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Steller Sea Lion Conceptual Model

Is It Food?

Is it Predation?

Fisheries Competition

Metabolic Disorders

Killer Whales

Declining Steller Sea Lion Population

Which One(s)?

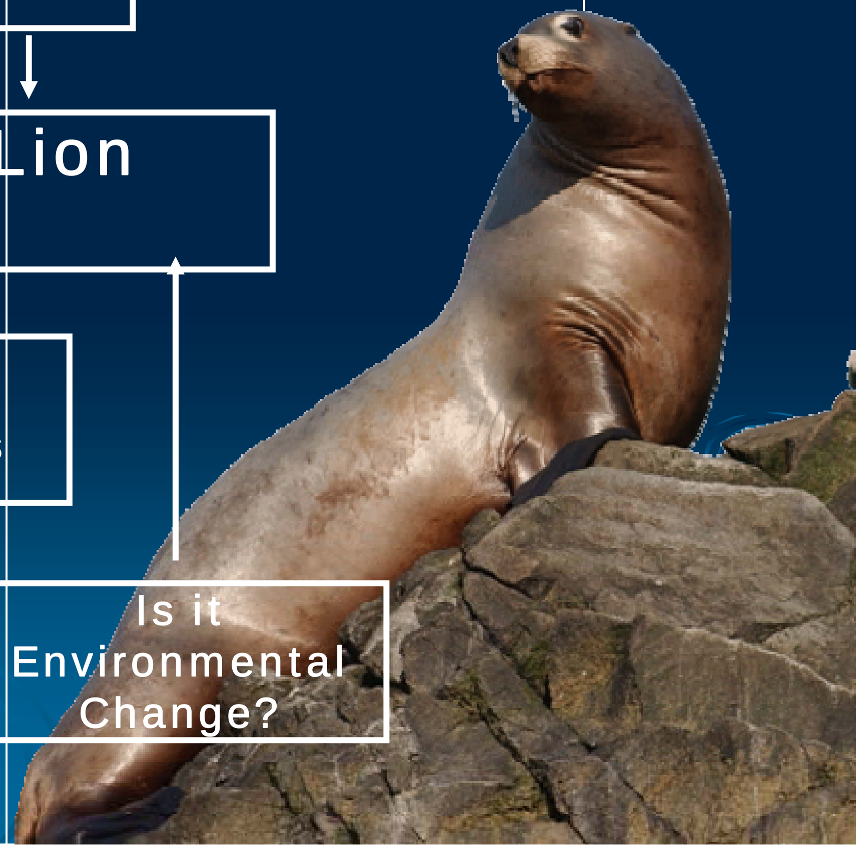
Persistent Organic Pollutants

Heavy Metals

Is it Disease?

Is it Pollution?

Is it Environmental Change?



Manuscript Plan

Master Paper
It's not junk food…
(Calkins)

Diet Papers (lead author)
Diet Morphometrics and Intakes (Burkanov)
Proximate Composition (Inglis)
Proximate Composition (Bando and Norcross)
Rate of Passage Digestibilities (AIA) (Carpenter)

Body Comp Papers
Diet Regime (Atkinson)
Pollock Study (Calkins)

Blood Chemistry/Hormone Papers
CBC's (Castellini)
Hormones (Atkinson)
Captive Hematology/chemistry (Conner)
Wild Steller sea lion Blood (Castellini)
BIA (Castellini)

Impact of Changing Diet Regimes on Steller Sea Lion Body Condition

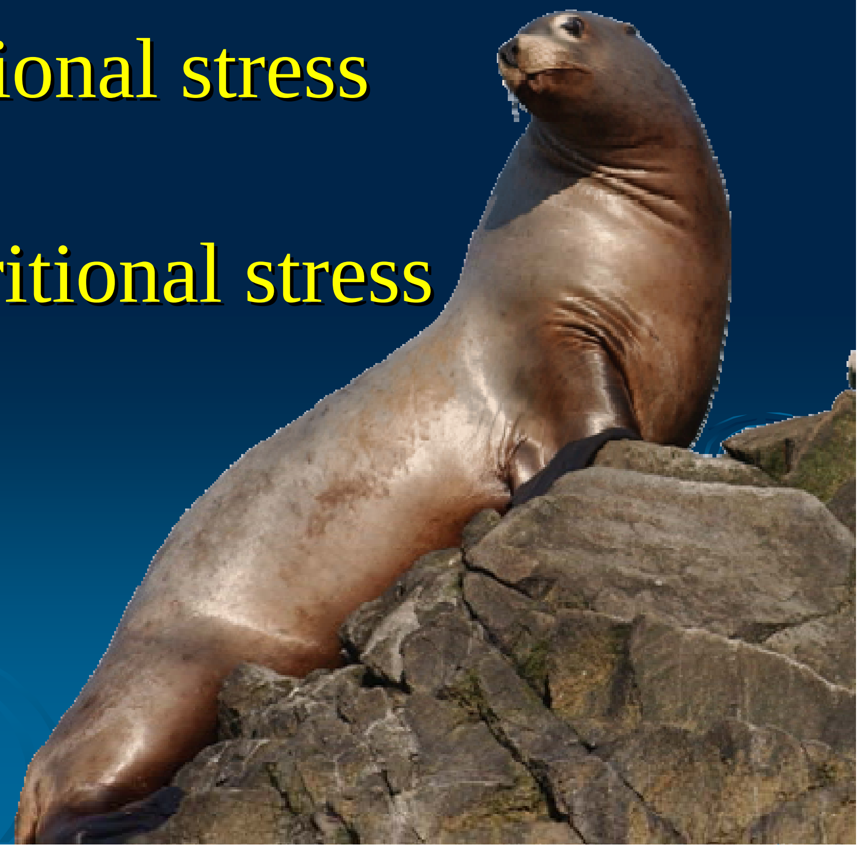
Shannon Atkinson, Donald Calkins, Michael Castellini, Vladimir Burkanov, Susan Inglis, and Daniel Hennen

Theory of Nutritional Stress

Physiological responses to suboptimal quantity or quality of available prey

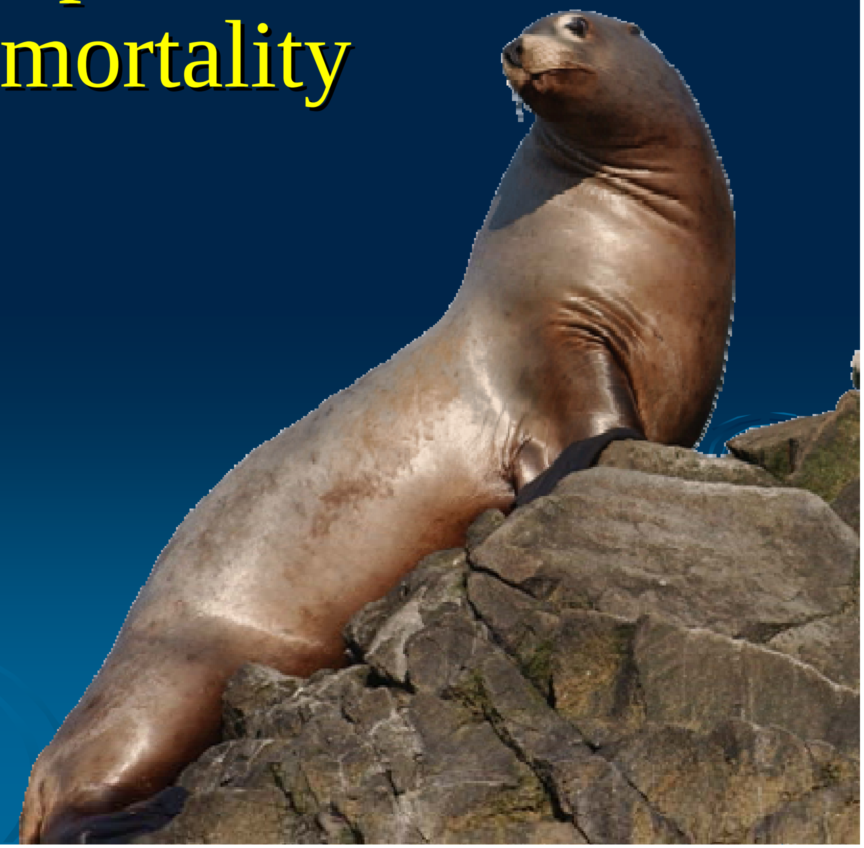
↓ Prey quality → ↑ nutritional stress

↓ Prey abundance → ↑ nutritional stress



Nutritional Stress → Chronic high Juvenile mortality

→ Episodic adult mortality



Calkins, and Goodwin 1998
York. 1994; Merrick 1999

Purpose or Objectives

•Test the hypothesis that Steller sea lions can maintain good health on a diet similar to those found in the Gulf of Alaska prior to the decline, (diet 1) Gulf of Alaska at the height of the decline (diet 2), and southeastern Alaska (diet 3).

