Biophysical gauntlet regulating young walleye pollock survival in the Gulf of Alaska and other study cases:

Emphasis on meso and submesoscale eddies

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Outline

Biophysical gauntlet regulating young walleye pollock survival in GOA
Models at different resolutions
Connectivity patterns
Exploration of physical indices
Summary

Expanding the conceptual model of Jack Mackerel in the South Pacific
Model experiments
Logbook data from Russian cruises
Stationary eddies in seamount region
Summary

Gaps, Challenges for the future
Biophysical gauntlet regulating young walleye pollock survival

Carolina Parada, Albert Hermann, Sarah Hinckley, Carol Ladd, Ken Coyle, Georgina Gibson, William Stockhausen
GOAIERP: Modeling component

Management Strategies For GOA fisheries

H1
H2
H3
UTL Component

Modeling Component

Multi Species Model

Effect of Processes causing recruitment variability & changes in fishing strategy on ecosystems
Relative performance of management strategies

Indices of recruitment

Hypothesized states of nature
Management strategies

Offline IBM Models

Hydrography and zooplankton biomass

Lower Trophic Level Model nested GOA-NPZ

Physical Ocean Model GOA Grid 3km

Physical Ocean Model GOA Grid 10km

Decision of which runs
Boundary and Initial Conditions

Model Validation

UTL Component

Distribution of juveniles

Forage Based Component

Retrospective Recruitment correlations

UTL Component

Habitat maps
POP genetics

nursery areas, diet, abundance, production and consumption

Forage fish diet, abundance, production and consumption

LTL and Physical Component

Initial Larval Distributions
Plankton process rates

Hydrography

EOF Pattern analysis

Atmospheric forcing products

LTL and Physical Component

Larval horizontal and vertical distribution
Plankton biomass, Nutrients, Production

Oceanographic Data

Model Validation
The Gauntlet
The primary determinant of year-class strength for marine groundfishes in the GOA is early life survival.

This is regulated in space and time by climate-driven variability in a biophysical gauntlet comprising offshore and nearshore habitat quality, larval and juvenile transport, and settlement into suitable demersal habitat.

Regional Comparisons

The physical and biological mechanisms that determine annual survival of juvenile walleye pollock and forage fishes differ in the eastern and western GOA regions.

Interactions

Interactions among species (including predation and competition) are influenced by the abundance and distribution of individual species and by their habitat requirements, which vary with life stage and season.
Questions associated to the early life history of walleye pollock

How conditions experienced along the trajectories will impact young fish growth, survival and mortality?

Are any strong connectivity pattern (spawning-nursery relationships) associated to the GOA?

What is the role of Eddies (different scale) in relation to transport and connectivity in the GOA?

Are these features realistic in the model?

Are there any connectivity between GOA and BS?

How to assess the role of predation?
Connectivity in GOA and Low resolution model
Spawning-nursery area in GOA
Retention in GOA: low resolution model

Spawning areas

Retention

Years

0.00-0.10  0.10-0.20  0.20-0.30  0.30-0.40

Spawning areas

Years

Connection to BS and potential nursery grounds

![Diagram showing proportions in Gulf of Alaska, Aleutians, and Bering Sea]

- **Gulf of Alaska**
- **Aleutians**
- **Bering Sea**

Proportion bars labeled with months: March, April, May.
Transport and connectivity within the GOA: high resolution model
Walleye pollock IBM compartments

Eggs
- Spawning conditions
- Development
- Buoyancy
- Mortality

Yolk sac larvae
- Growth (temp)
- Vertical movement
- Mortality

Feeding larvae
- Bioenergetics
- Turbulence effect
- Vertical movement
- Starvation
- Mortality

Juveniles
- Bioenergetics
- Vertical movement
- Horizontal movement
- Predation
- Starvation
- Mortality
Comparison 2002 - 2011

Connectivity matrix: All Spawning - nursery 1st Sept

2002

2011

Transport to Shumagin

Retention and transport in EGOA

Advection to the basin
More realistic initial conditions
Climatological initial conditions from Myriam Doyle
Climatological initial conditions
Describing Eddy activity and young pollock habitat
Identify eddies and generate indices

