Shellfish and the Environment

Honoring the data: a review of recent studies on ecological consequences of geoduck aquaculture in southern Puget Sound

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Introduction

Biology & aquaculture

- Long-lived clam
  - 100+ years, >3kg
- Soft bottom habitat
- California to Alaska
- Intertidal culture
- ~$20 million market

Photo credit: PS McDonald

Introduction

Culture cycle

- Year 1: Planting
  - Placing structures and juvenile clams
- Years 2-5: Grow out
  - Removal of structures
- Years 5-7: Harvest
  - Liquefaction
  - Extraction of geoducks

Photo credit: PS McDonald

Introduction

Culture cycle

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Geoduck seed

PVC tube placement

Photo credit: PS McDonald

Introduction

Culture cycle

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Nets and tubes


Net removal

Photo credit: PS McDonald

Introduction

Culture cycle

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  - Placing structures and juvenile clams
- Years 2-5: Grow out
  - Removal of structures
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  - Liquefaction
  - Extraction of geoducks


Harvesting


Harvest disturbance

Photo credit: PS McDonald, G VanBlaricom

Introduction

Initial concern

- Lack of peer-review science
- Heated debate
  - User group conflict

Opposition groups


Public meeting

Photo credit: nogeoduckfarm.com & Kitsap Sun

Introduction

SSHB 2220

- The environmental effects of structures commonly used in the aquaculture industry to protect juvenile geoducks from predation;
- The environmental effects of commercial harvesting of geoducks from intertidal geoduck beds, focusing on current prevalent harvesting techniques, including a review of the recovery rates for benthic communities after harvest;
- The extent to which geoducks in standard aquaculture tracts alter the ecological characteristics of overlying waters while the tracts are submerged, including impacts on species diversity, and the abundance of other benthic organisms;
- Baseline information regarding naturally existing parasites and diseases in wild and cultured geoducks, including whether and to what extent commercial intertidal geoduck aquaculture practices impact the baseline;
- Genetic interactions between cultured and wild geoduck,including measurements of differences between cultured geoducks and wild geoducks in terms of genetics and reproductive status; and
- The impact of the use of sterile triploid geoducks and whether triploid animals diminish the genetic interactions between wild and cultured geoducks.

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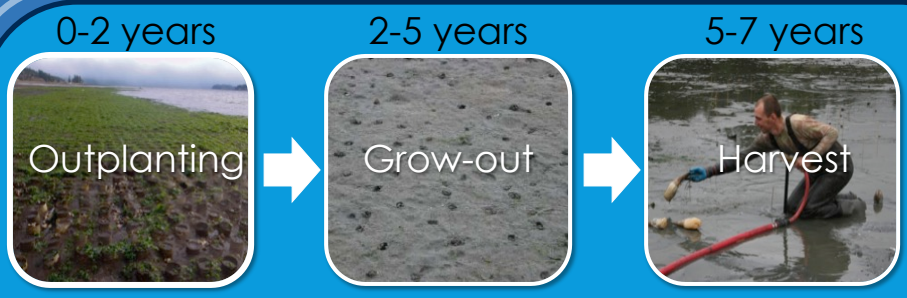
Introduction



Introduction

Gear effects study

McDonald, P.S., A.W.E. Galloway, K.C. McPeek, and G.R. VanBlaricom. *In press*. Effects of geoduck (*Panopea generosa* Gould, 1850) aquaculture gear on resident and transient macrofauna communities of Puget Sound, Washington, USA. *Journal of Shellfish Research*.

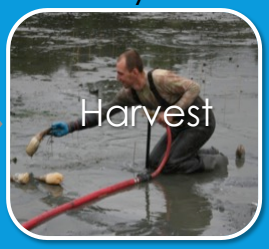
Introduction

Foraging effects study

McPeek, K.C., P.S. McDonald, and G.R. VanBlaricom. 2014. Aquaculture disturbance impacts the diet but not ecological linkages of a ubiquitous predatory fish. *Estuaries and Coasts*. Published online 8 November 2014.

Introduction

0-2 years | 2-5 years | 5-7 years



Harvest effects study

VanBlaricom, G.R., J.L. Eccles, J.D. Olden, and P.S. McDonald. *In press*. Ecological effects of the harvest phase of geoduck clam (*Panopea generosa* Gould, 1850) aquaculture on infaunal communities in southern Puget Sound, Washington USA. *Journal of Shellfish Research*.

Introduction

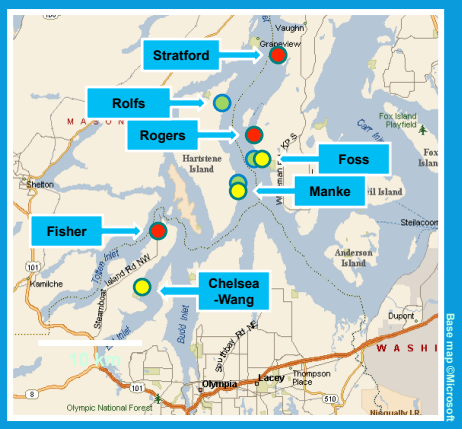
Study sites

- Industry scale
  - Temporal/spatial
- Realistic conditions
- Press disturbance
  - Planting
- Pulse disturbance
  - Harvest

Photo credit: Google Earth

Introduction

Study sites



- Gear effects sites
- Foraging effects sites
- Harvest effects sites

Photo credit: Google Maps

Introduction

Study design: Before-After-Control-Impact

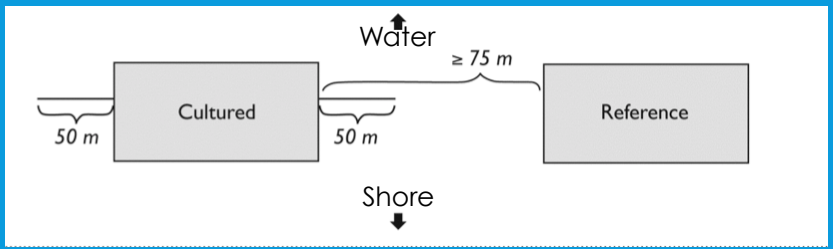


Photo credit: G VanBlaricom

Introduction

Project approach

- Disturbance - "...**discrete event** in time that disrupts ecosystem, community, or population structure and changes resources, substratum availability, or the physical environment." (Pickett & White 1985)

- Resilience - measured by the **magnitude of disturbance** that can be absorbed before the system reorganizes. (Gunderson 2000)

Photo credit: mdancause, Island guardian,

Introduction | Gear effects

Gear effects study

Are transient & resident communities affected by geoduck outplanting?

