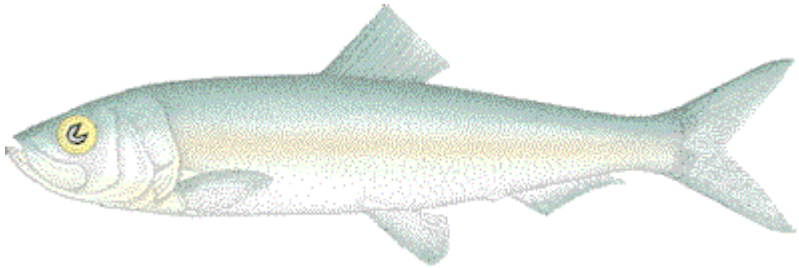
Recruitment strength indices for northern British Columbia stocks of Pacific herring



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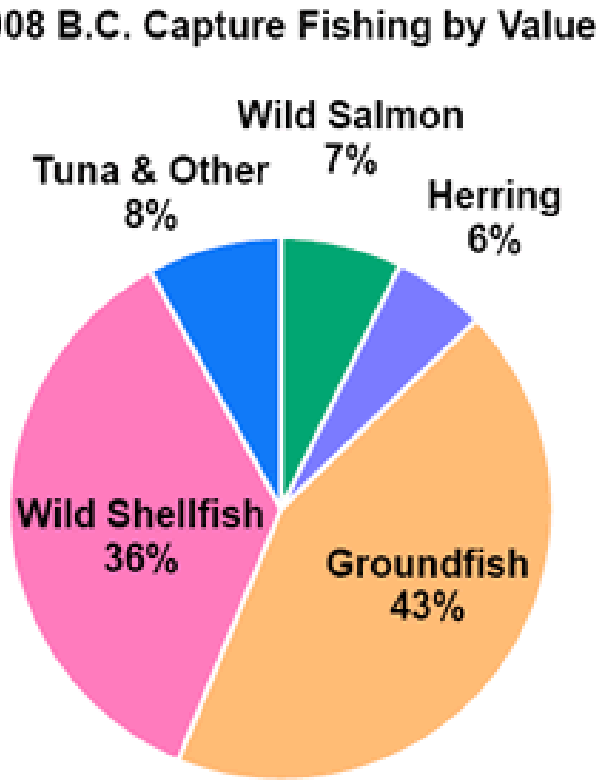
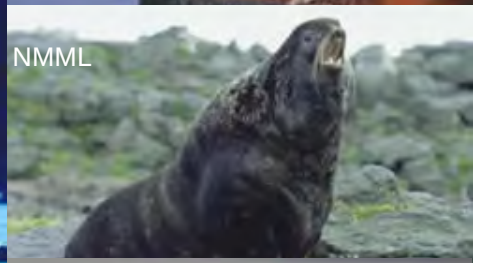
Nanaimo
Portland
Arctic Ocean
Kara Sea
Barents Sea
Baffin Bay
Northwestern Passages
Chukchi Sea
Beaufort Sea
Norwegian Sea
Iceland Sea
Davis Strait
Hudson Bay
Labrador Sea
Bering Sea
Bering Sea
North Pacific Ocean
NORTH AMERICA
EUROPE
ASIA
North Atlantic Ocean
North Pacific Ocean
Gulf Of Mexico
Caribbean Sea
AFRICA
Arabian Sea
SOUTH AMERICA
Solomon Sea
Coral Sea
South Pacific Ocean
Tasman Sea
South Atlantic Ocean
5000 km
2000 miles
Imagery © 2007 i-cubed, Data © 2007 Navteq, TeleAtlas