•Provide a mixed species diet that was changed at set intervals to allow for a variety of additional physiological measurements

Animal Measurements

- Food intake (in Kg and kCal)
- Body mass
- Body composition (via D_20)
- Blood chemistries and hormones
  (Data not in this talk)
- Each animal on each diet during each season

<table>
<tr><th colspan="2">Pre-Decline</th><th colspan="2">Post-Decline</th><th colspan="2">SE Alaska</th></tr>
<tr><th>SPECIES</th><th>%</th><th>SPECIES</th><th>%</th><th>SPECIES</th><th>%</th></tr>
<tr><td>Walleye Pollock</td><td>60</td><td>Walleye Pollock</td><td>50</td><td>Walleye Pollock</td><td>30</td></tr>
<tr><td>Pacific Herring</td><td>16</td><td>Giant Pacific Octopus</td><td>25</td><td>Pacific cod</td><td>15</td></tr>
<tr><td>Squid</td><td>5</td><td>Flatfish</td><td>17</td><td>Pink Salmon</td><td>14</td></tr>
<tr><td>Capellin</td><td>11</td><td>Sand lance</td><td rowspan="3">6</td><td>Flatfish</td><td>13</td></tr>
<tr><td>Pacific cod</td><td>1</td><td>Pacific cod</td><td>Pacific Herring</td><td>14</td></tr>
<tr><td>Pink Salmon</td><td>6</td><td>Pink Salmon</td><td>Rockfish</td><td>7</td></tr>
<tr><td></td><td></td><td></td><td></td><td>Cephalopods</td><td>5</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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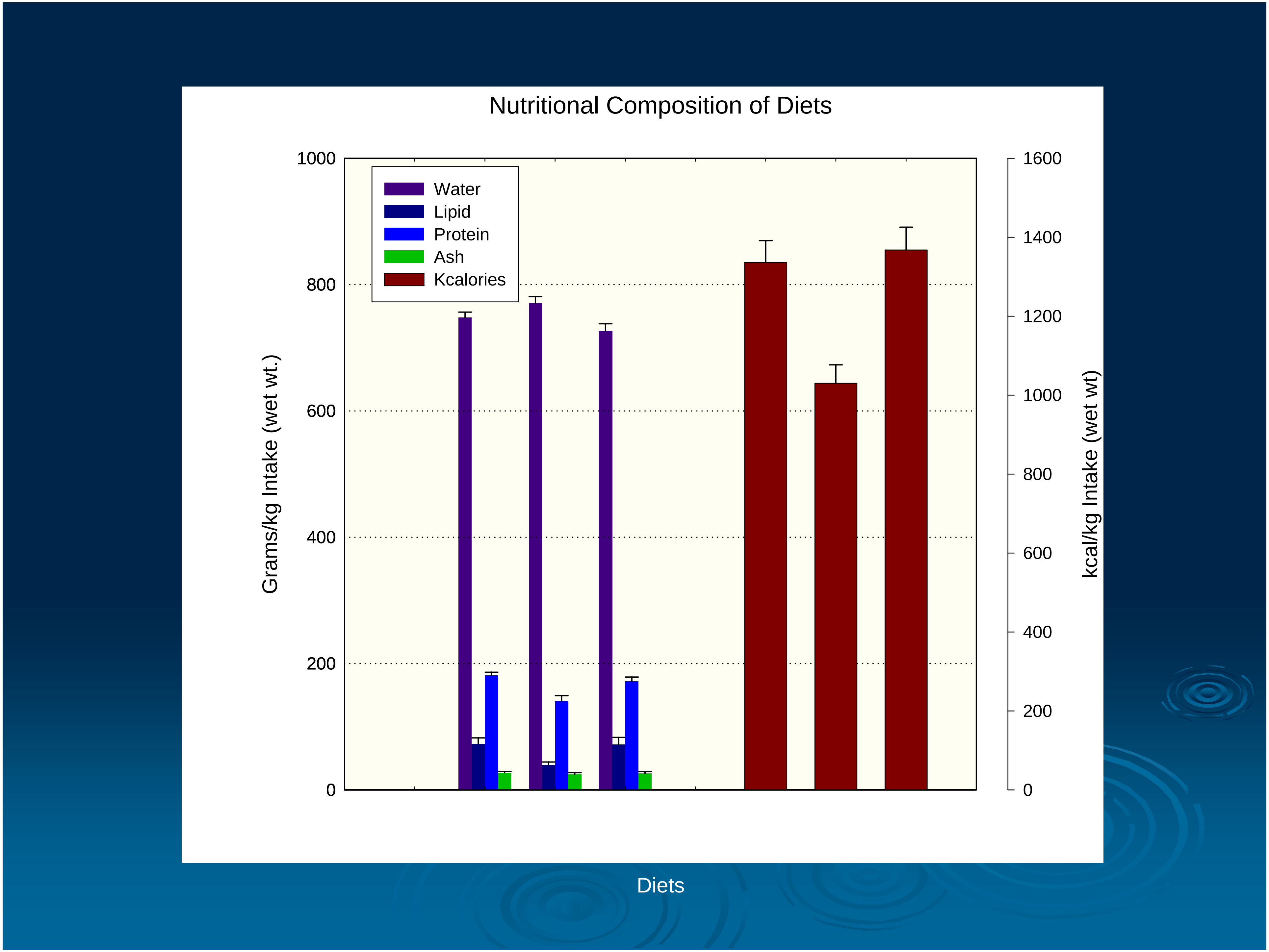
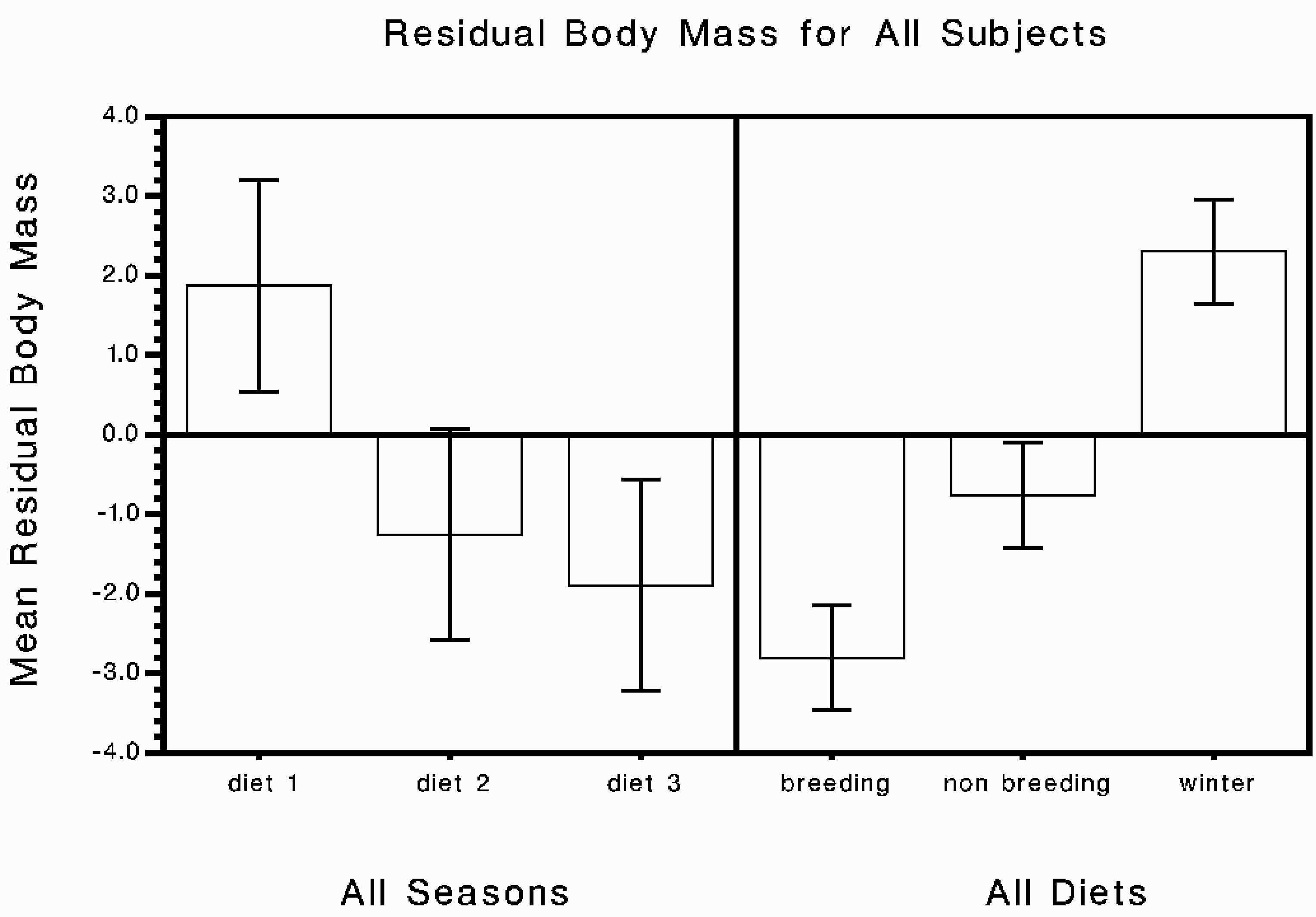
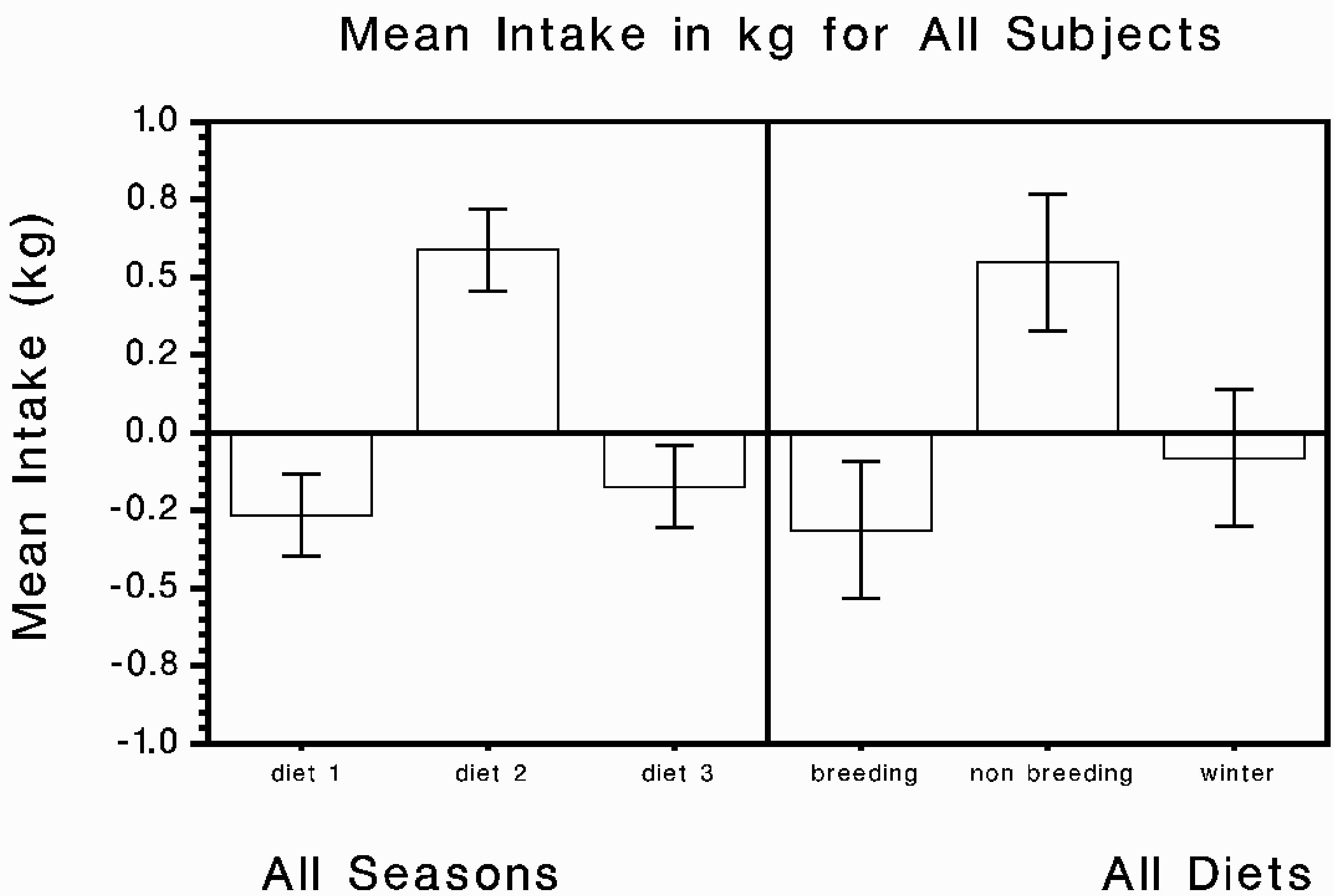
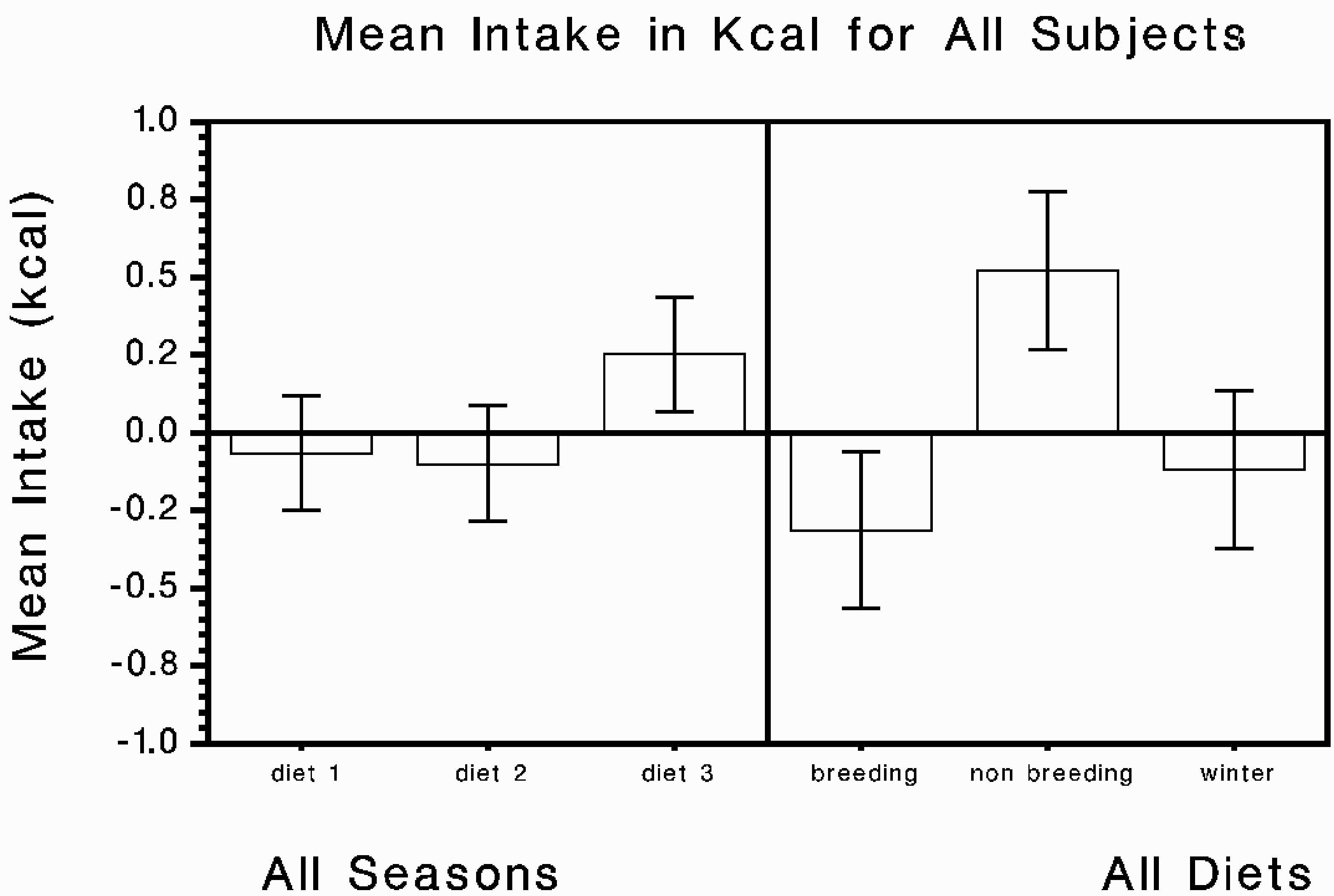