Introduction | Gear effects

Gear effects study

Are transient & resident communities affected by geoduck outplanting?

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Gear effects study

Are transient & resident communities affected by geoduck outplanting?

Introduction | Gear effects

Methods: SCUBA

- Diver pairs
  - Transect tool
- Culture/reference
  - 45-m transects
  - Summer(monthly) winter (bi-monthly)
- Species ID
  - Number and size


SCUBA transects


Measuring seastar

Photo credit: G Jensen, J Eggers

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Methods: SCUBA

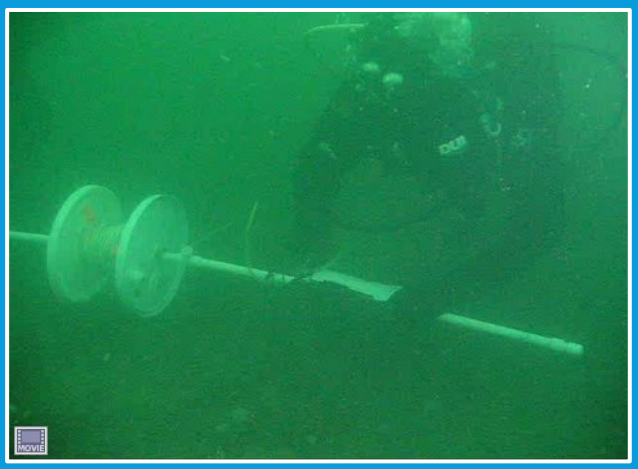

Photo credit: G Jensen,

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Methods: shore survey

- Single observer
  - 5-minute scan
- Culture/reference
  - 50-m transect
  - March-July
- Species ID
  - Number and size
  - behavior

Photo credit: PS McDonald, Sacramento Bee

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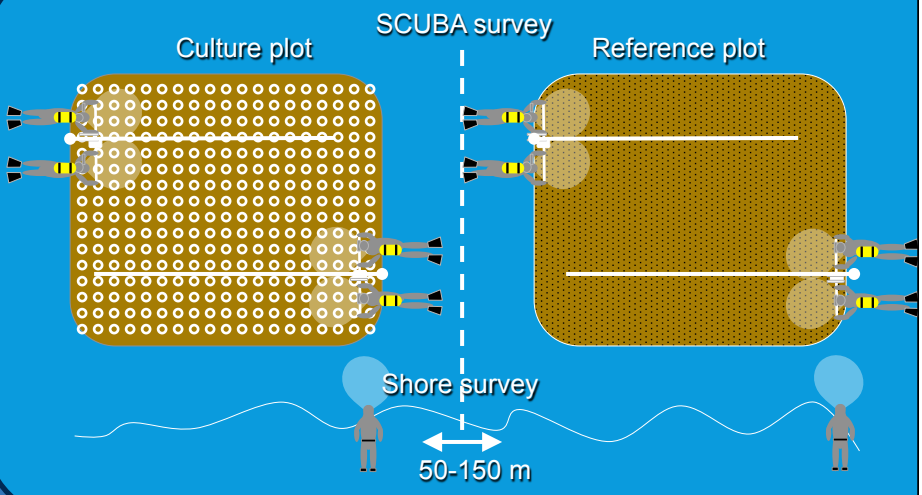

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Methods: coring

- Culture/reference
  - Ten samples each
  - Before-during-after
- Lab processing
- Species ID
  - Number

Photo credit: PS McDonald

Introduction | Gear effects

Methods: analysis

- Transient data
  - nMDS
  - Anosim
  - SIMPER
- Resident data
  - PerMANOVA
  - HMD
  - GLMM

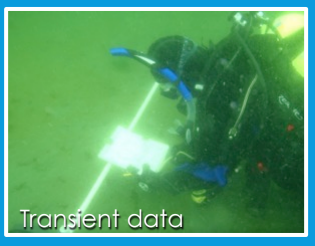

Photo credit: J Eggers, K McPeek

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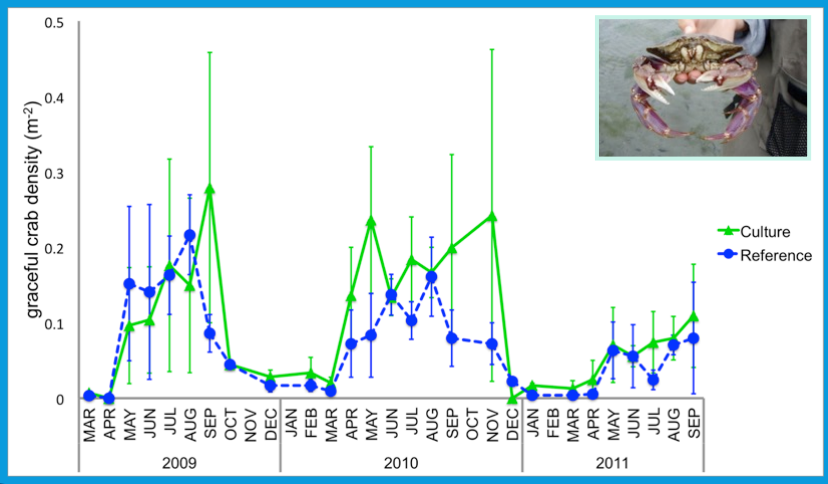
Results: transients abundance



