sea and Southwest Kodiak being most severely infected. Molecular analyses confirmed that the Alaskan parasite is *M. kathae*, i.e., the same apicomplexan that caused the collapse of Icelandic scallops and a suspected cause for gray meat and mass mortality of Atlantic sea scallops in northeast North America.

Conclusions (so far)

- Severe pathology & linked to poor survival
- Wide geographic- Atlantic/Pacific, circumpolar?
  - Alaska, East US (Maine), East Canada (Georges Bank), Europe (Iceland, Scotland, Faroe Is)
  - Norway, Greenland, Svalbard, Russian Barents, North Quebec (Kristmundsson & Freeman 2018)
- Wide host specificity – 5 scallop species so far
  - Weathervane, sea, Iceland, queen, king

Conclusions (so far)

- Parasite ID'd: *Merocystis kathae* Dakin, 1911
  - Definitive host: common whelk, *Buccinum undatum*
    - Molecular/histological confirmation (Kristmundsson & Freeman, Nature 2018)
    - No *B. undatum* in AK, but prelim results = 100% seq match in 4 *Buccinum* sp. from Yakutat from 2022, tentatively *B. plectrum* (Sinuous whelk)
- Distant spread benthic hosts?
  - Possibly ballast water in fishery??
    - East coast⬇= vessels moved to AK fishery
  - Iceland scallop recorded in Alaska
    - False Iceland scallop *C. pseudoislandica* = *C. behringiana*

Mitigation Options ?

- Iceland: total collapse *C. islandica* 2000's
  - Fishing ban 2003; IS Ministry Fish attribute parasite + warm sea temps assoc North Atlantic Oscillation
    - Long-term surveillance evaluate parasite impact
    - Decline continues
- East Coast: gray meat, reduced biomass, & mortality events *P. magellanicus* since 1949
  - Closures & rotational closures
    - Surveillance efforts (e.g., 2015 report)
    - Declines continue: 2013 closed early due to parasite; many affected post-closure (similar in Iceland)

Mitigation Options ?

- Alaska: weak meat since fishery began in 1967, worse in recent yrs (e.g., 2015 & 2023)
  - Due to *M. kathae* (Ferguson et al., 2021)
  - Definitive host *Buccinum* sp., likely *B. plectrum*, the sinuous whelk (manuscript in prep.)
  - Impacts fishery

Mitigation Options ?

- Fishery: to close or not to close ??
  - Closure may help recovery
  - Could also result in more widespread infections
    - Difficult decision with fishable population
- **Retain** "weak meats" to prevent spread = best practice!

Mitigation Options ?

- Whelks-
  - Need market for fishery to remove source
  - Should **retain** when caught = Best practice!

- Treatment: freshwater dip prior to disposing offal?
  - May or may not help
  - Some info on direct transmission b/w scallops, but likely limited

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Questions

ADF&G Fish Pathology Lab website: https://www.adfg.alaska.gov/index.cfm?adfg=fishingpathologylab.main

"Diseases of Wild & Cultured Shellfish in Alaska": https://www.adfg.alaska.gov/static/species/disease/pdfs/shellfish_disease_book.pdf