British Columbia Pacific Herring



Fisheries and Oceans Canada

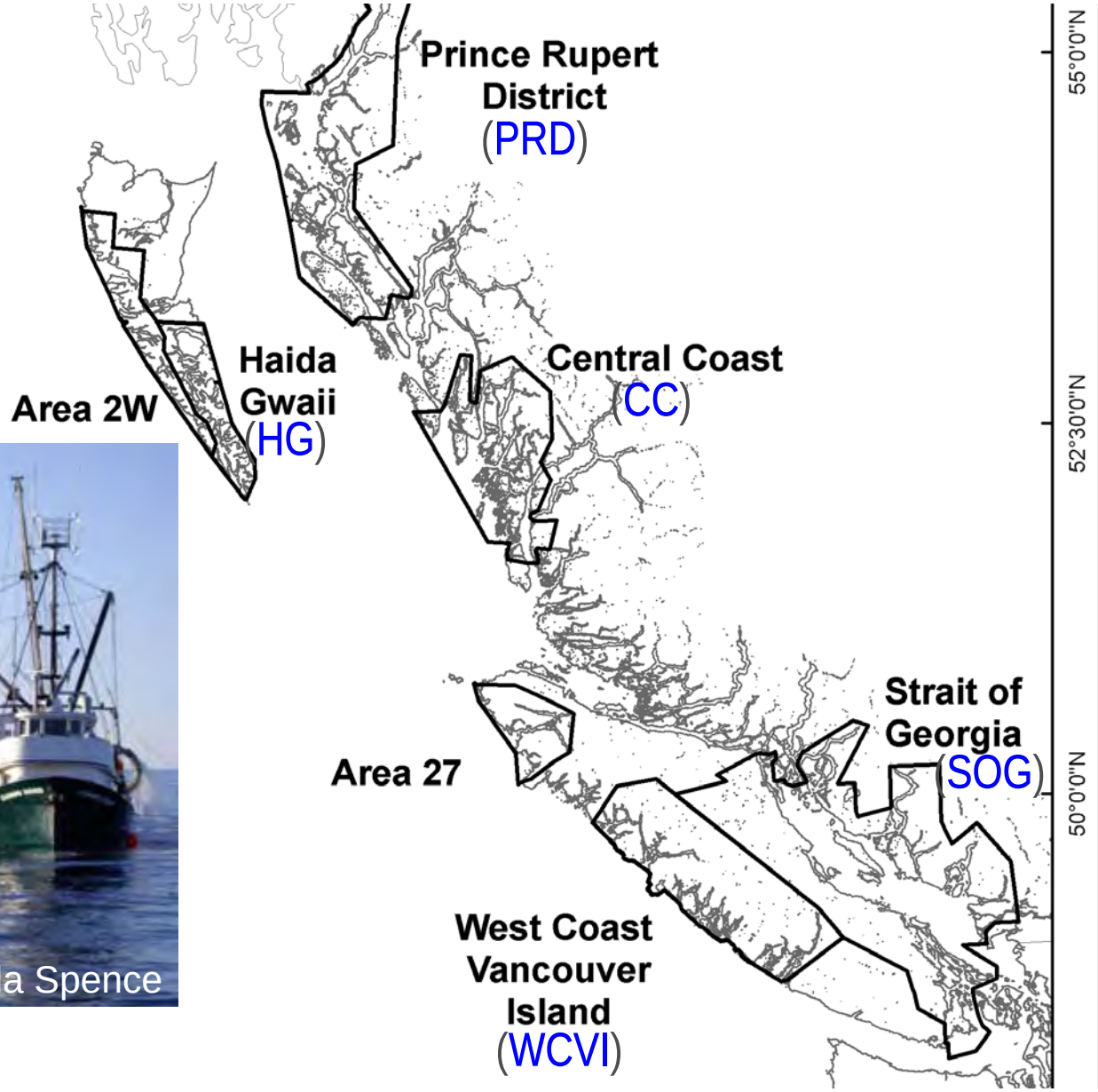
Herring are an important prey species



Canada

British Columbia Pacific Herring

5 major & 2 minor fishing stocks



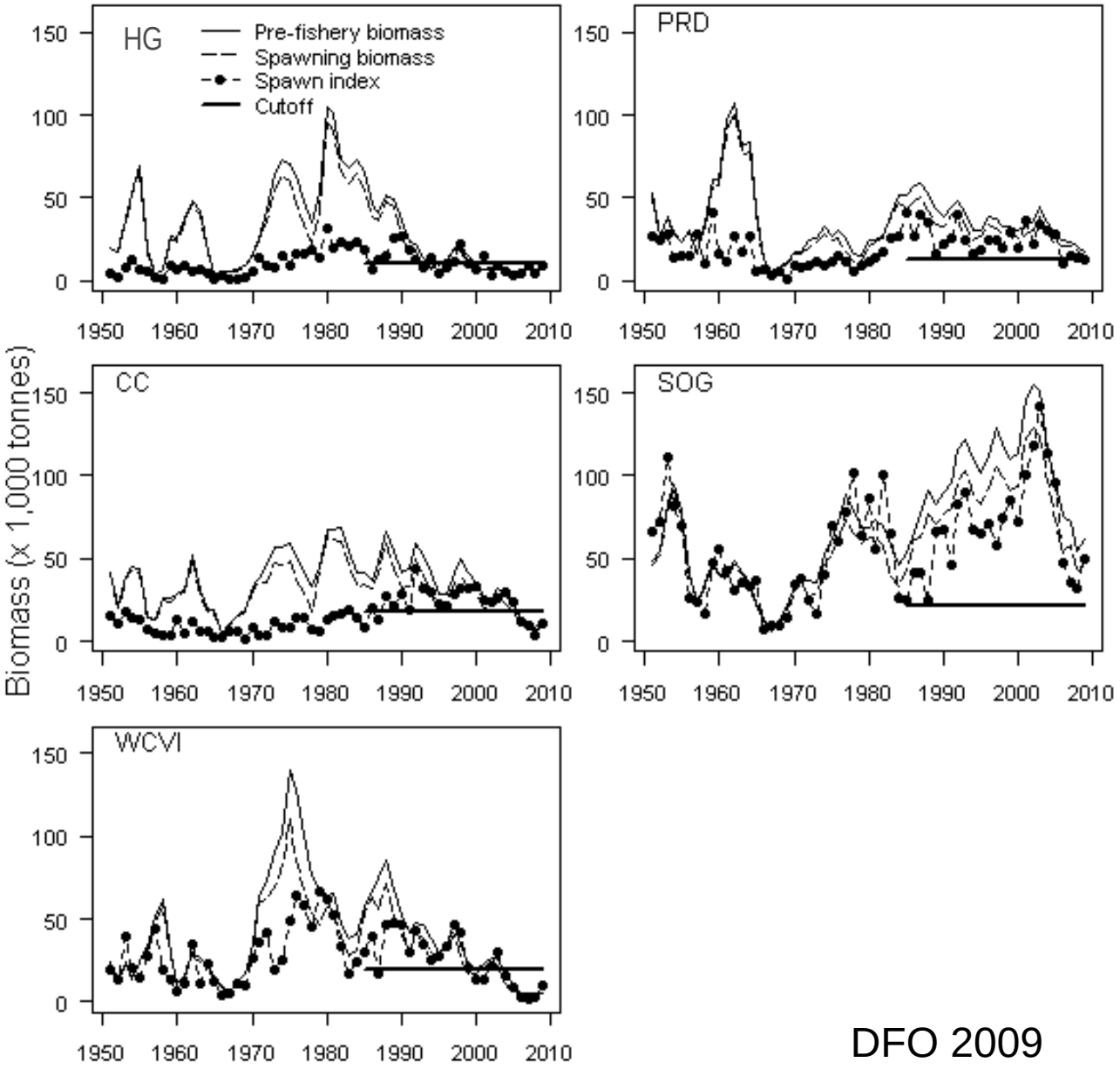
Map courtesy of Kristen Daniel, DFO

DFO 2010

Stock Assessment & Fishery Management

- Catch-Age model using spawn survey data as independent abundance index
- Harvest Control Rule in place since 1986
- 20% fixed harvest rate
- Fishing threshold reference point set at 25% of estimated B_0

Pacific Herring Biomass, 1951-2009



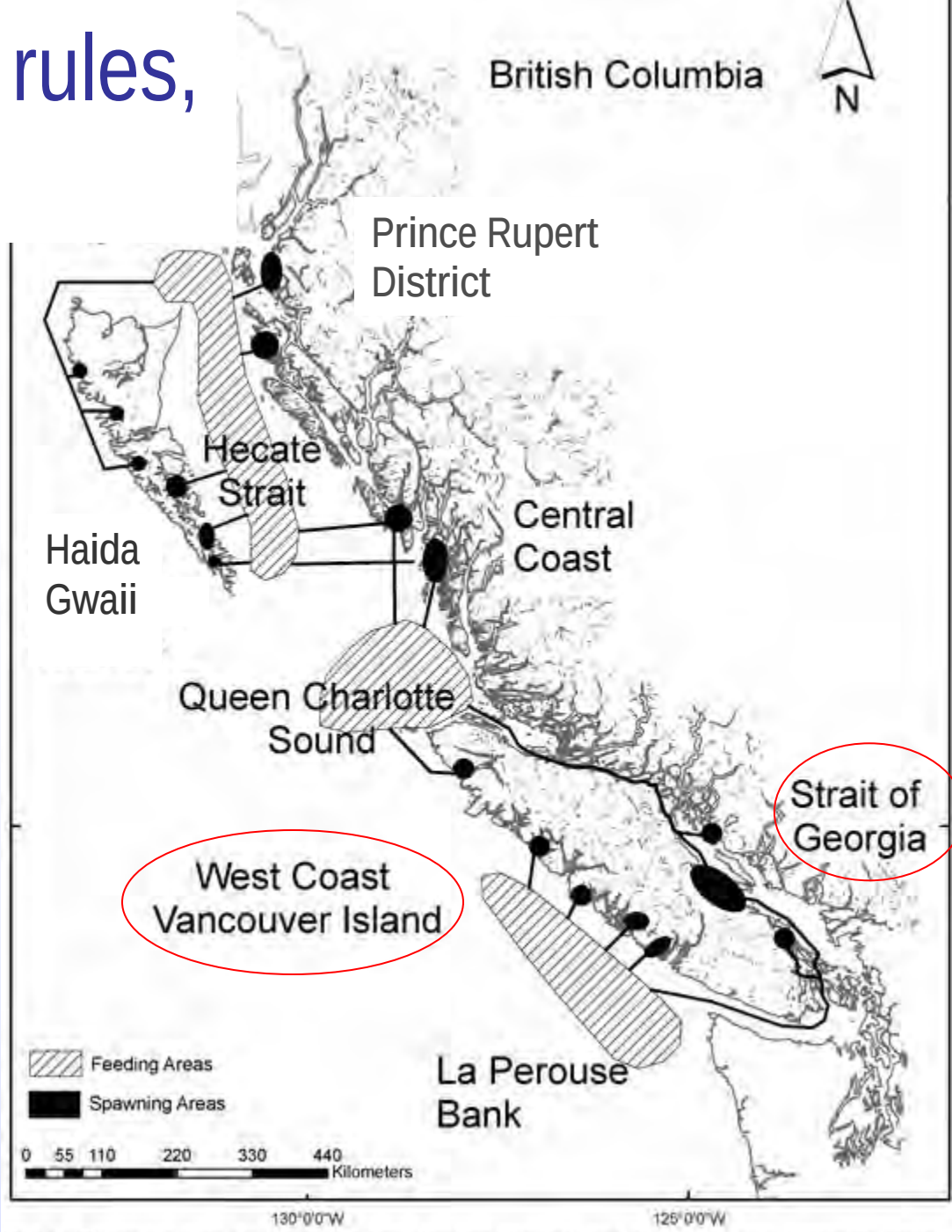
DFO 2009

Pacific Herring

- Most recruit to fishery at age 3
- Recruits can represent up to 50% of the population
- Migrate between summer feeding grounds (mixed stocks) and winter spawning grounds