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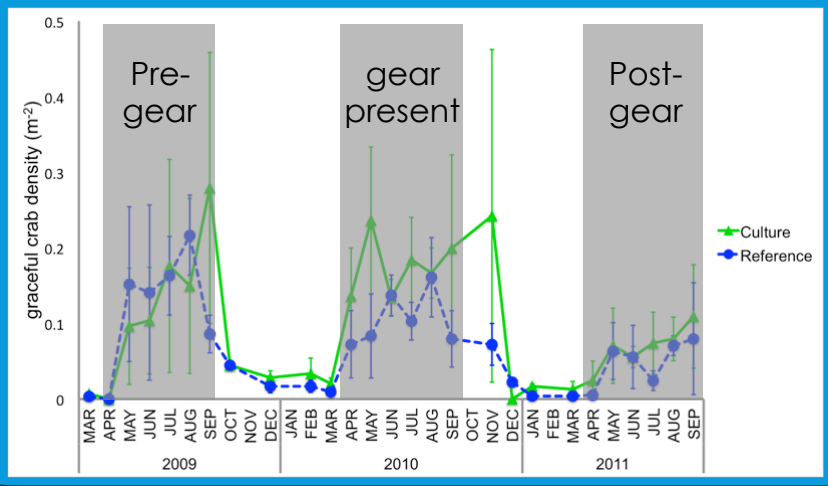

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Results: transients functional groups


seaperches


other nearshores


flatfishes

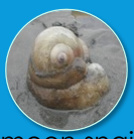

gunnels


sculpins


other demersals


crabs


hermit crabs


moon snails


seastars


cockles


other inverts

Photo credit: L Thomson, PS McDonald, M Gieselman, M Adams, J Grose, N Elder

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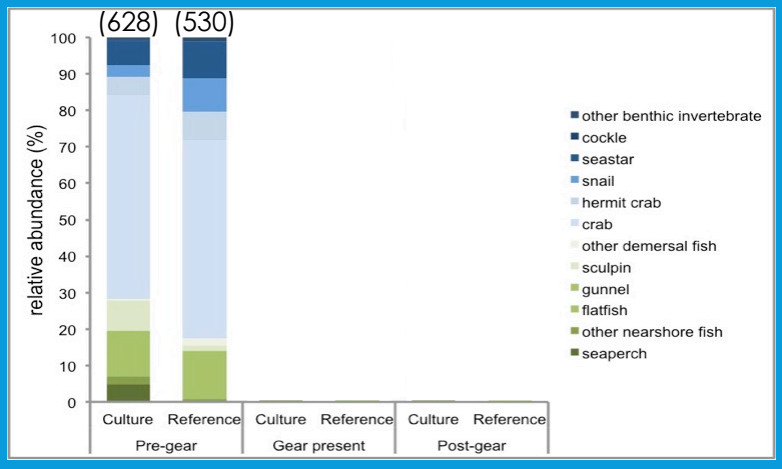
Results: transients abundance



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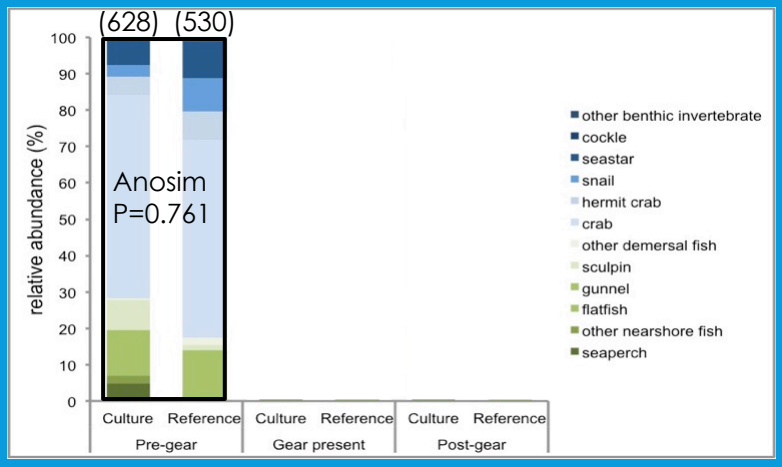

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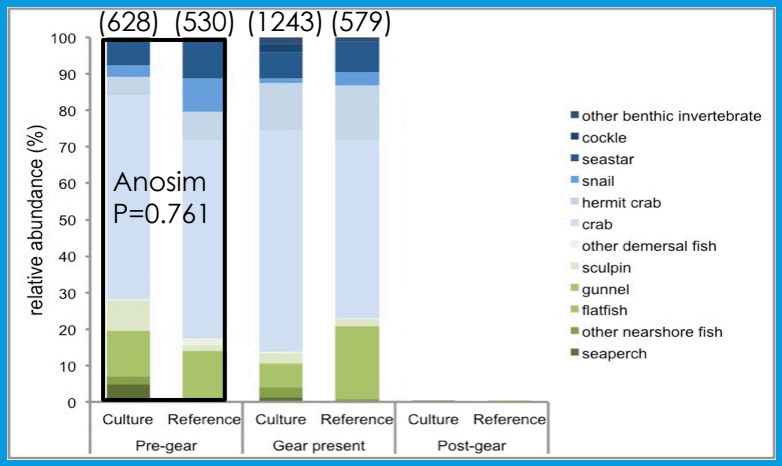

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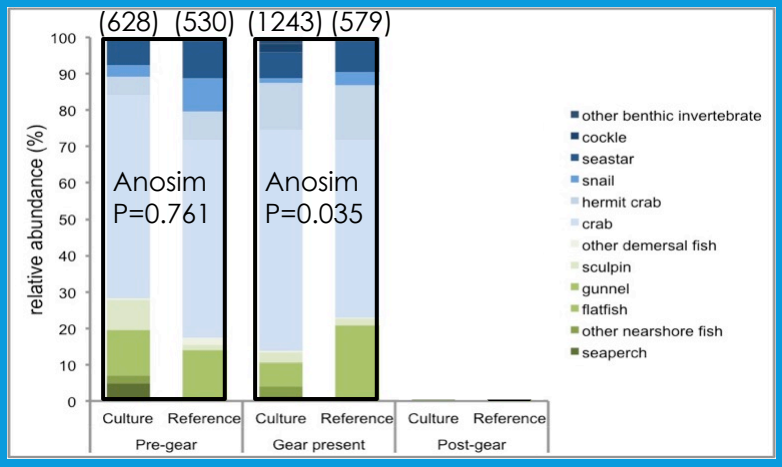