1. Okubo
   - Eddies identification
   - Linking on time
     - Cyclonic
     - Anticyclonic

2. Edies Trajectories
   - Filtering by scale

3. Submesoscale vs Mesoscale
   - Filtering by bathymetry
   - Regionalized Trajectories
     - Applying Jason–Franz criterion
       - 147ºW
     - Eastern vs Western
     - Eddies index
     - Compare Franz Rec. indices
     - Recruitment indices
E-W Trends in groundfish abundance & diversity

Breakpoints at ~148 °W
Spatial patterns

Hypothesis: Breakpoint in physical and biological characteristics around 147 °W

Motivation
Pronounced differences in species composition east and west of 147 °W (Mueter & Norcross 2002)

Updated from Mueter & Norcross (2002)
Submesoscale Eddies 2002: Cyclonic vs Anticyclonic

Anticyclonic Eddies

Cyclonic Eddies
Submesoscale Eddies 2004: Cyclonic vs Anticyclonic
Submesoscale Eddies 2011: Cyclonic vs Anticyclonic
Mesoscale Eddies 2002: Cyclonic vs Anticyclonic
Mesoscale Eddies 2004: Cyclonic vs Anticyclonic

Anticyclonic Eddies

Cyclonic Eddies
Mesoscale Eddies 2011: Cyclonic vs Anticyclonic

Anticyclonic Eddies

Cyclonic Eddies
### Eddies Statistics:

- **Number of Eddies**
  - **Ne= Number of eddies**
  - **Ed=Eddies_day**

- **Bathimetry**: 500, >500
- **Eddies Scale**: <=100m, >100m
- **Region**: Western, Eastern
- **Gyre**: Cyclonic, anticyclonic

<table>
<thead>
<tr>
<th>Bathimetry</th>
<th>Eddies Scale</th>
<th>Year</th>
<th>Western Cyclonic</th>
<th>Western Anticyclonic</th>
<th>Eastern Cyclonic</th>
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</table>
Eddies indices

Location

Type of eddies

Years

Refine indices
Food availability
Comparing with Recruitment indices

Franz PC and cluster analysis

Recruitment Indices

Recruitment Indices

Frantz PC and cluster analysis

Recruitment Indices

Recruitment Indices

Recruitment Indices

Recruitment Indices

Recruitment Indices

Recruitment Indices

Recruitment Indices

Recruitment Indices

Recruitment Indices

Recruitment Indices

Recruitment Indices
How to integrate predation data into the models?
Description of databases available for predation


- **Large mesh trawl databases**: Survey catch data for identified predators on focal species. Total weight of fish caught, sex, length, number of fish caught, years 1988-2011.

- **MACE surveys**: Catch data for identified predators on focal species from pelagic trawl catches from reference trawls during Midwater Acoustic surveys.

- **Observer data**: Commercial catch data for identified predators on focal species, 1995 to present.
Filtering – processing - outcomes

Databases

- Filtered target species
- + Predators

Spatial predator-prey display

- Points
- Polylines

Georeferencing

ArcGIS10

Joint

Predator

Overlapping index
Categorical index
Ratio
Consumption estimate

Prey

Juvenile distribution

NetCDF

At rho points
ROMS grid
Where information is available?

AFSC Groundfish Surveys (all years)

Hauls with stomach samples

GOA_MaytoOct_predprey
What predators?

What years available?

Diet Data

<table>
<thead>
<tr>
<th>PREDATOR</th>
<th>ARROWTOOTH</th>
<th>PCOD</th>
<th>POP</th>
<th>SABLEFISH</th>
<th>POLLOCK</th>
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<td>Arrowtooth</td>
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<td>Big Skate</td>
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<td>Northern Rock</td>
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<td>W. Pollock</td>
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</table>

PREDATOR: Arrowtooth, PCOD, POP, Sablefish, Pollock

What predators? What years available?
**IBM requirements**

- Predation on YOY by older fish, birds & other community members

**Products to the IBMs**

- Spatially explicit predation mortality estimates with interannual variability
- Predation mortality estimates with interannual variability
- Spatially explicit predation mortality estimates
- Relative indices indicating high, medium, low, none predation risk

**Data Availability**

- HIGH
- LOW

**Problems - limitations**

- Integration of data collected at different spatial scales (intensive small scale vs large scales samples)
- Unbalanced spatial sampling across the Eastern and Western GOA
- Unbalanced temporal sampling, mainly from summer
- Lack of temporal resolution to appropriately represent interannual variability in most of target species
Summary

- Low resolution model reproduces observed features of GOA in terms of spawning-nursery grounds.