Nutritional Composition of Diets
Water
Lipid
Protein
Ash
Kcalories
Grams/kg Intake (wet wt.)
kcal/kg Intake (wet wt)
0
200
400
600
800
1000
1200
1400
1600
Diets

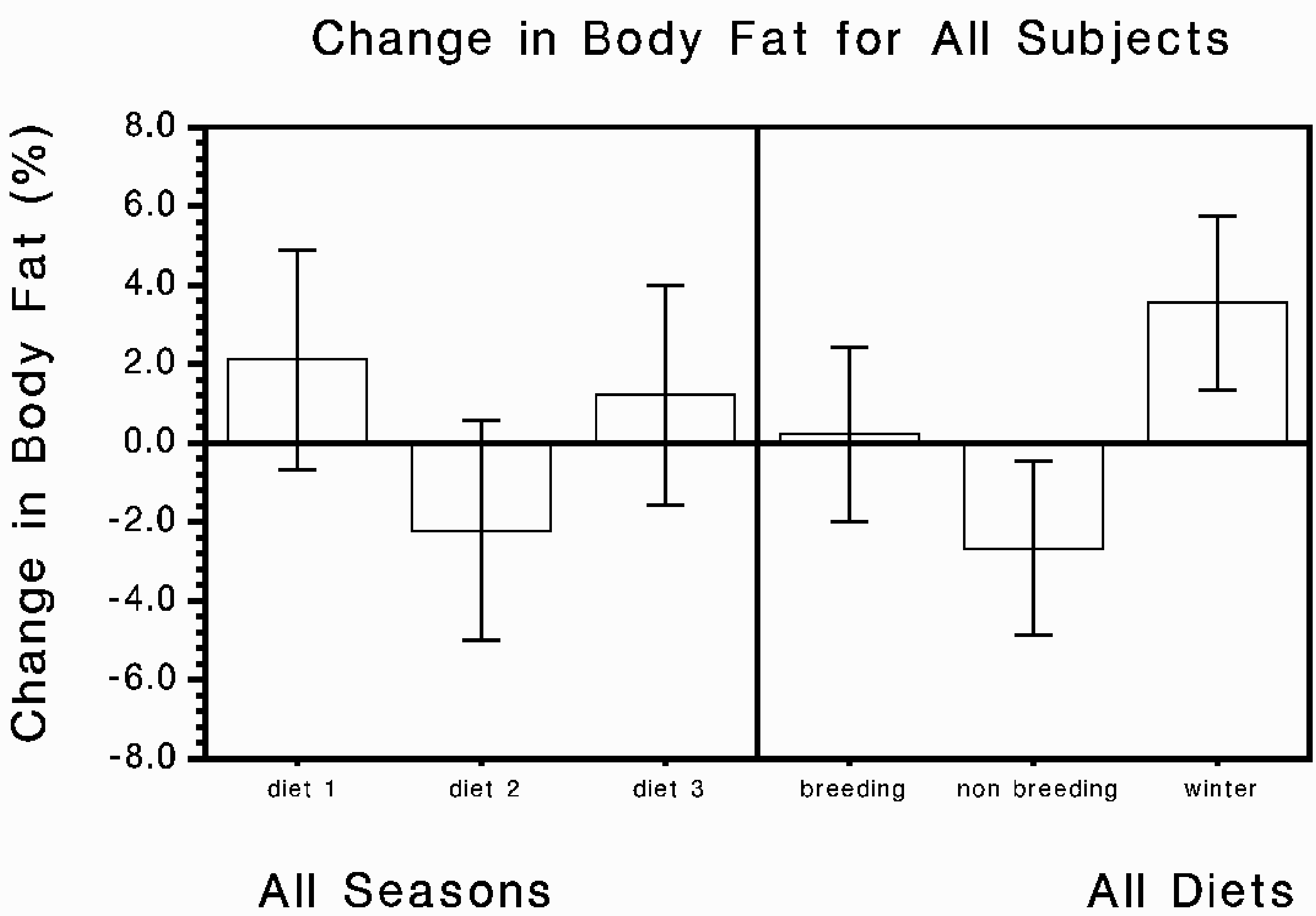


Residual Body Mass for All Subjects
Mean Residual Body Mass
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
diet 1
diet 2
diet 3
breeding
non breeding
winter
All Seasons
All Diets



Mean Intake in kg for All Subjects
Mean Intake (kg)
1.0
0.8
0.5
0.2
0.0
-0.2
-0.5
-0.8
-1.0
diet 1
diet 2
diet 3
breeding
non breeding
winter
All Seasons
All Diets


Mean Intake in Kcal for All Subjects
Mean Intake (kcal)
1.0
0.8
0.5
0.2
0.0
-0.2
-0.5
-0.8
-1.0
diet 1
diet 2
diet 3
breeding
non breeding
winter
All Seasons
All Diets



Change in Body Fat for All Subjects
Change in Body Fat (%)
8.0
6.0
4.0
2.0
0.0
-2.0
-4.0
-6.0
-8.0
diet 1
diet 2
diet 3
breeding
non breeding
winter
All Seasons
All Diets

Conclusions

Response to diet seen mainly in food intake

a) Biomass consumed increased on diet 2 and during Non-breeding seasons

b) Little difference in caloric intake on diets, but still greater intake in non-breeding season.

Discussion in relation to theory

1. Opportunistic feeders
2. Plastic foraging strategies
3. ↓ quality → ↑ intake of biomass
4. Prey biomass not lacking

Thus: Inadequate quantity or quality of available prey not likely responsible for the decline of SSL

But . . .