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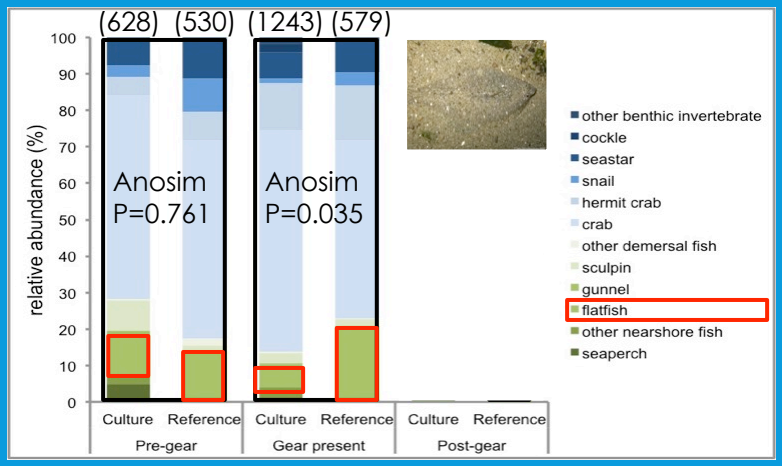

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Results: transients dissimilarity

SIMPER

Group	Contribution	Cumulative
crab:	39.93%	39.93%
hermit crab:	15.09%	55.02%
flatfish:	14.86%	69.88%
seastar:	8.23%	78.10%
sculpin:	4.90%	83.00%
cockle:	3.46%	86.47%
nearshore fish:	3.33%	89.80%
snail :	3.25%	93.05%

Photo credit: L Thomson, PS McDonald, M Gieselman

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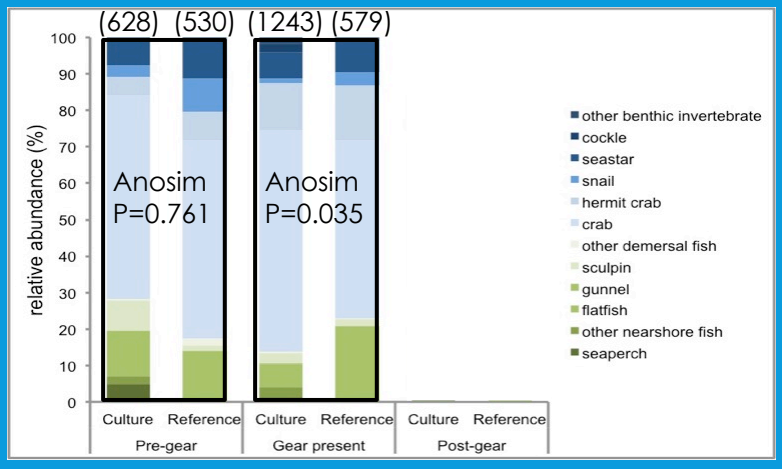
Results: transients abundance



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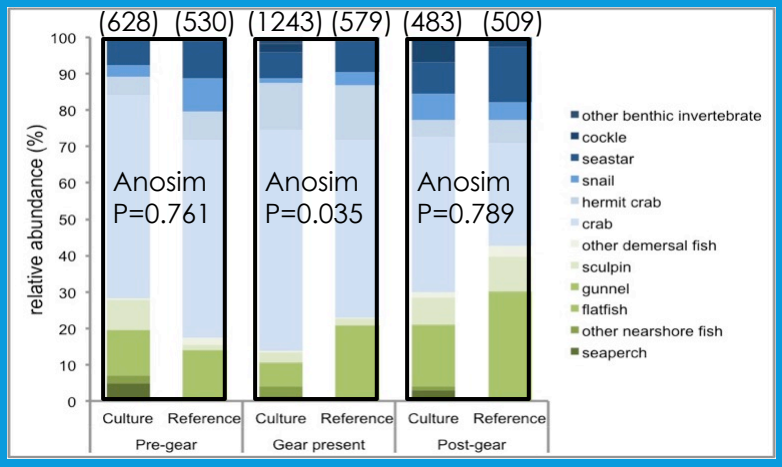

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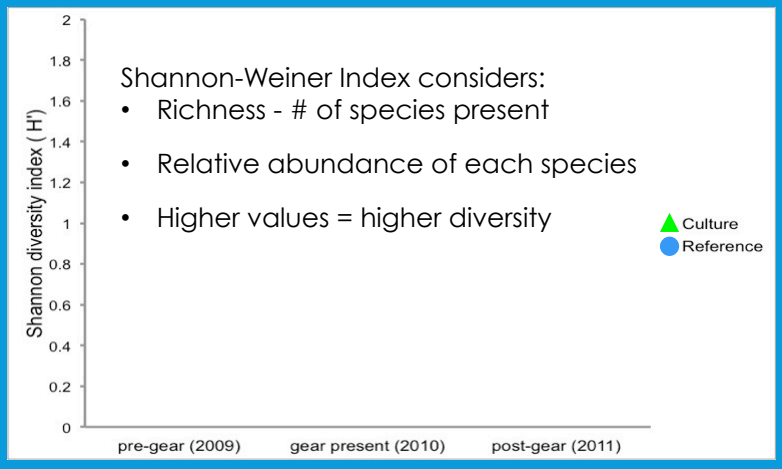
Results: transients community diversity



Shannon-Weiner Index considers:

- Richness - # of species present
- Relative abundance of each species
- Higher values = higher diversity