- High resolution model showed submesoscale oceanographic structures playing an important role on transport and connectivity within GOA. How realistic are those?

- GOA and BS seem to be connected, this requires to be explored as well as the potential implicances on stock structure concept.

- The western GOA showed a significant larger amount of submesoscale eddies than eastern GOA.

- Spatially, predation indices are patchy. Not enough data to reproduce temporal variability. That might be critical in the attempts to model recruitment variability (as well as other sources of mortality).
Expanding the conceptual model of Jack Mackerel in the South Pacific

Carolina Parada – Sebastián Vásquez – Emuanuelle Di Lorenzo – Billy Ernst
Spatial and temporal connectivity – Recruitment indices

Vásquez et al., submitted
Jack Mackerel conceptual model

NURSERY AREA
Juveniles (< 25 cm)

SPAWNING ZONE
(Oct-Dec)
Adults (> 26 cm)

FEEDING AREA (Mar-Jul)
Adults (> 26 cm)

Migration of adult fish to spawning area
Migration of adult fish to feeding area
Juveniles and larval losses
Nursery area
Spawning area
Feeding area
Migration of juvenile (<=1 year) fish
Temporal retention of larvae and juvenile fish

Parada et al., submitted
Challenger break: seamount region

Parada et al., submitted
Spawning habitat in the Seamount region

Parada et al., submitted
Juvenile collected since 1980’s in seamount region

Table 2. Compilation of jack mackerel juveniles data collected by Industrial fishing Russian fleets and Oceanographic cruises in the southeast Pacific Region associated to seamounts region.

<table>
<thead>
<tr>
<th>Cruise</th>
<th>Dates</th>
<th>Region prospected</th>
<th>Minimum and Size of Maximum size aggregations of juvenile jack mackerel sampled (cm)</th>
<th>References</th>
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<tr>
<td>Fisheries Oceanography Research cruises organized by VNIRO and AtlantNIRO, Ex Soviet Union.</td>
<td>January 1980</td>
<td>40°41’20”S-111°30’W</td>
<td>4-6 cm</td>
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<td>February 1987</td>
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<td>8-13 cm</td>
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<td>Industrial boat Margiris Theodora</td>
<td>1 September 2008</td>
<td>southeast Pacific</td>
<td>12-20 cm and Commercial aggregations</td>
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<td>Russian Industrial opportunity ships</td>
<td>May-June 2010</td>
<td>40°-44°S/98°-104°W</td>
<td>20-25 cm</td>
<td>Commercial aggregation</td>
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</tbody>
</table>

Parada et al., submitted
Age-length function and birthdate retrocalculation

Parada et al., submitted
Simulated Temporal and Spatial Retention

Parada et al., submitted
• Jack mackerel oceanic spawning region is connected to nursery ground in the north of Chile (>30°S)

• Recruitment indices from IBM simulation are in good agreement with stock assessment estimates

• There are spawning/nursery regions in seamount region that might be important for the population

• The role of stationary eddies (on retention) in the seamount challenger break region

• Expand the conceptual model of Jack Mackerel in the South Pacific
Future and Challenges

- Explore whether modeled eddies and its scales are realistic (physics involved)

- Explore how productive those eddies are?

- Explore whether biophysical indices can be informative and input in single/multi species population dynamic model (increase predictability?)

- Refine further mortality sources (and data collected) to improve our ability to model population dynamic variability
Acknowledgement

- FATE
- North Pacific Research Board
- Conicyt

- Franz Mueter
- Jaison Waite
- Myriam Doyle
- Sebastian Vasquez
- Alexandre Gretchina
From lobster to the Ecosystem in the Juan Fernandez Archipelago: challenges in modelling

Billy Ernst - Carolina Parada – Pablo Manriquez - Javier Porobic – Stewart Frusher – Beth Fulton
Oceanic islands

- NAZCA ridge
- Desventuradas
- SALA Y GOMEZ ridge
- JUAN FERNANDEZ ridge
Fisheries in Juan Fernandez Archipelago

• Started in 1883

• Modern fishery took shape after 1914

• Has remained an artisanal activity

• Lobster fishery is the mainstay of the archipelago community

• The lobster fishery through several associated bait fishery has an impact on the pelagic, demersal and benthic communities.
Landings