1) **Captive study limits extrapolation to free-ranging sea lions**

2) **Experimental design only focused on sub-adult animals – doesn’t account for other life history stages**

3) **Still need to account for indices that reflected possible nutritional effects**

4) **No accounting for localized depletion**


Does Consuming Pollock Truly have Negative Impacts on Steller Sea Lions?
By
Don Calkins, Jo-Ann Mellish, Shannon Atkinson and Daniel Hennen

Manuscript Plan

<u>Master Paper</u>
It's not junk food…
(Calkins)

<u>Diet Papers (lead author)</u>
Diet Morphometrics and Intakes (Burkanov)
Proximate Composition (Inglis)
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CBC's (Castellini)
Hormones (Atkinson)
Captive Hematology/chemistry (Conner)
Wild Steller sea lion Blood (Castellini)
BIA (Castellini)

Introduction

- Work done at Alaska Sealife Center in transient juvenile facility
- Nutritional stress as a cause of the decline
- Importance of pollock in sea lion diets

Introduction Continued

- Junk food hypothesis
  - Presumption of nutritional deficiency from heavy reliance on pollock (Alverson 1992)
  - Rosen and Trites (2000) concluded juveniles are unable to consume sufficient pollock to maintain mass

- Testing the junk food hypothesis
- ASLC transient juvenile Steller sea lion research facility

Experiment:

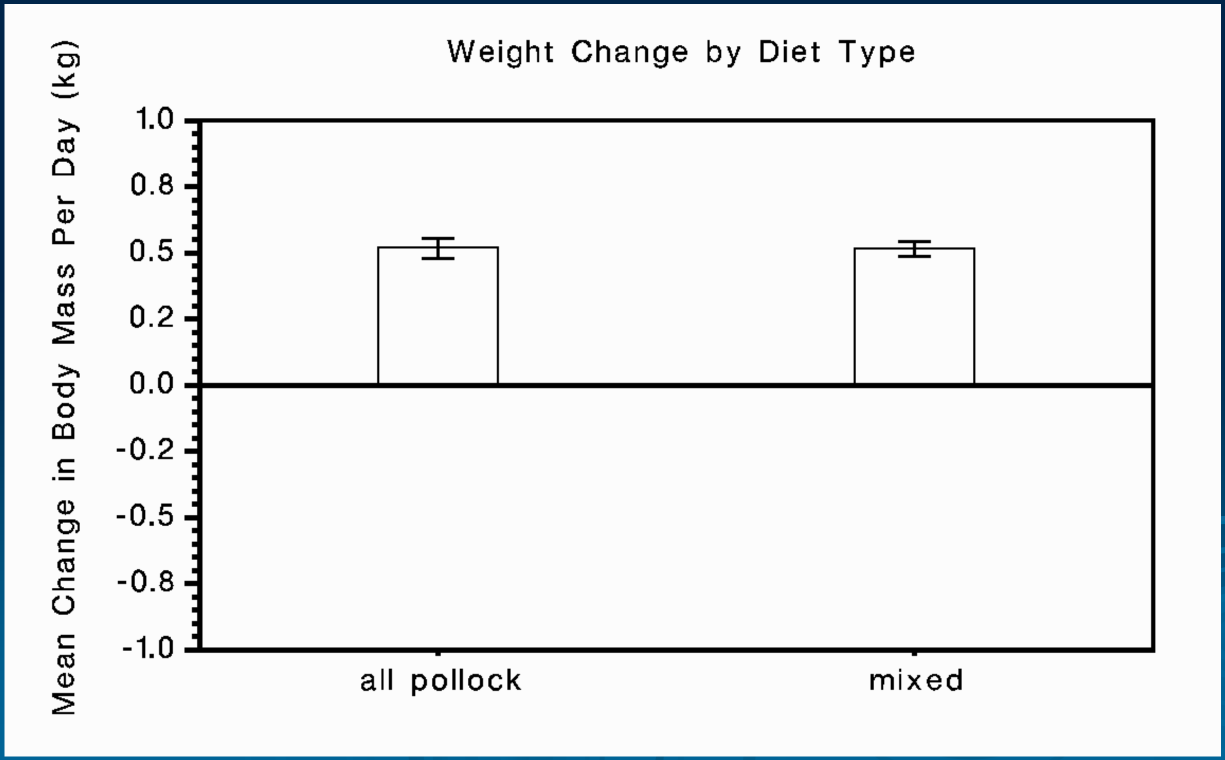
- 7 experimental sea lions (2 groups)
  - 14 to 21 months of age
  - 23 July – 30 September 2004 (2m, 1f)
  - 22 February- 28 April 2005 (3m, 1f)
- 4 control sea lions (2 groups)
  - 12 to 15 months of age
  - 21 August - 2 October 2003 (1m, 1f)
  - 20 October - 2 December 2003 (1m, 1f)

Experiment cont'd:

- 100% Pollock Treatment
  - Group 1: 11.0 kg pollock daily for average of 46d
  - Group 2: 11.9 kg pollock daily for 55d
- Control Group
  - Group 1: 5.6 kg mixed species daily for 32d
  - Group 2: 8.4 kg mixed species daily for 48d

Results

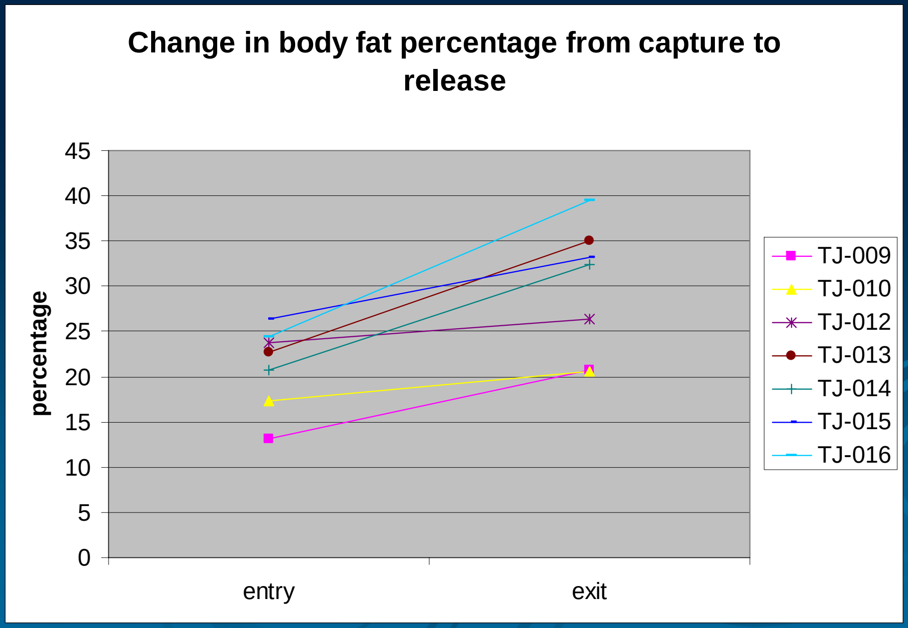
- All animals in both treatment and control groups gained mass
  - No significant difference in mass gain between treatment and control



Results continued

- Animals in treatment group gained fat mass as part of body mass
  - Average % body fat at capture was 20.0 % (+ 1.92%) and at release was 28.2 (+ 2.83 %)
  - Gain in mean body fat was statistically significant ($t_{0.05,12} = -2.606$, $p=0.023$)

Change in percent body fat from capture to release of treatment group



Discussion

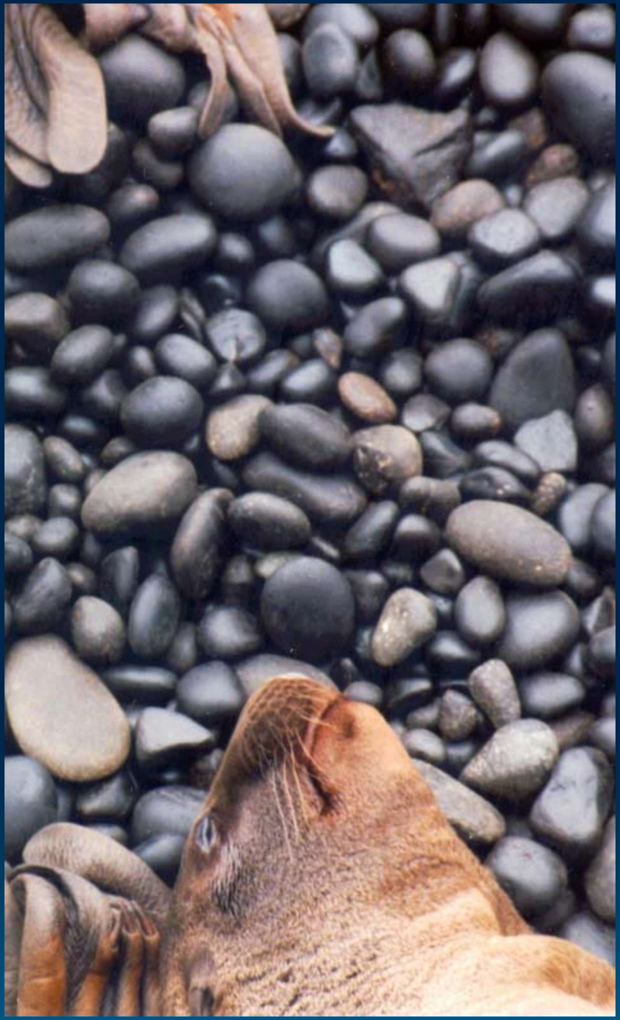
- By all measures the animals remained clinically healthy while consuming exclusively pollock over a 48 day period
- All animals gained both lean and fat mass with no significant differences between treatment and control groups
- In comparing the western stock during it's decline and eastern stock that has increased, both relied heavily on pollock

Discussion and Conclusions

- We found no negative health effects from consumption of pollock to juvenile Steller sea lions when quantities were sufficient
- Differences between this study and other pollock feeding trials
  - Test animals were not trained, permanent captive sea lions
  - Feeding was done through a fish cannon rather than by hand
  - Animals fed ad libitum rather than maintenance diet

Conclusions

Finally, I think that sea lions only occasionally feed on single species and probably only for short periods



Associations Between the Steller Sea Lion Decline and the Bering Sea / Gulf of Alaska Fishery

Ecological Applications

Daniel Hennen
Alaska SeaLife Center

What We Know

- The SSL decline was steeper in the 1980's than it was in the 1990's
- There was much more regulation regarding SSL in the 1990's than the 1980's

What Were The Regulations?