Recruitment forecast rules, Southern stocks

- Independent estimates of recruitment based on offshore survey (Tanasichuk 2002).
- Proportion age 2+ fish in offshore summery feeding area indicative of proportion age 3 fish on spawning grounds (i.e., recruits).



British Columbia map depicting offshore feeding grounds and major, inshore spawning areas.

Map courtesy of Kristen Daniel, DFO

Recruitment forecast rules, Northern Stocks

- No dedicated survey
- Precautionary Rules:
  1. If pre-fishery biomass < cutoff in previous year, assume POOR recruitment for forecast
  2. If pre-fishery biomass > cutoff in previous year & recruitment good in previous 2 years, assume GOOD recruitment for forecast
  3. If Rule 1 or Rule 2 DO NOT APPLY, assume AVERAGE recruitment for forecast

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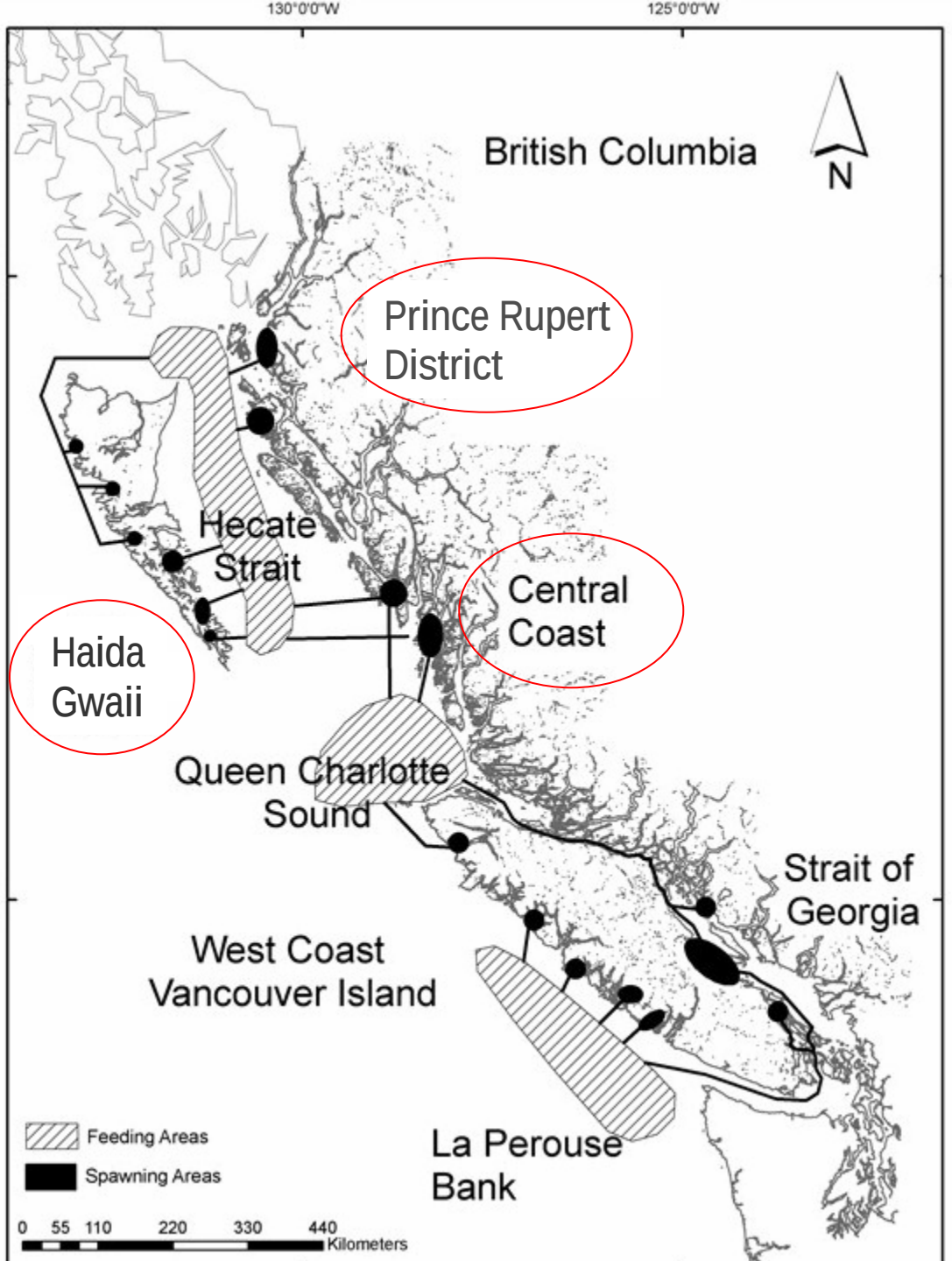
Summer feeding & winter spawning grounds