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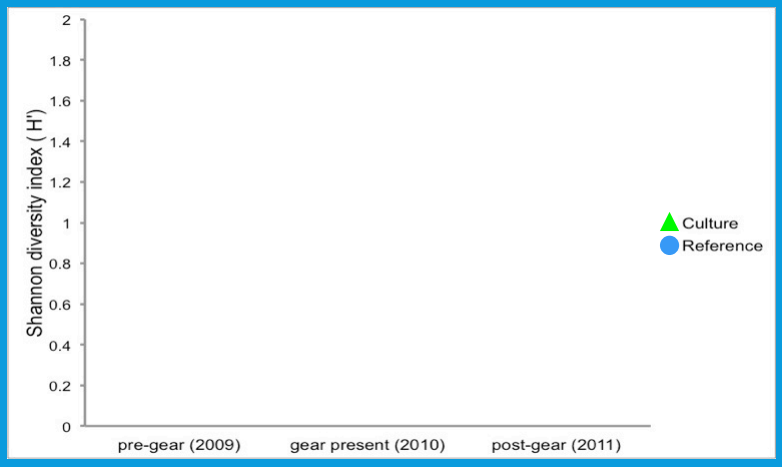
Results: transients community diversity



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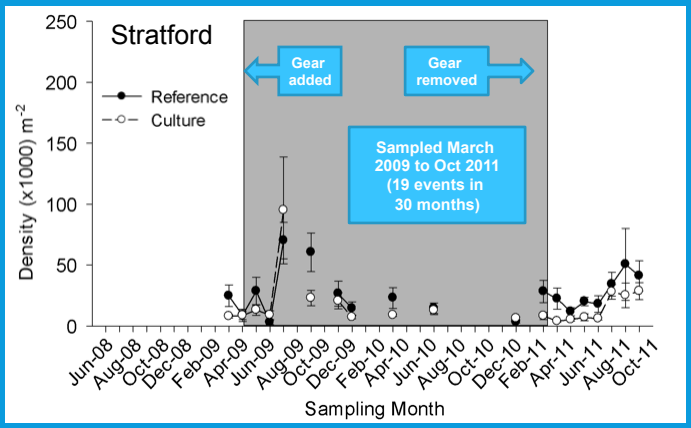
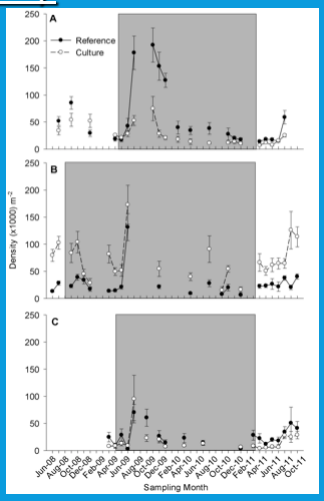
Results: residents community



Introduction | Gear effects

Results: residents community

- PerMANOVA
  - Month, Plot, Phase
  - No detectable aquaculture effect
- HMD test
  - No detectable aquaculture effect



Introduction | Gear effects

Results: residents individual response

Pre-gear

Gear-present

Post-gear

Photo credit: J Cordell, Wikipedia

Introduction | Gear effects

Results: residents individual response

	crustaceans		polychaetes		mollusc	nemertean
Pre-gear						
Gear-present						
Post-gear						

Photo credit: J Cordell, Wikipedia

Introduction | Gear effects

Results: residents individual response

	crustaceans		polychaetes		mollusc	nemertean
Pre-gear	none	none	none	none	none	none
Gear-present						
Post-gear						

Photo credit: J Cordell, Wikipedia

Introduction | Gear effects

Results: residents individual response

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Photo credit: J Cordell, Wikipedia

Introduction | Gear effects

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Pre-gear	none	none	none	none	none	none
Gear-present	-	-	-	+	none	none
Post-gear	none	+	none	none	none	none

Photo credit: J Cordell, Wikipedia

Introduction | Gear effects

Summary

- Transients
  - Community affected by gear but recovers to reference condition
- Residents
  - Community largely unaffected
  - No consistent pattern in individual taxa response
  - Few taxa did not recover/increase following abatement of disturbance

Introduction | Gear effects | Foraging effects

Pacific staghorn sculpin

- Ecologically Relevant
  - Abundant
  - Opportunistic
  - Diet reflects local prey composition

Photo credit: A Fuller, Divebums.com

Foraging effects study

Do sculpin demonstrate fidelity for geoduck culture plots or adjacent areas?

Does aquaculture affect sculpin diet and/or trophic linkages?

Introduction | Gear effects | Foraging effects

Methods: fidelity

- Mark-recapture
  - Monthly beach seine
  - Ebb tide
- Data
  - Tagged, weighed, measured
  - Release time/site

Photo credit: PS McDonald

Introduction | Gear effects | Foraging effects

Methods: food habits

- Field collection
  - Sculpin & likely prey
- Diet analysis
  - Prey ID & number
- Tissue processed
  - Isotope analyses

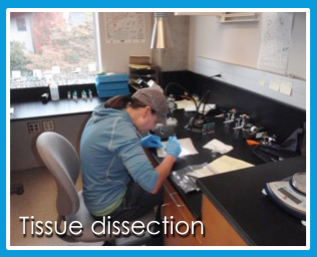

Photo credit: K McPeek, A Fuller

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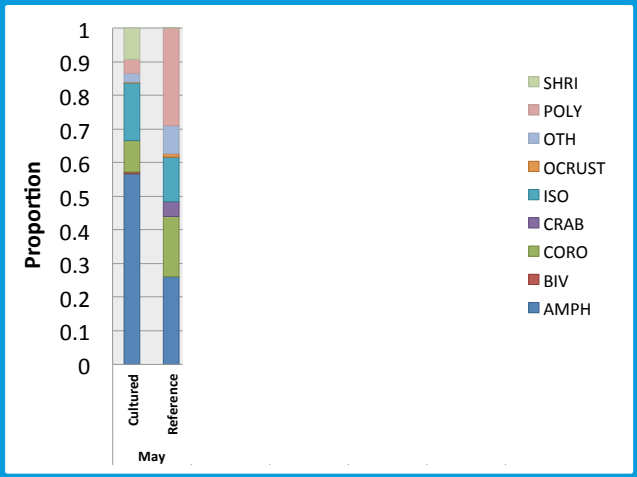
Results: fidelity