- Introduction of traps
- Transition from "aparonados" to independent fishers
- Use of small winches expanded

Year

Landings (ton)


WW II

Cooperative

Logbook program initiated
SERNAPESCA officer stationed permanently
• Formal regulations (SSS type fishery)

• Informal (Sea tenure system of individual discrete fishing spots)
  – We developed several surveys, interviews and field measurements to describe this system.
Access to resources is controlled by historical rights of INDIVIDUAL DISCRETE FISHING SPOTS

The role of the community is to endorse this system
The «log book program»

- In the past not enough data was collected
- Common problem in S-fisheries
- Development of a cost-effective logbook program:
  - Use local manpower
  - Barefoot ecologist type of approach
  - No hyperstability of indicators
  - Known spatial coverage of participants
  - This has evolved into a cost-effective government financed monitoring program
Commercial Lobsters per Trap in RC-SC

- **CPUE Standardized**
- **CPUE Nominal**

Season:
- 2006-07
- 2008-09
- 2010-11
- 2012-13

Commercial Catch per Trap

0.0 - 2.0
Sustainability of the island System

- Lobster fishery has operated sustainably for 120 years

- New challenges are associated to increase in fishing effort and other fishing activities that might impact the ecosystem

- Given the configurations of the islands there is a need for understanding connectivity

- Effect of environment at different temporal scales (low and high frequency)
Oceanographic models

- Low resolution OFES model for the Eastern South Pacific.
- High resolution ROMs model for the Juan Fernández ridge
- Effect of mesoscale gyres and EMI on chlorophyll-a distribution around the islands
- Intrathermocline eddies fertilizing the Juan Fernández ridge.
Connectivity of *Jasus frontalisis* Subpopulations

Overview:

- High level of genetic connectivity
  Porobić et al., 2013

- Significant migration flows among subpopulations (Biophysical Model)
  Porobić et al., 2012

- Pelagic stage up to 12 months
  Arana, 1987

- Connectivity highly influenced by oceanographic processes.
  Porobić et al., 2012
Ecosystem-based management

• Under the light of recent advances in understanding the physical environment and the interaction with biological systems

• Small and vulnerable ecosystem
• Interplay of different fisheries (e.g. lobster and all bait fisheries)

• Ecosystem approach to study sustainability of Juan Fernández resources

• Develop a comprehensive research program for the Juan Fernández ecosystem → Using ATLANTIS framework
The biophysical submodel of ATLANTIS is a 3D deterministic model, conformed by a system of irregular polygons whose size is characterized by the scale of the process at each location.

The horizontally generated polygons have a bathymetric representation associated to vertical layers, which go from 3 to 6 depending on the polygon bathymetry and species habitat definition.
Functional Groups

- Domestic fauna DMF
- Otaridos OTA
- Octopus OCT
- Birds BIR
- Spiny lobster SPL
- Golden Crab GCR
- Large Pelagic fish LPF
- Small pelagic fish SPF
- Large Benthic fish LBF
- Small benthic fish SBF
- Zooplankton ZOO
- Small crustacea SCRU
- Deposit feeders BFF
- Phytoplankton PHY
- Sea Urchins SUR
- Nitrate NO
- Bacteria BAC
- Labile detritus DL
- Refractory detritus DR
- Carrion DC
Outcomes and challenges

- Assess the impact of various management actions, with spatial considerations
  - MPA performance
  - Input and output controls
- Impact of the development of new fisheries on the lobster complex and JF ecosystem
- Assess the productivity of different JF ecosystem
- Identify research gaps associated to ecosystem modelling
Acknowledgement

- All syndicates from the islands (STIPA, SPIIAS)
- Chilean Undersecretariat of Fisheries
- SERNAPESCA
- CREO Scholarship
- And many other people that collaborated
Future and Challenges

- Explore whether modeled submesoscale eddies and its scales are realistic (physics involved)

- Explore how productive those eddies are?

- Explore whether biophysical indices match recruitment variability of target species

- Explore whether biophysical indices can be informative and input in single/multiple population dynamic model (reduce uncertainty – increase predictability)

- Refine further mortality sources (and data collected) to improve our population dynamic variability

- Discriminate the effect of environmental variables