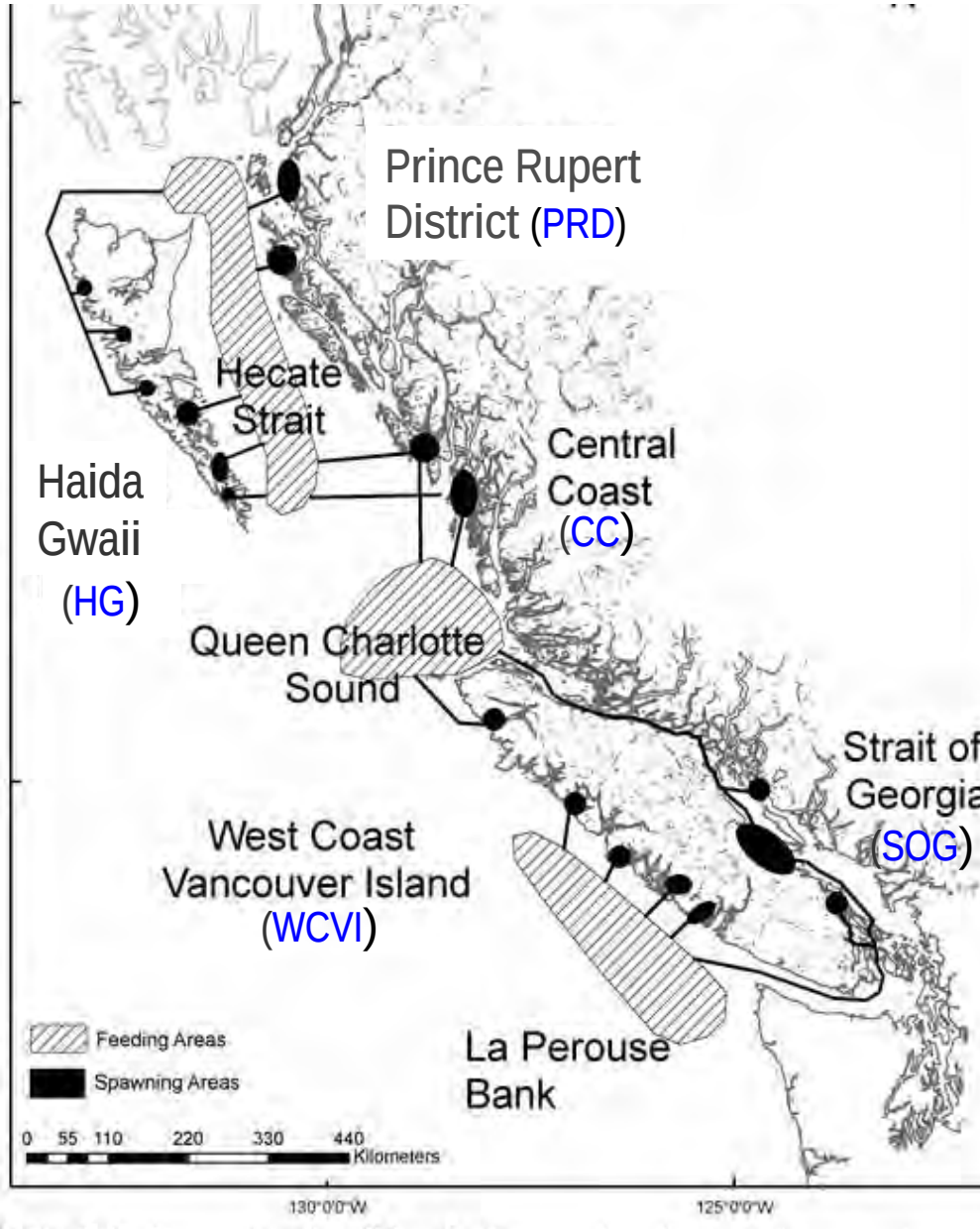


Map courtesy of Kristen Daniel, DFO

Herring Dispersal Related to Temperature

(Ware and Schweigert 2001 and 2002)

- High fidelity to spawning grounds
- Straying rates = 2-25%
- Summer exchange individuals in feeding areas
- Dispersal rate affected by:
  - temp, SSB, recruits



Map courtesy of Kristen Daniel, DFO

Goal, Objectives, Hypotheses

- GOAL: predict recruitment strength to enhance stock assessment and management advice.

- OBJECTIVES:
  1. Examine other survey data for bycatch of herring (groundfish, juvenile salmon, juvenile herring surveys)
  2. Explore potential to provide indices of herring recruitment strength for the three northern stocks.

- HYPOTHESES:
  1. Recruitment to winter fishery related to prop. age 2+ in summer
  2. Recruitment to winter fishery related to summer temperature

Methods

Estimate recruitment strength based on the relationship between:

RESPONSE: recruit fish (prop. age 3 herring) present on spawning grounds (as sampled in herring test fisheries)

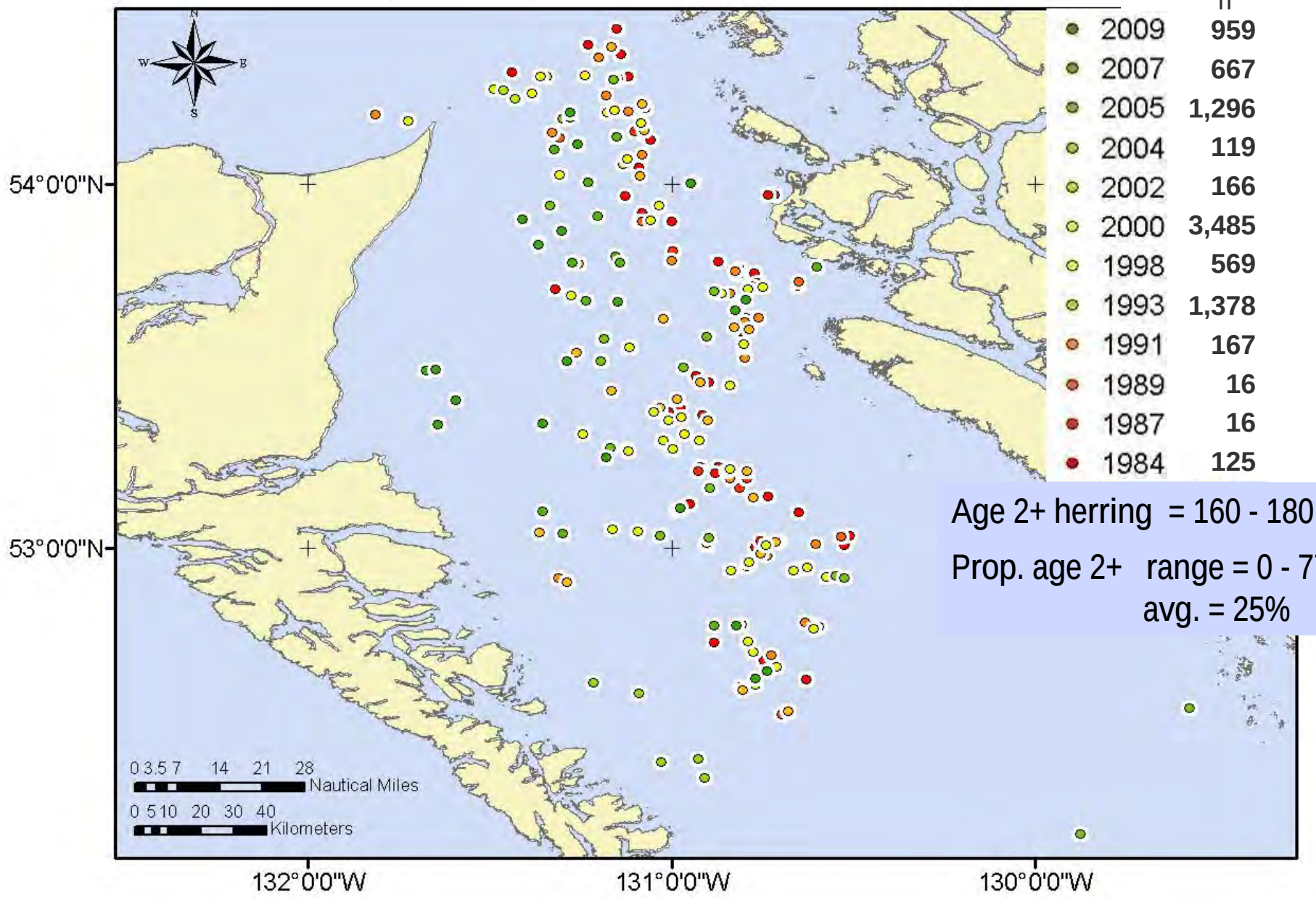
PREDICTOR: pre-recruit herring in summer feeding aggregations (prop. age 2+ fish)

PREDICTOR: average summer sea surface temperature in feeding grounds (BC lighthouse)