- Killing SSL now illegal
- Fishing excluded from areas immediately surrounding SSL rookeries
- Fishing effort spread out over time and space

Question

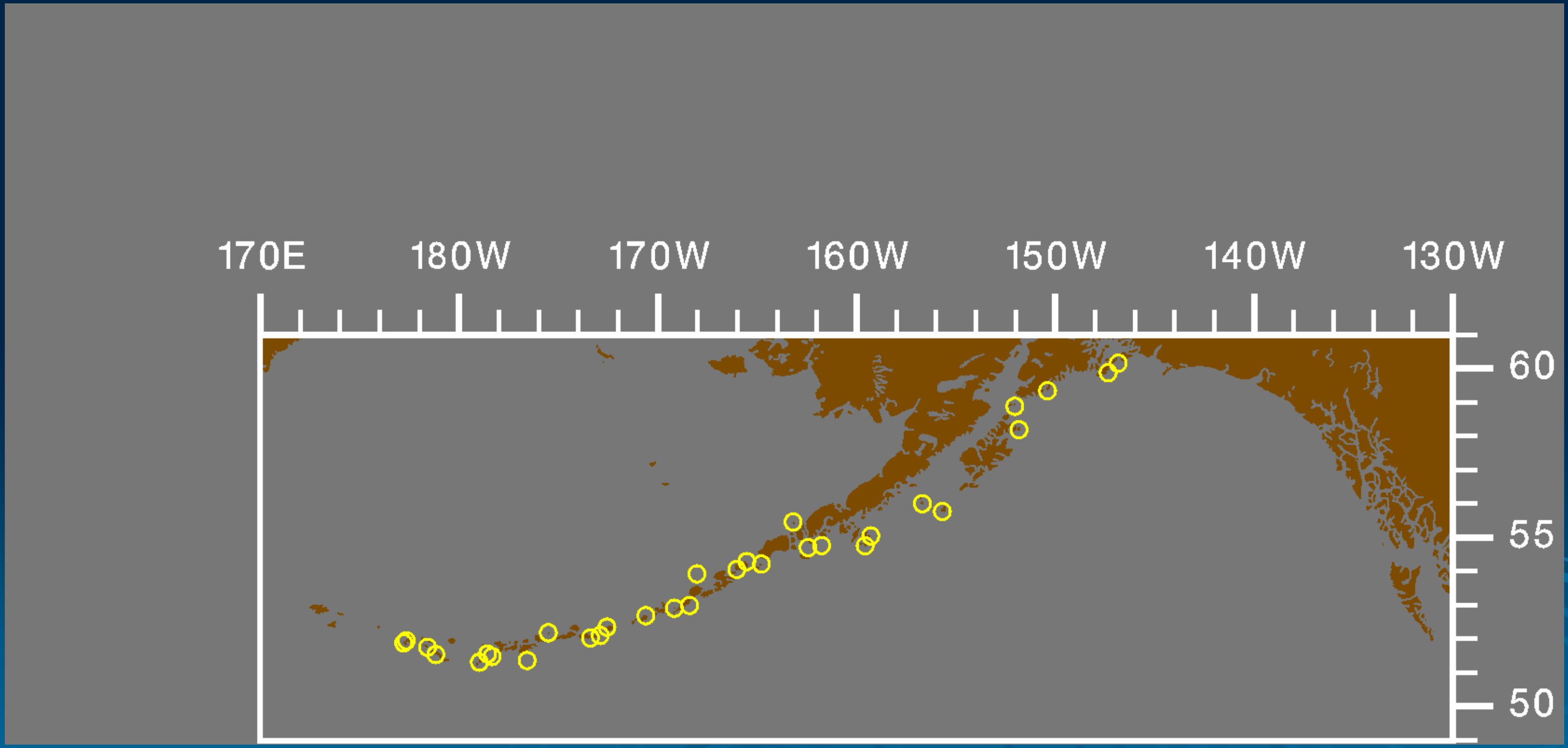
- Is there a pattern in the SSL decline that is associated with fishing activity?

SSL Data

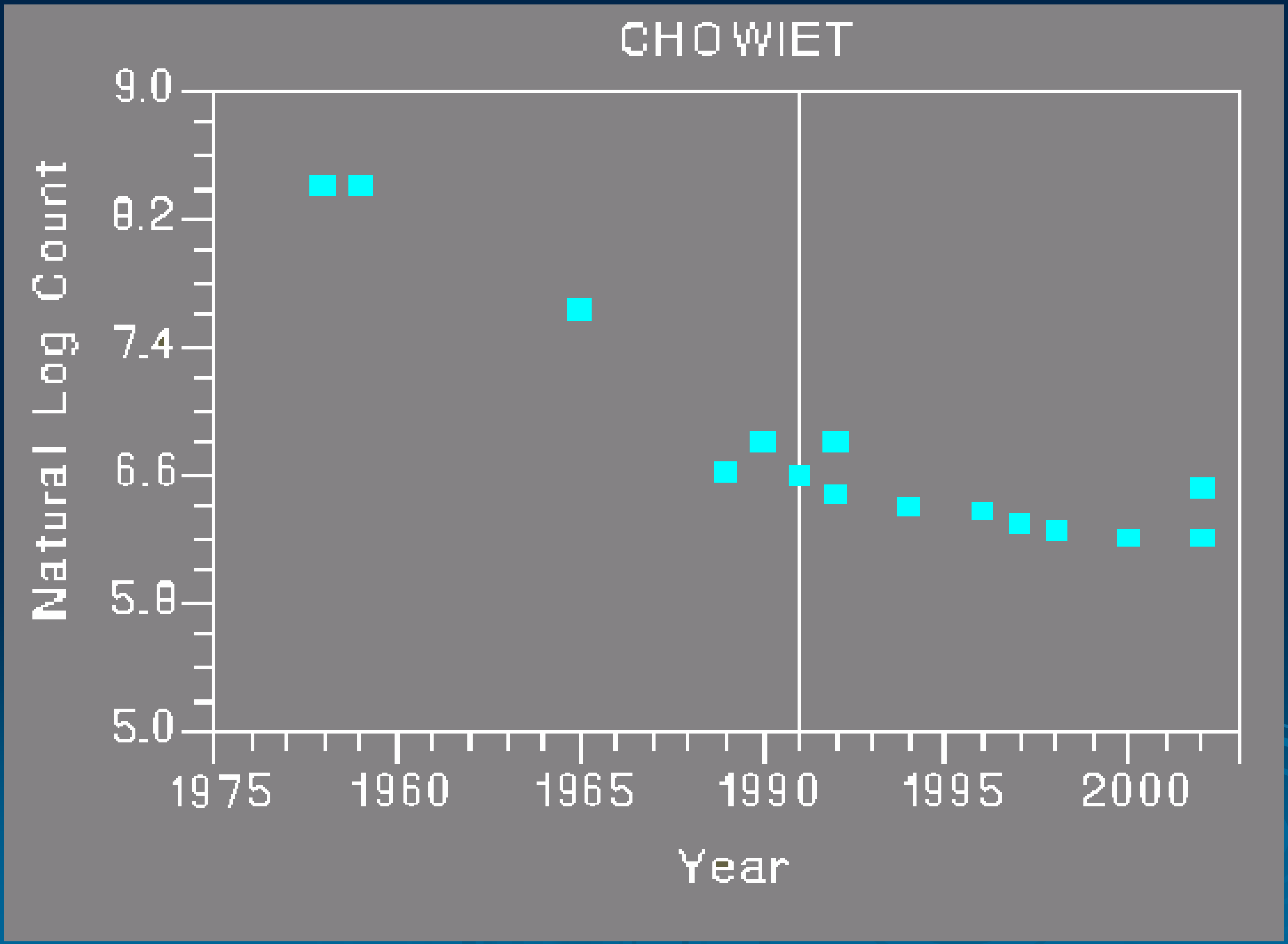
- From NMFS Adult Count Database
- 1977 - 2001
- Examines data on the level of the individual rookery (only rookeries included)
- Sites west of 144º longitude

SSL Data

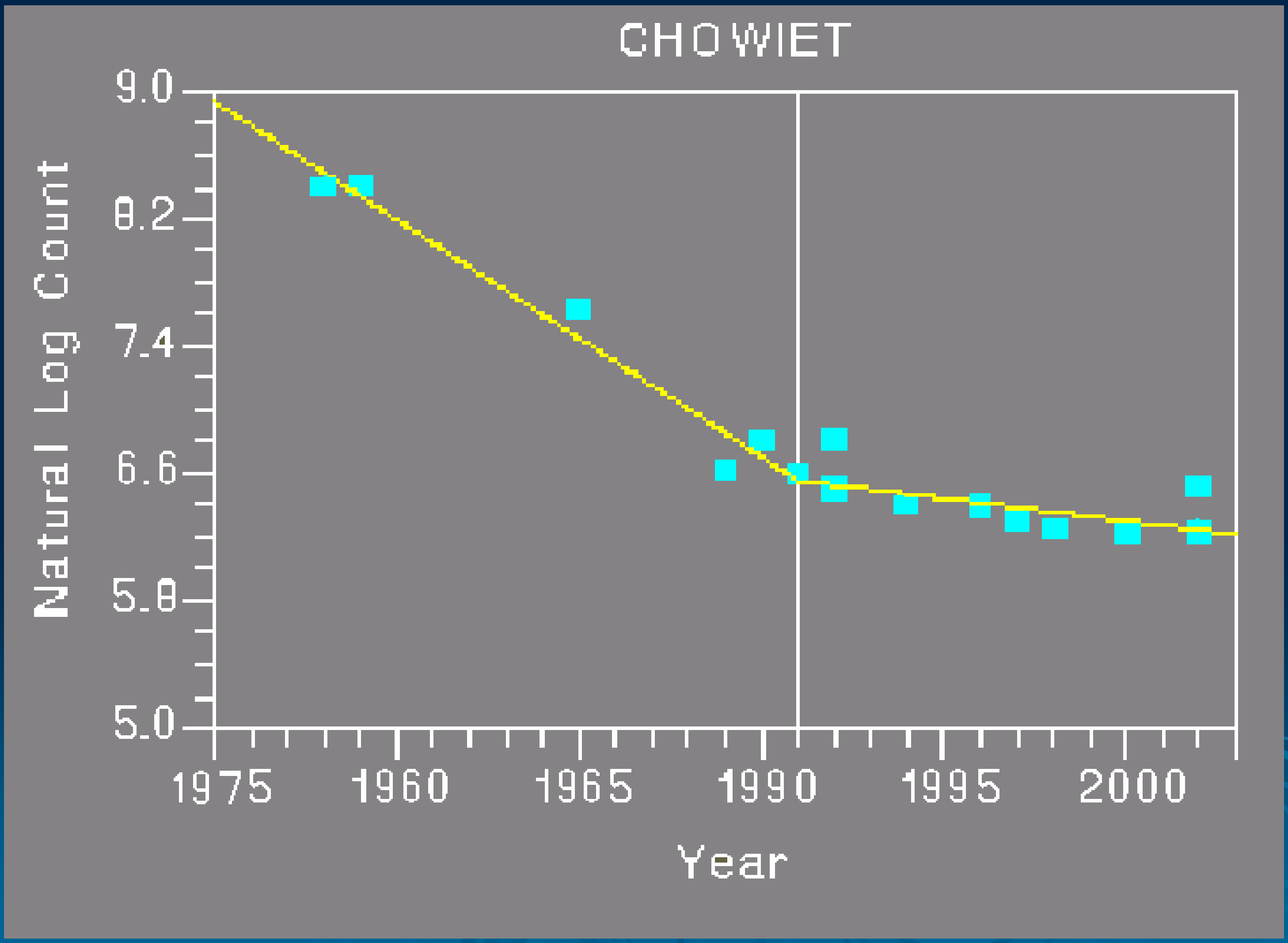
- 33 rookeries had enough observations to be included