- Tagged >1000 sculpin/plot
- Recapture rate
  - Low (~5%)
- High along-shore fidelity
  - 1 stray

K. McPeek (all)

Introduction | Gear effects | Foraging effects

Results: food habits



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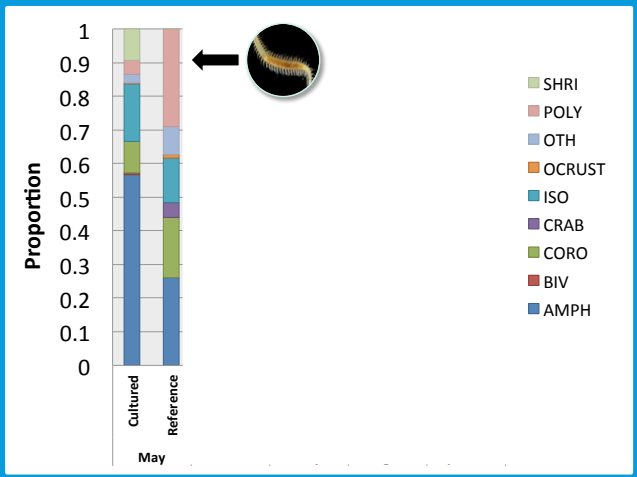
Results: food habits



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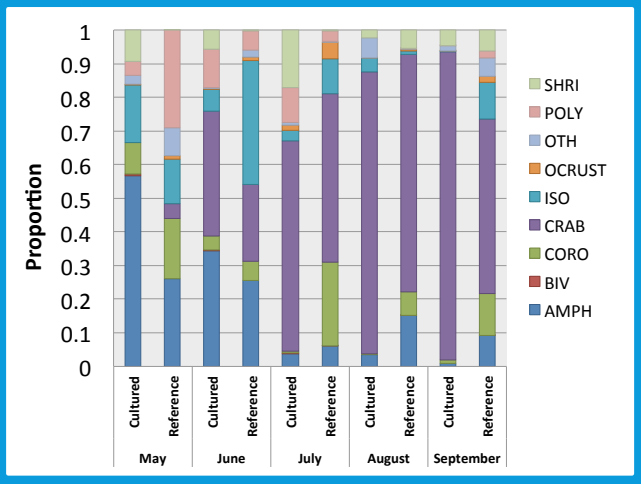
Results: food habits



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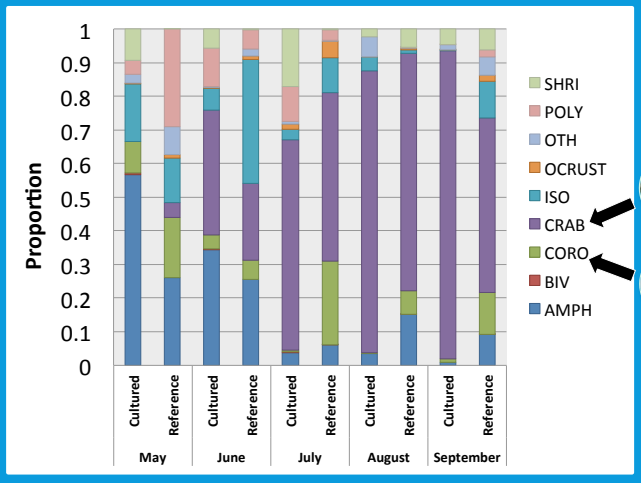
Results: food habits



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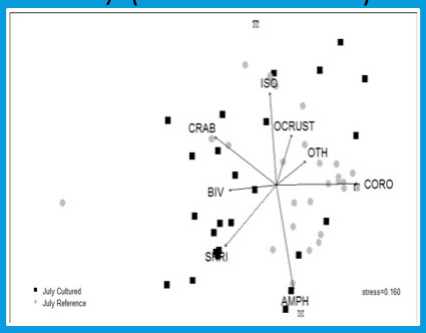
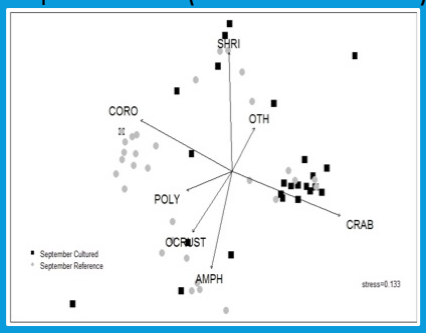
Results: food habits

July (Anosim P<0.01)



September (Anosim P<0.01)



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Results: food habits

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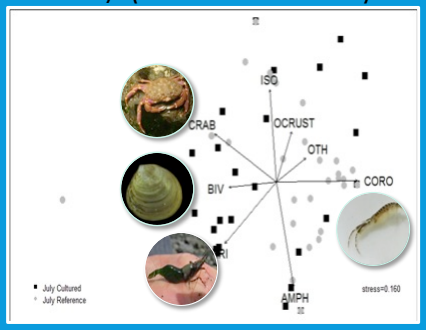

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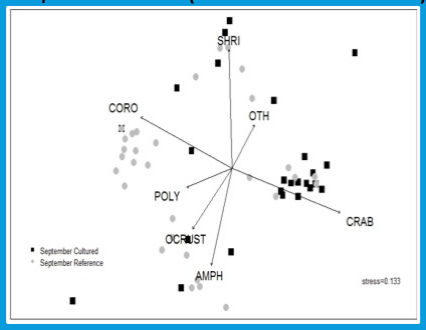

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Results: food habits

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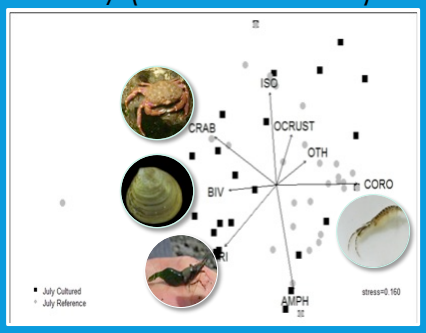