Methods

- Test for normality (Shapiro-Wilk)
- Test for autocorrelation (Durbin-Watson)
- Least squares linear regression (recruits ~ survey prop. age 2^+)
- Leave-one-out analysis
- Geometric mean regression (recruits ~ survey prop. age 2^+)
- Multiple regression (recruits ~ survey prop. age 2^+ and SST)

Proportion age 2+ herring in offshore summer feeding grounds sampled by groundfish survey, Hecate Strait

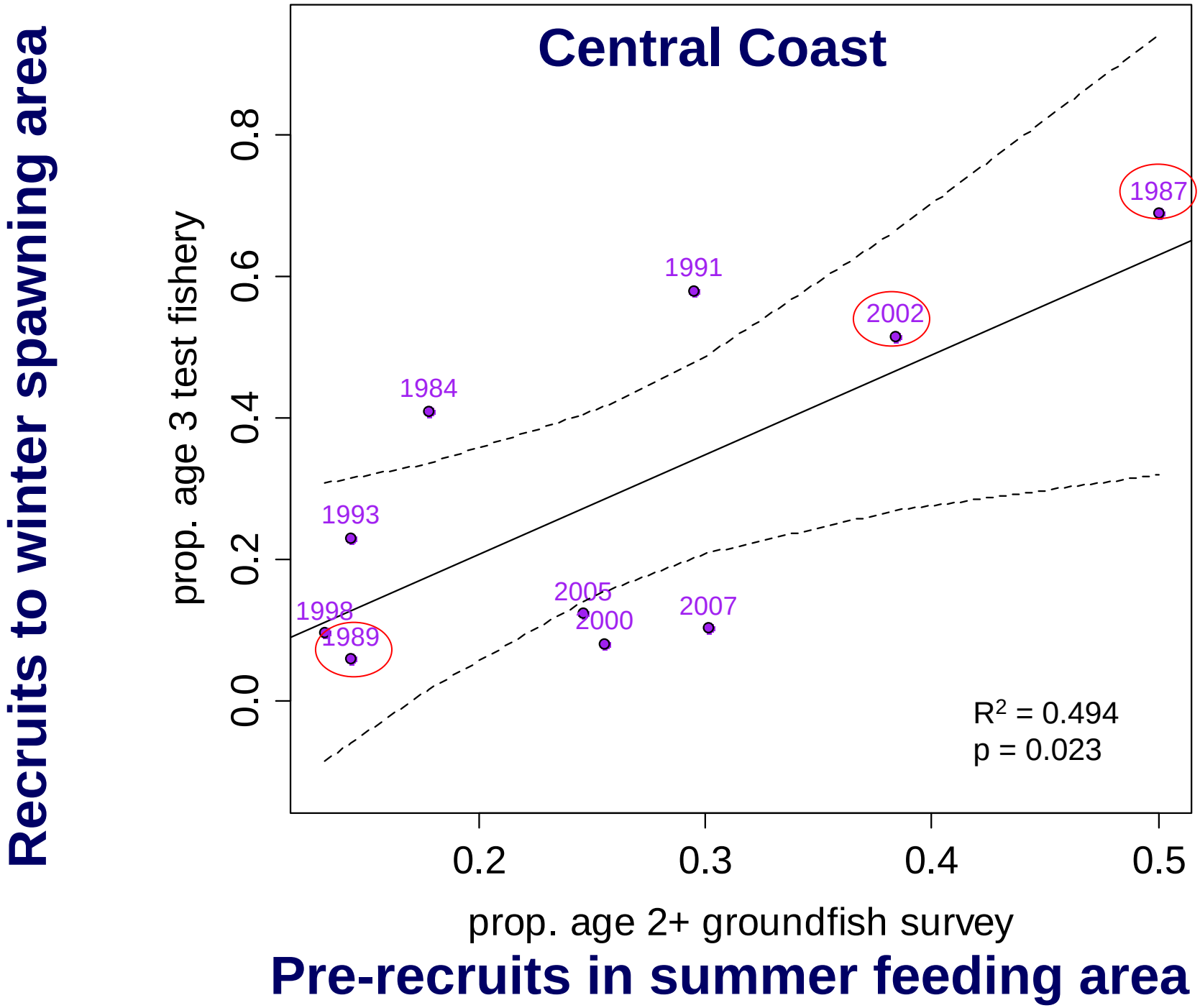


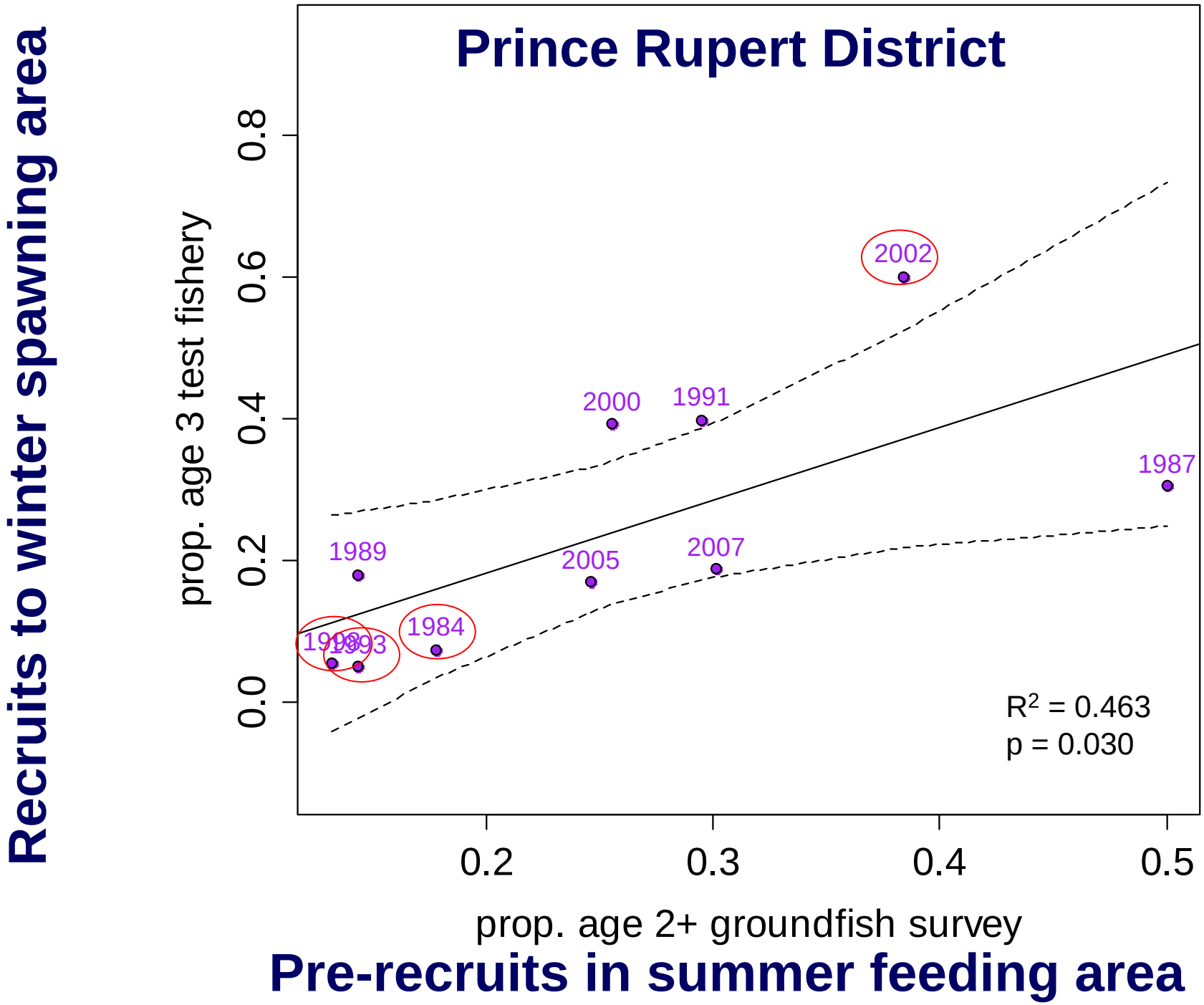
Sample size

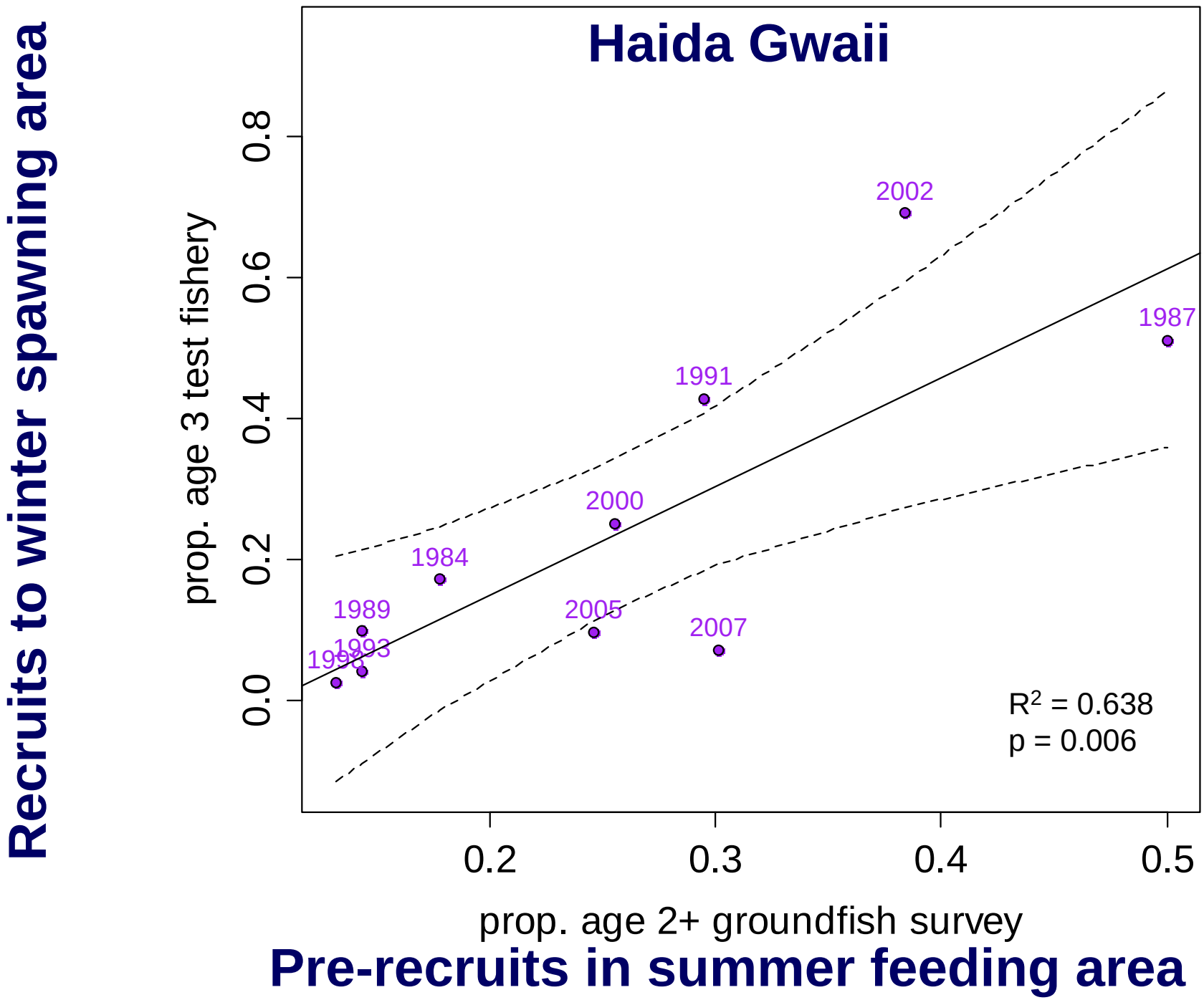
Response: recruit fish (prop. age 3 herring) present on spawning grounds (pre-fishery herring test fisheries)

Year (winter fishery)	CC Adults	CC Age 3	PRD Adults	PRD Age 3	HG Adults	HG Age 3
1985	4,081	1,670	2,869	216	2,653	458
1988	4,181	2,879	2,981	911	1,676	855
1990	4,682	278	4,100	737	3,942	389
1992	6,282	3,641	3,340	1,330	2,294	983
1994	5,472	1,261	5,425	274	1,219	52
1999	3,884	376	1,720	95	487	13