Population Trend Estimates



Data Fit Numerically



Fisheries Data

Fisheries Data

- From NMFS Observer Database

1977 – 2000

- Corrected for observer coverage with a simple expansion
  - Year
  - Size of vessel

Fisheries Data

- Lumped into two time periods
  - 1977 – 1991
  - 1991 – 2000

Fisheries Data

- Measures of fishing activity are:
  - Number of hauls in a time period (num)
  - Sum of the weight (catch + bycatch) taken in a time period (sum)
  - Duration, ‘soak time’ of gear employed (dur)
- NUM, SUM, DUR

Fisheries Data

- Measures of fish abundance are:
  - SUM / DUR in a time period, a measure of CPUE
- CPU

Fisheries Data

- CPU is highly correlated with NUM, SUM and DUR.

PC 1 accounts for 72% of the variation in the data

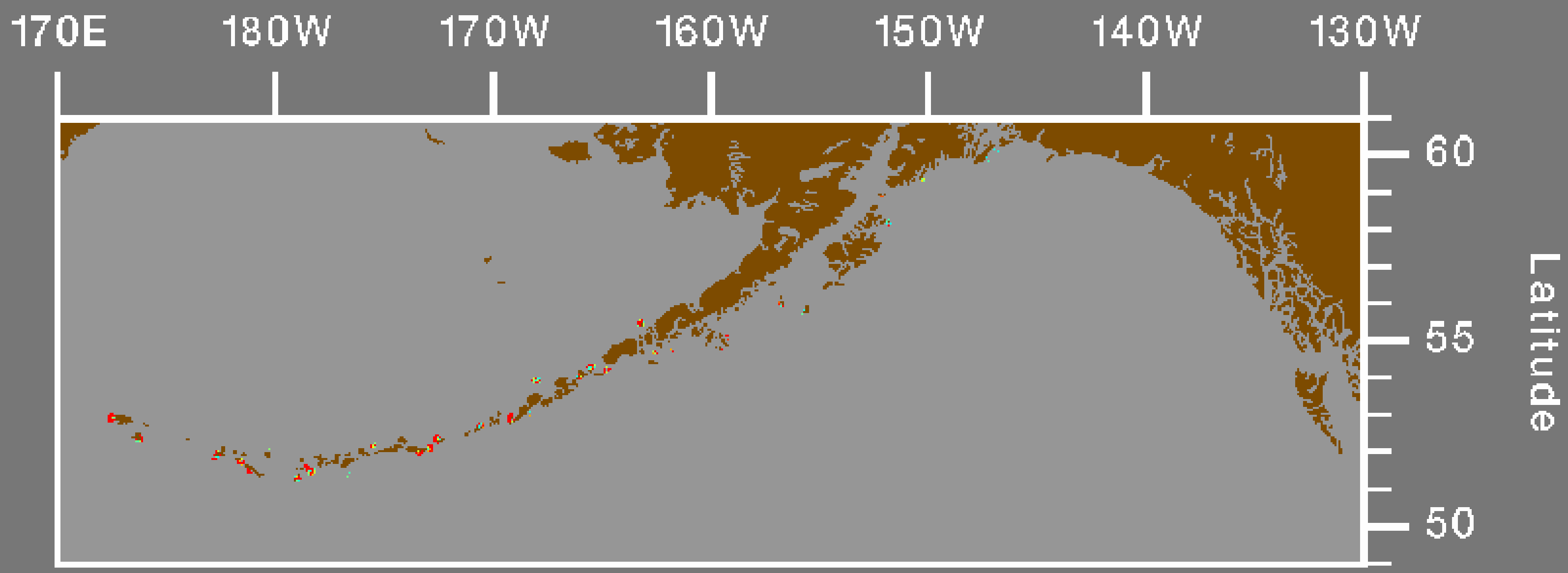
Eigenvector values from PC 1

1977 - 91 NUM 0-10 km	0.291
1977 - 91 SUM 0-10 km	0.300
1977 - 91 DUR 0-10 km	0.282
1977 - 91 CPU 0-10 km	0.241