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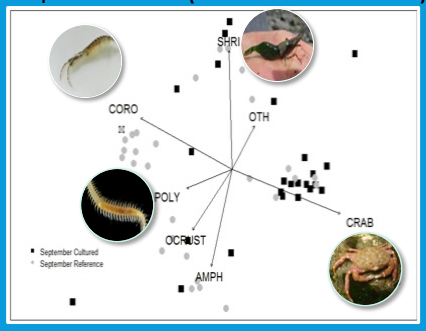

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Results: trophic links

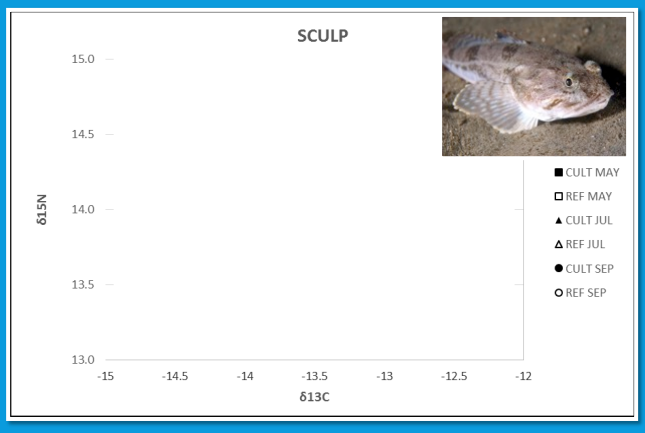

Photo credit: Divebums.com

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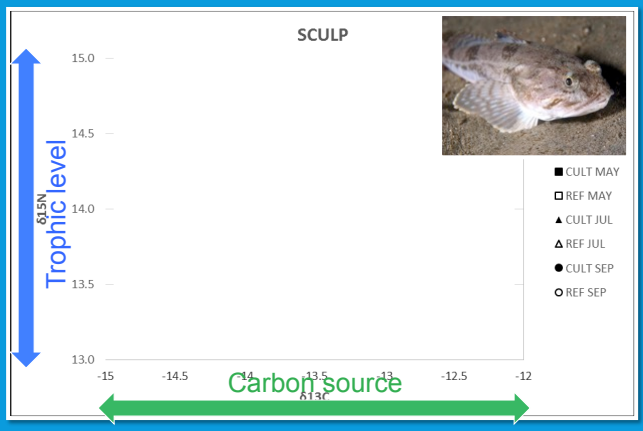

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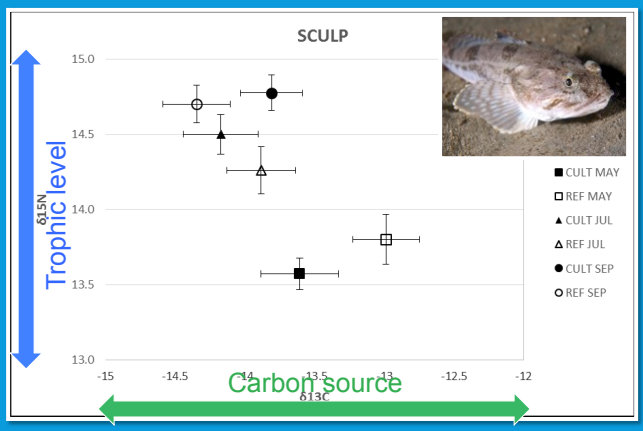

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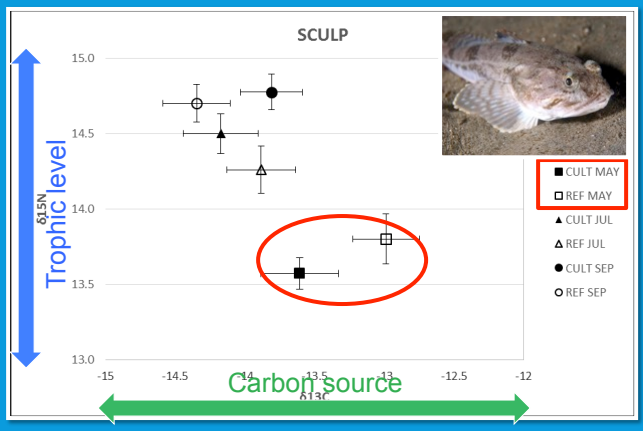

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Results: trophic links

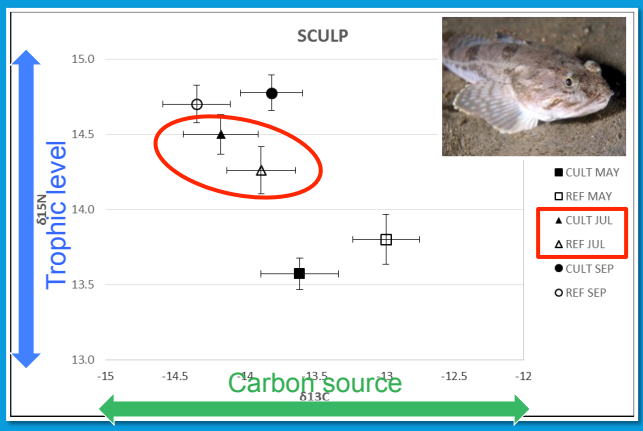

Photo credit: Divebums.com

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Results: trophic links

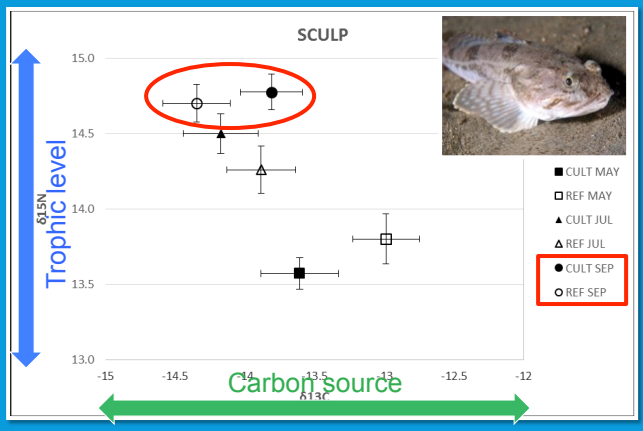

Photo credit: Divebums.com

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Summary

- Site fidelity
  - Sculpin have strong along-shore fidelity
- Food habits
  - Aquaculture associated with changes in sculpin prey composition
- Trophic linkages
  - No detectable effect on carbon source
  - No detectable effect on trophic level

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Harvest effects study

Are resident communities affected by geoduck harvest?