2001	3,052	250	2,710	1,064	913	230
2003	3,454	1,781	2,842	1,705	1,992	1,376
2006	5,135	639	1,663	283	734	72
2008	1,572	162	2,072	391	833	60

Prop. age 3 range = 2 - 69% avg. = 26%


Central Coast
Recruits to winter spawning area
prop. age 3 test fishery
0.0
0.2
0.4
0.6
0.8
1987
1991
2002
1984
1993
2005
2000
2007
1998
1989
R2 = 0.494
p = 0.023
0.2
0.3
0.4
0.5
prop. age 2+ groundfish survey
Pre-recruits in summer feeding area


Prince Rupert District
Recruits to winter spawning area
prop. age 3 test fishery
0.0
0.2
0.4
0.6
0.8
2002
2000
1991
1987
1989
2005
2007
1984
1993
R^2 = 0.463
p = 0.030
0.2
0.3
0.4
0.5
prop. age 2+ groundfish survey
Pre-recruits in summer feeding area


Haida Gwaii
Recruits to winter spawning area
prop. age 3 test fishery
0.0
0.2
0.4
0.6
0.8
2002
1987
1991
2000
1984
1989
2005
2007
1993
1998
R^2 = 0.638
p = 0.006
0.2
0.3
0.4
0.5
prop. age 2+ groundfish survey
Pre-recruits in summer feeding area