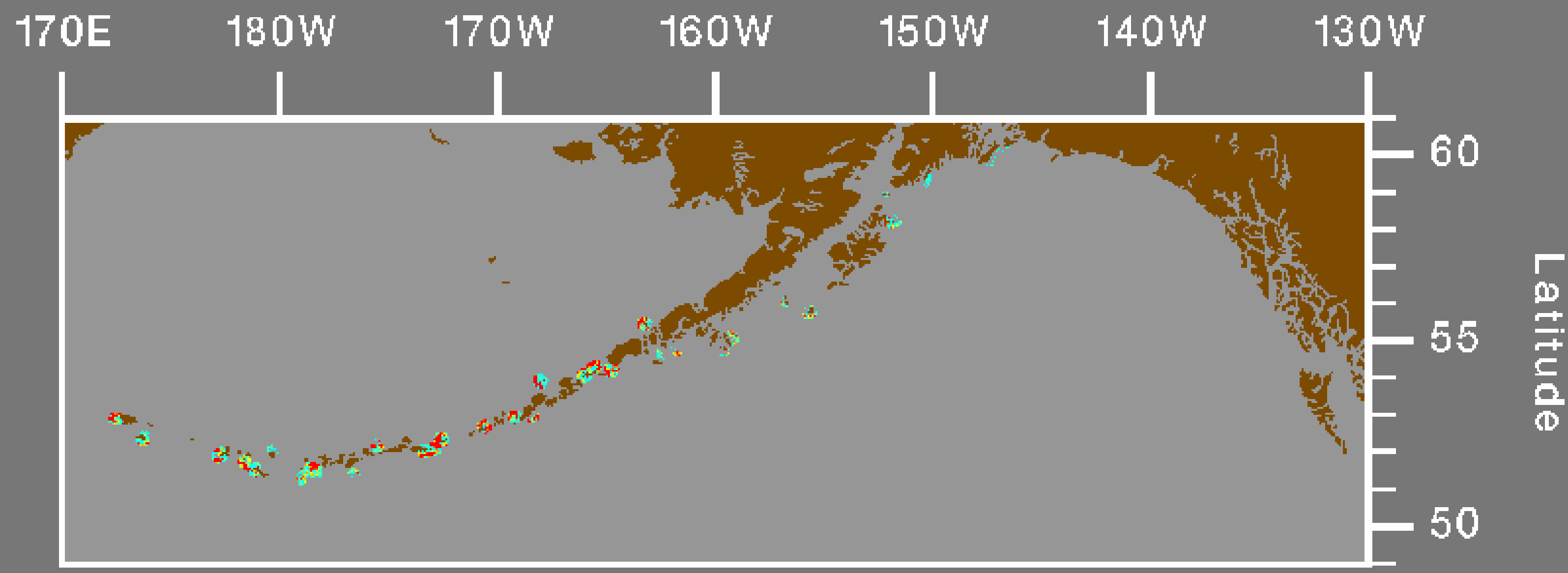
Fisheries Data

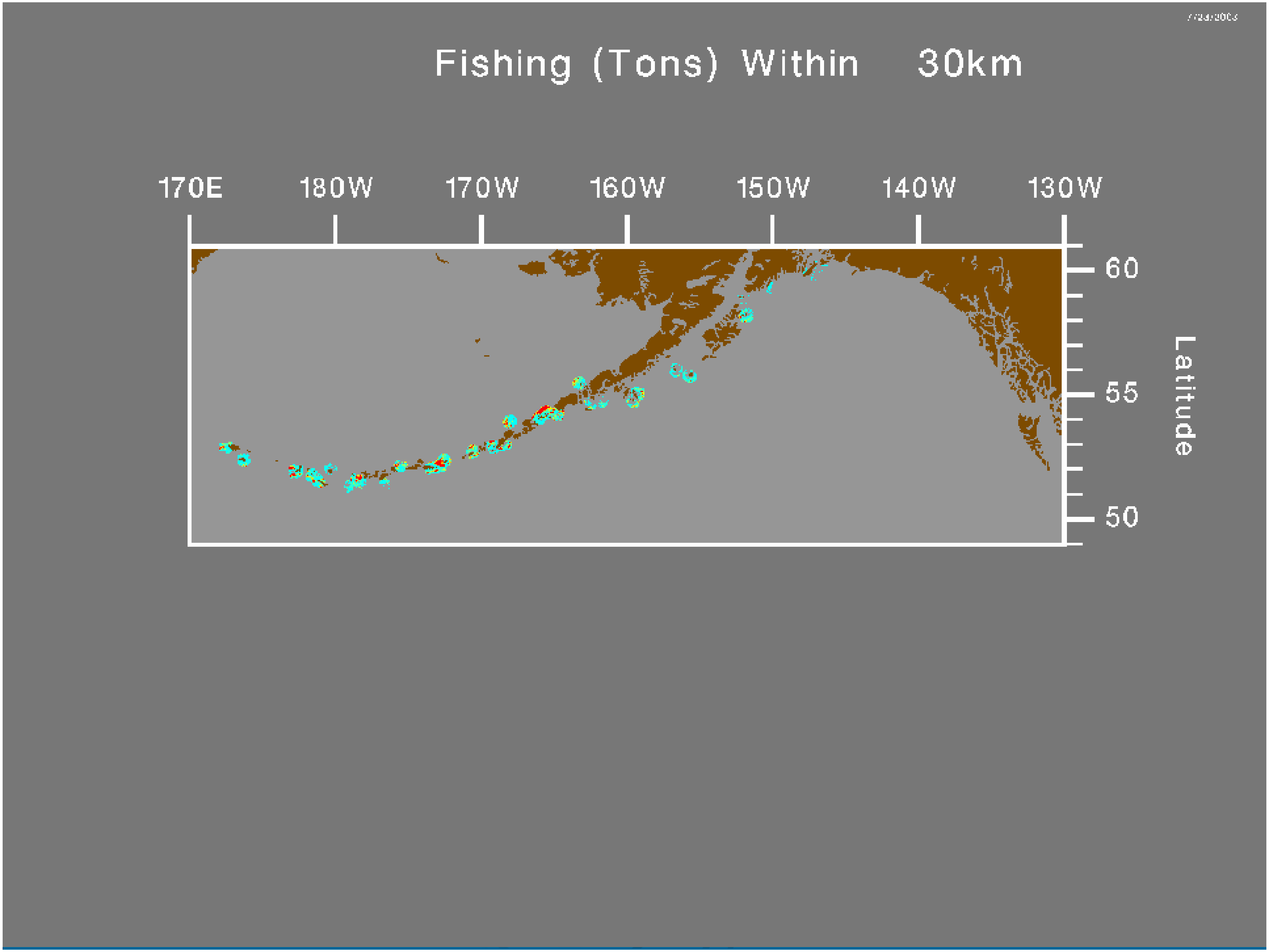
- Stratified by distance from SSL rookeries