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Methods: coring

- Culture/reference
  - Ten samples each
  - Before-during-after
- Lab processing
- Species ID
  - Number

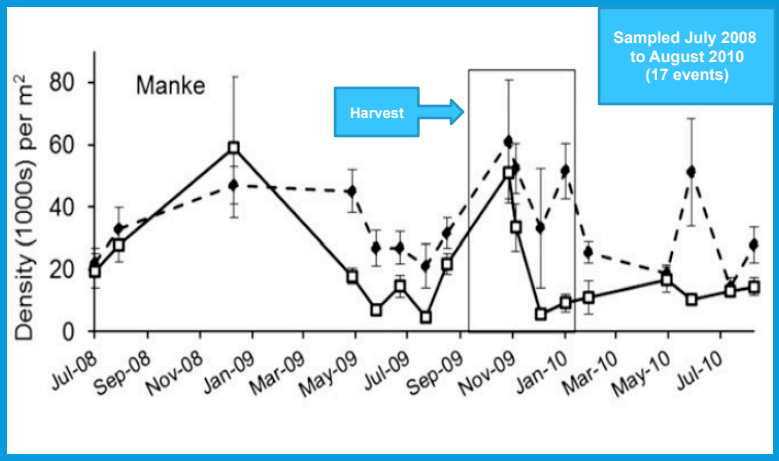
Photo credit: PS McDonald

Methods: analysis

- Resident data
  - PerMANOVA
  - HMD
  - GLMM

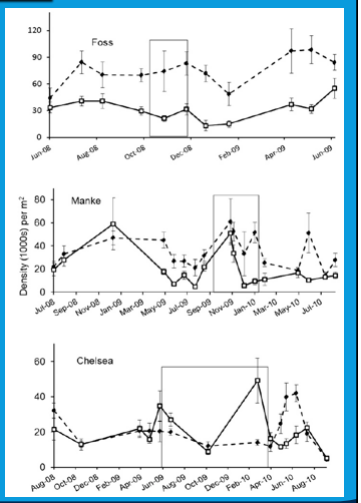
Photo credit: M Langness, PS McDonald

Results: community analyses



Results: community analyses

- PerMANOVA
  - Month, Plot, Phase
  - No detectable aquaculture effect
- HMD test
  - No consistent differences among plots



Results: resident individual response

	crustaceans		polychaetes		mollusc	nemertean
Pre-gear	none	none	none	none	none	none
Gear-present	-	-	-	+	none	none
Post-gear	none	+	none	none	none	none

Photo credit: J Cordell, Wikipedia

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Harvest-present						
Post-Harvest						

Photo credit: J Cordell, Wikipedia

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Post-Harvest						

Photo credit: J Cordell, Wikipedia

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Harvest-present	+	+	-	+	-	none
Post-Harvest	+	+	none	none	-	none

Photo credit: J Cordell, Wikipedia

Summary

- Harvest effects
  - Community largely unaffected
  - No consistent pattern in individual taxa response
  - Few taxa did not recover/increase following abatement of disturbance

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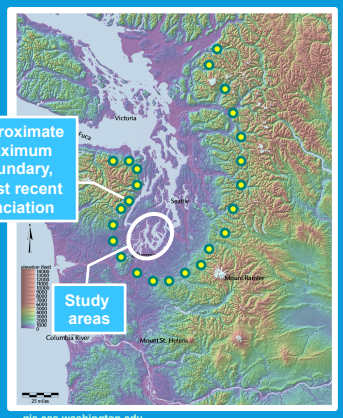
Disturbance revisited



gis.ess.washington.edu

geomaps.wr.usgs.gov

Photo credit: UW, USGS

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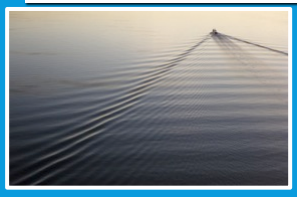
Disturbance revisited



- High-frequency small scale physical disturbances (e.g., wind waves, sedimentation via bluff erosion, and boat wakes)
- Regional-scale disturbances (e.g., floods, windstorms, and earthquakes) occur 1-2 times annually;
- Similarities in physical characteristics of natural disturbances and disturbances from geoduck aquaculture operations

Photo credit: mdancause, Island guardian, G VanBlaricom

Cumulative/indirect

- Cumulative effects in time
  - Multiple cycles in one area
- Cumulative effects in space
  - Multiple culture areas in close proximity
- Indirect effects
  - Potential effects translated through food web

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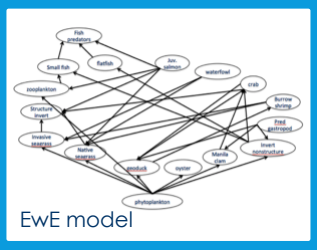
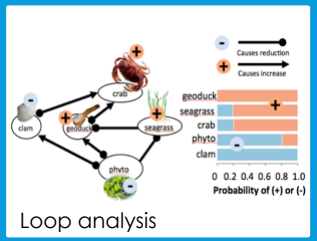
Cumulative/indirect

- Ecosystem models
  - Evaluate alternative management
- Qualitative models
  - Organize system knowledge
- Solicit stakeholder input



EwE model



Loop analysis

Images: J Reum

Thank you!

- Funding Sources
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  - NOAA Aquaculture
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  - Chelsea shellfish Farms
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