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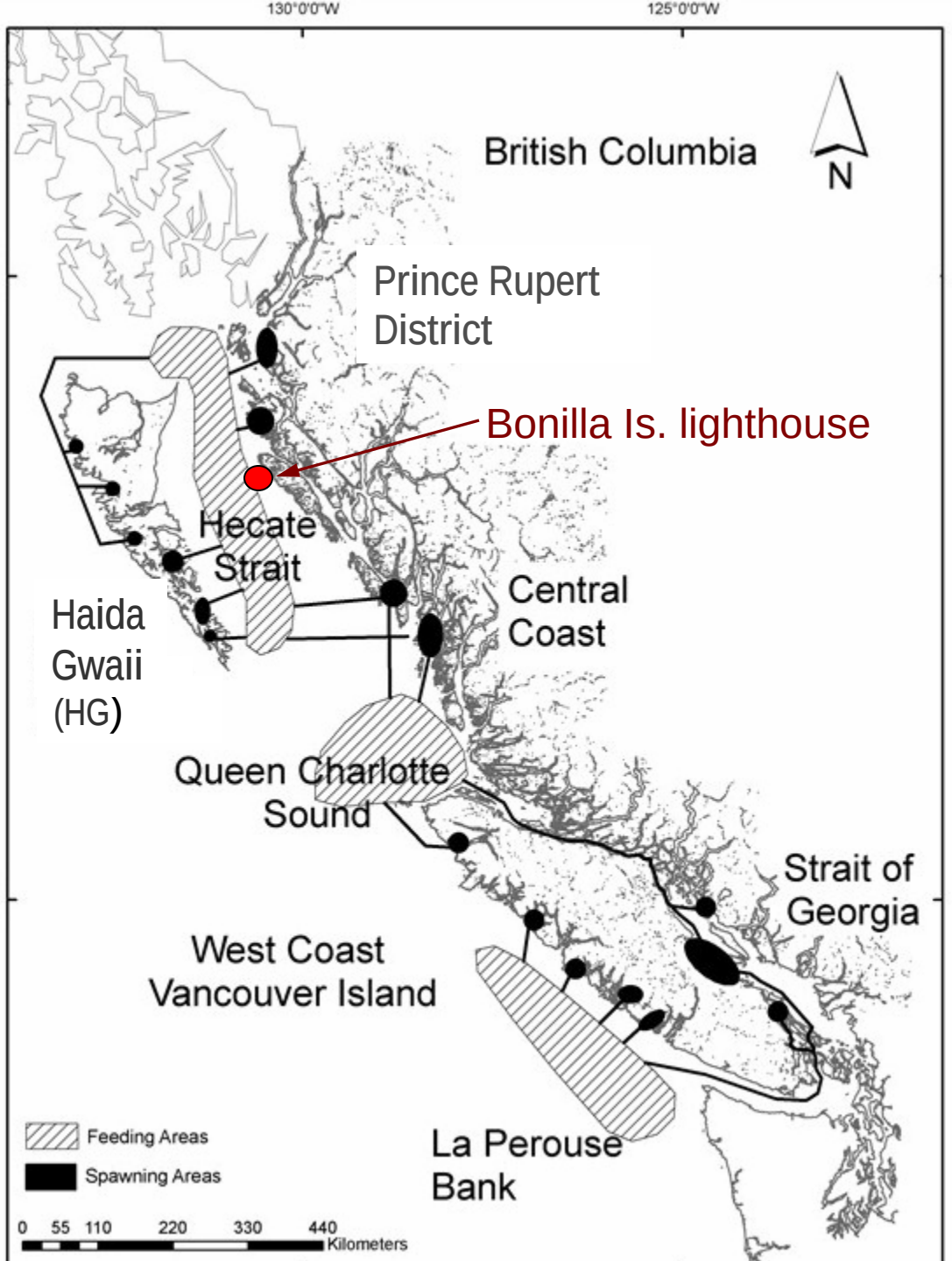
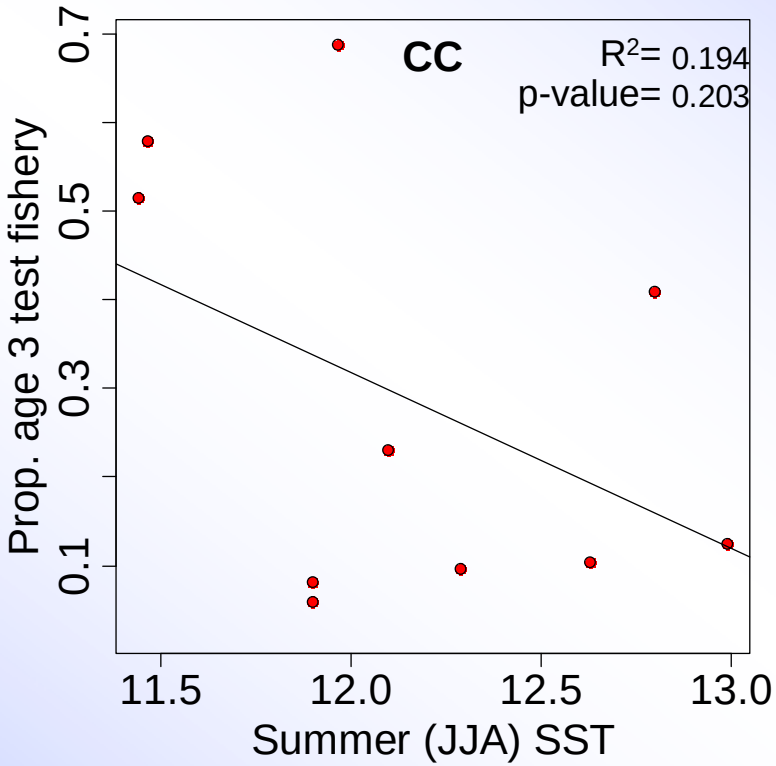
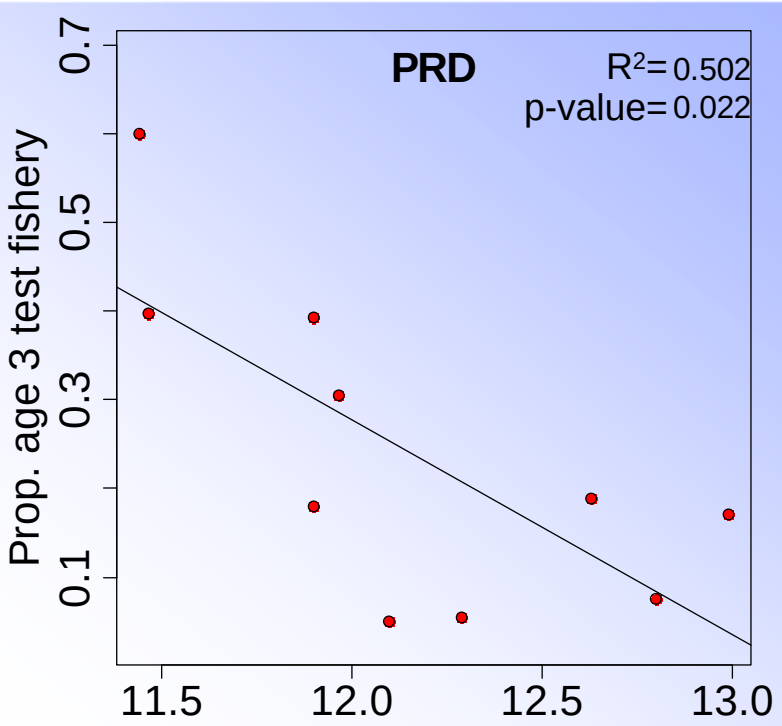
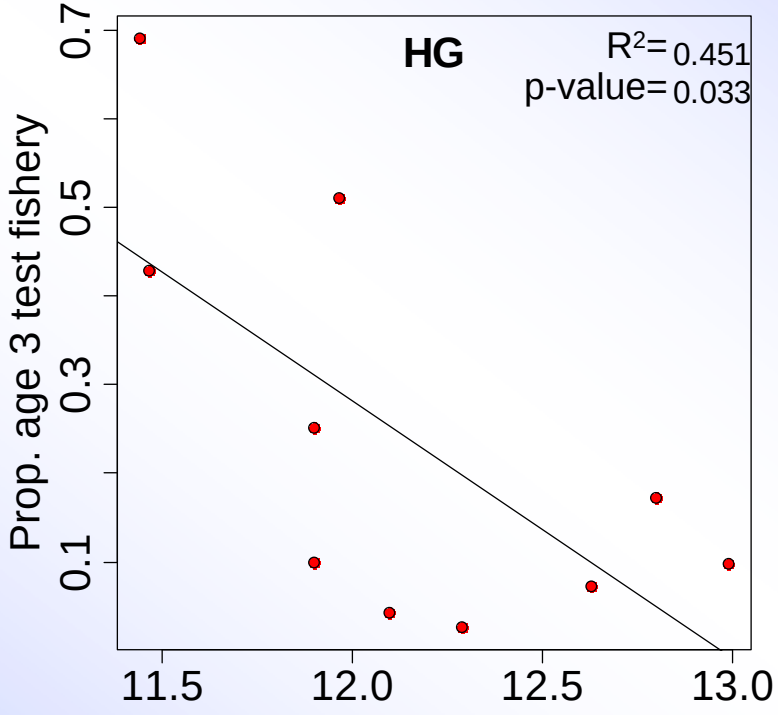
Summer feeding & winter spawning grounds



Map courtesy of Kristen Daniel, DFO







Recruits vs. Summer sea surface temperature

Multiple Regression

Recruits ~ prop. age 2^+ and summer SST

Stock	R^2	p-value Prop. age 2^+	p-value Summer SST
CC	0.544	0.053	0.408
PRD	0.729	0.046 *	0.034 *
HG	0.829	0.006 *	0.027 *

* significant $p<0.05$

Conclusions
Hypothesis 1

- Positive relationship between recruitment to winter fishery and prop. age 2+ in summer.
- Groundfish survey samples sufficient to test hypotheses.
- Lack of annual survey precludes annual recruit prediction.
- Relationships suggest significant mixing of stocks in common summer feeding ground.

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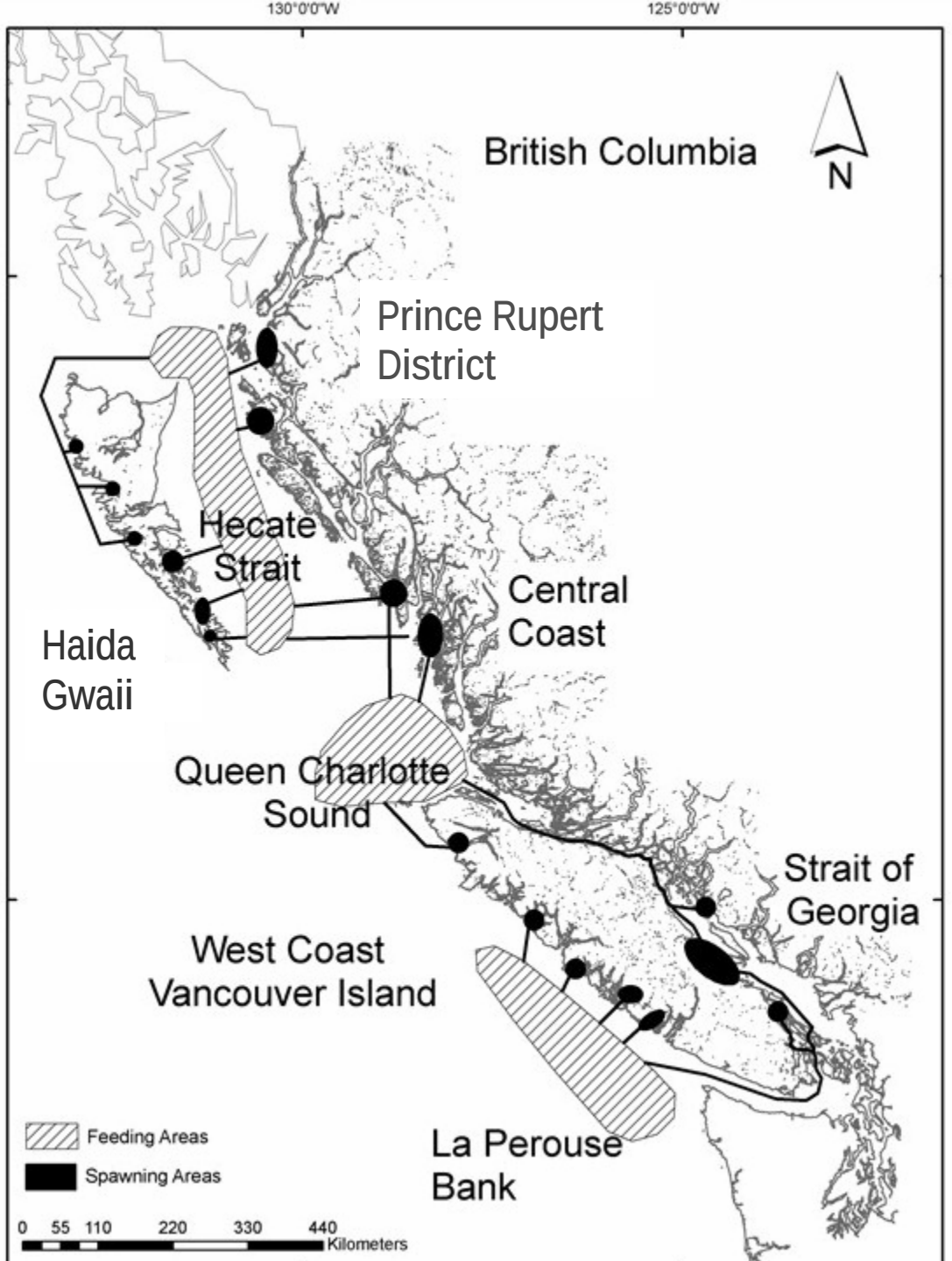
Summer feeding & winter spawning grounds



Map courtesy of Kristen Daniel, DFO

Conclusions

Hypothesis 2

- Negative relationship between recruitment to PRD and HG winter fisheries and summer temp.
- CC recruitment not related to Hecate St. temp. indicating:
  - no relationship with temp., or
  - more fish using QC Sound feeding area (not examined here).

Note: Stocker et al. (1985) dome-shaped relationship between SOG recruits/spawner and temp.

Implications

- Collaboration, coordination across programs:
  - Summer offshore groundfish survey -herring age structure provides predictor of recruitment strength to northern stocks.
- Progress towards increased understanding of climate effects on marine ecosystems:
  - Summer SST improves the prediction (2 of 3 stocks),
  - Temperature changes may affect recruitment strength via dispersal rates between areas.
- Other factors
  - Food availability and/or quality
  - Predator abundance (e.g., cod (Walters et al. 1986))
  - Competitor abundance (e.g., sardine)
  - Larval transport (Ramey and Wickett 1973)

Future Work

- Explore possibility of including recruit forecast in stock assessment.
- Continue using groundfish survey data; explore data in QCS.
- Continue collection of herring recruit data on other surveys (juvenile salmon and herring surveys).
- Explore possibility of dedicated annual herring recruit survey.
- Further explore inclusion of environmental/biological components.

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