Fishing (Tons) Within 10km



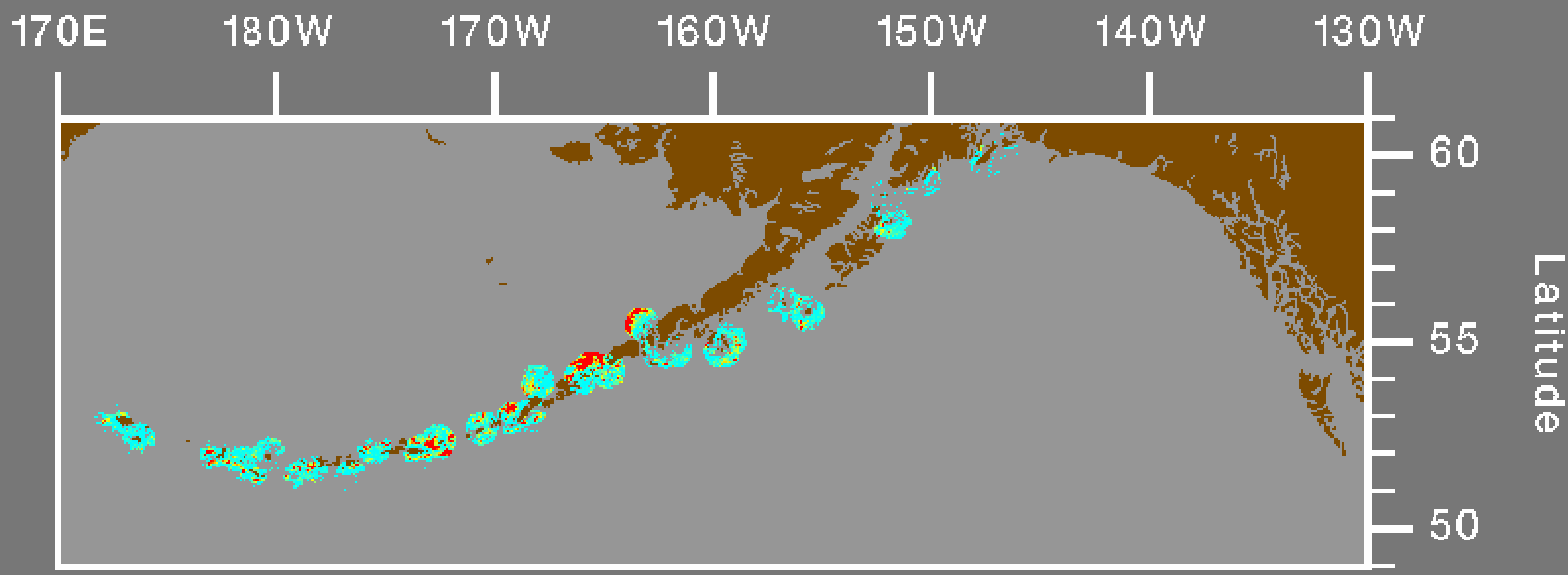
Fishing (Tons) Within 20km



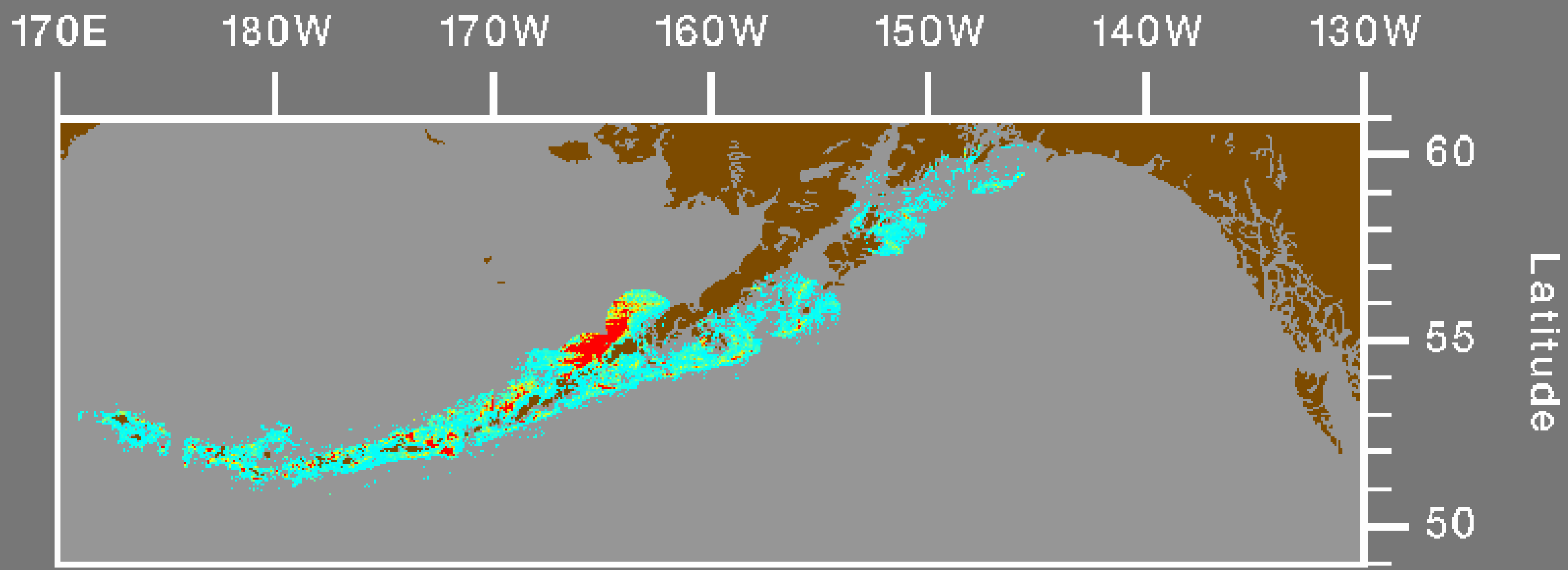


Fishing (Tons) Within 30km
170E
180W
170W
160W
150W
140W
130W
60
55
50
Latitude

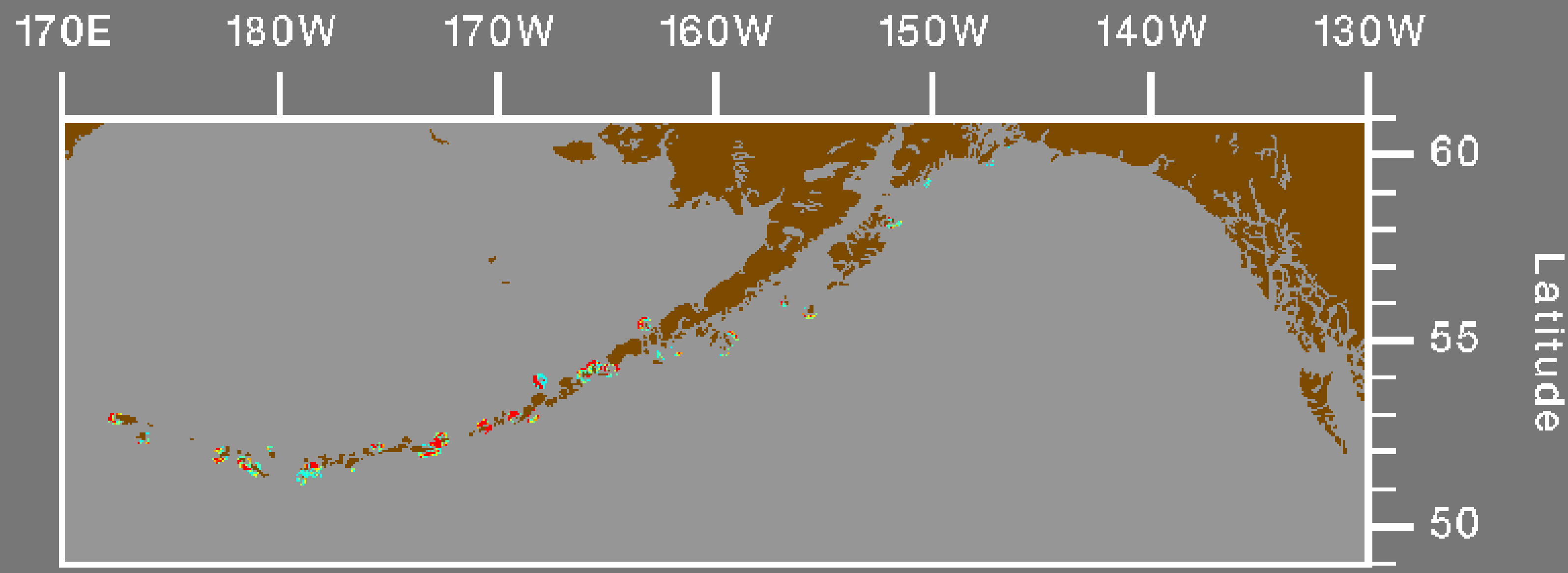
Fishing (Tons) Within 50km



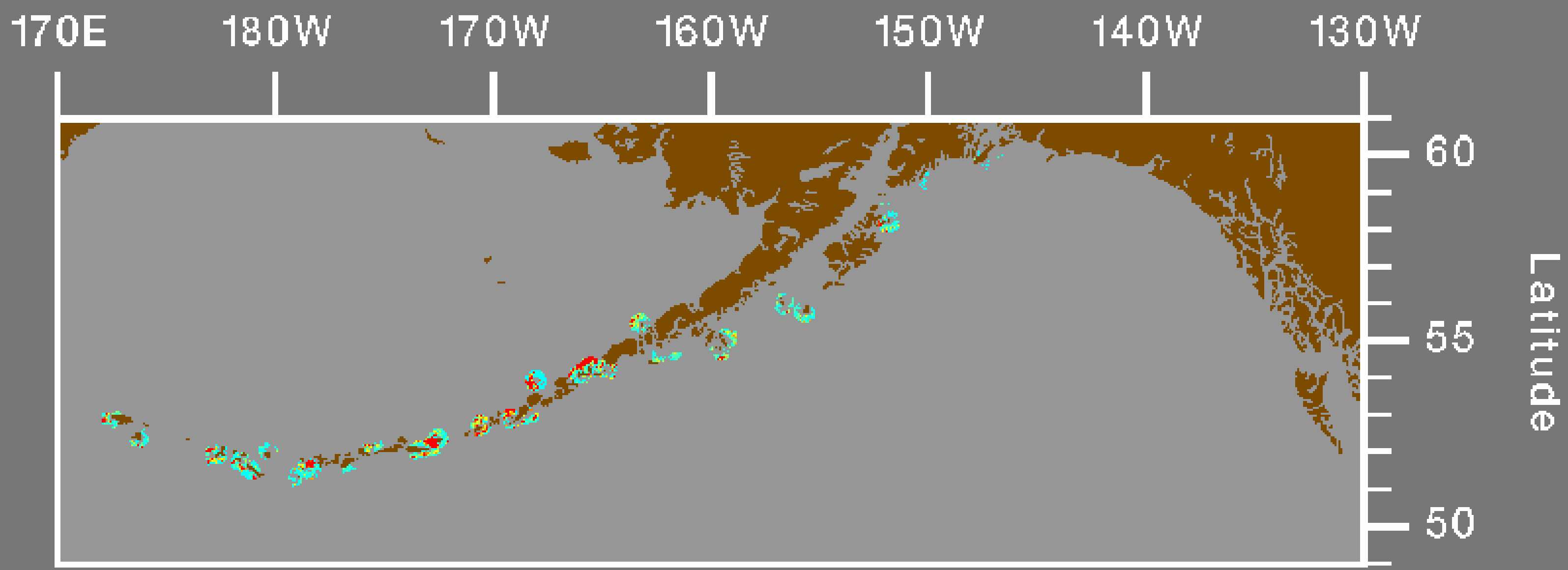
Fishing (Tons) Within 100km



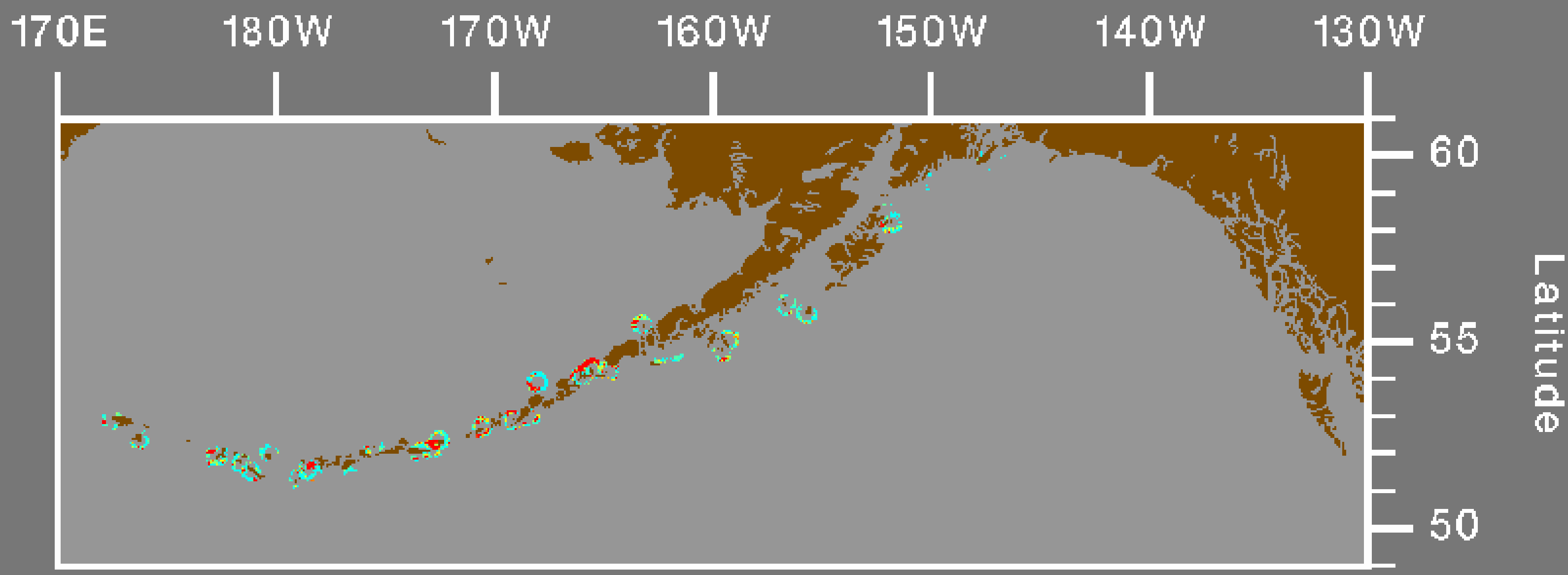
Fishing (Tons) Within 10-20km



Fishing (Tons) Within 10-30km

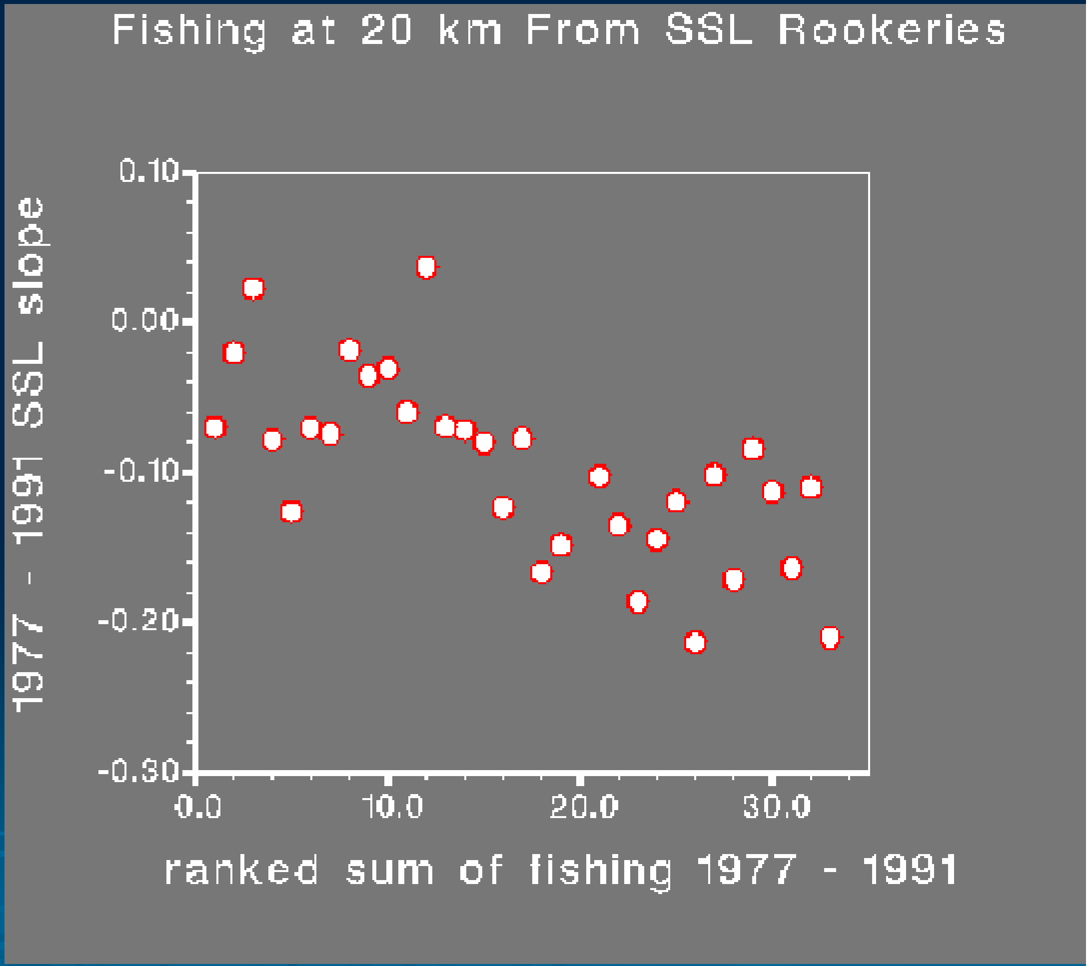


Fishing (Tons) Within 20-30km



Methods

- Linear regression
- Ranked fishing variable vs. SSL population growth variable



Comparisons

1977 – 1991 SSL Population Growth Rate

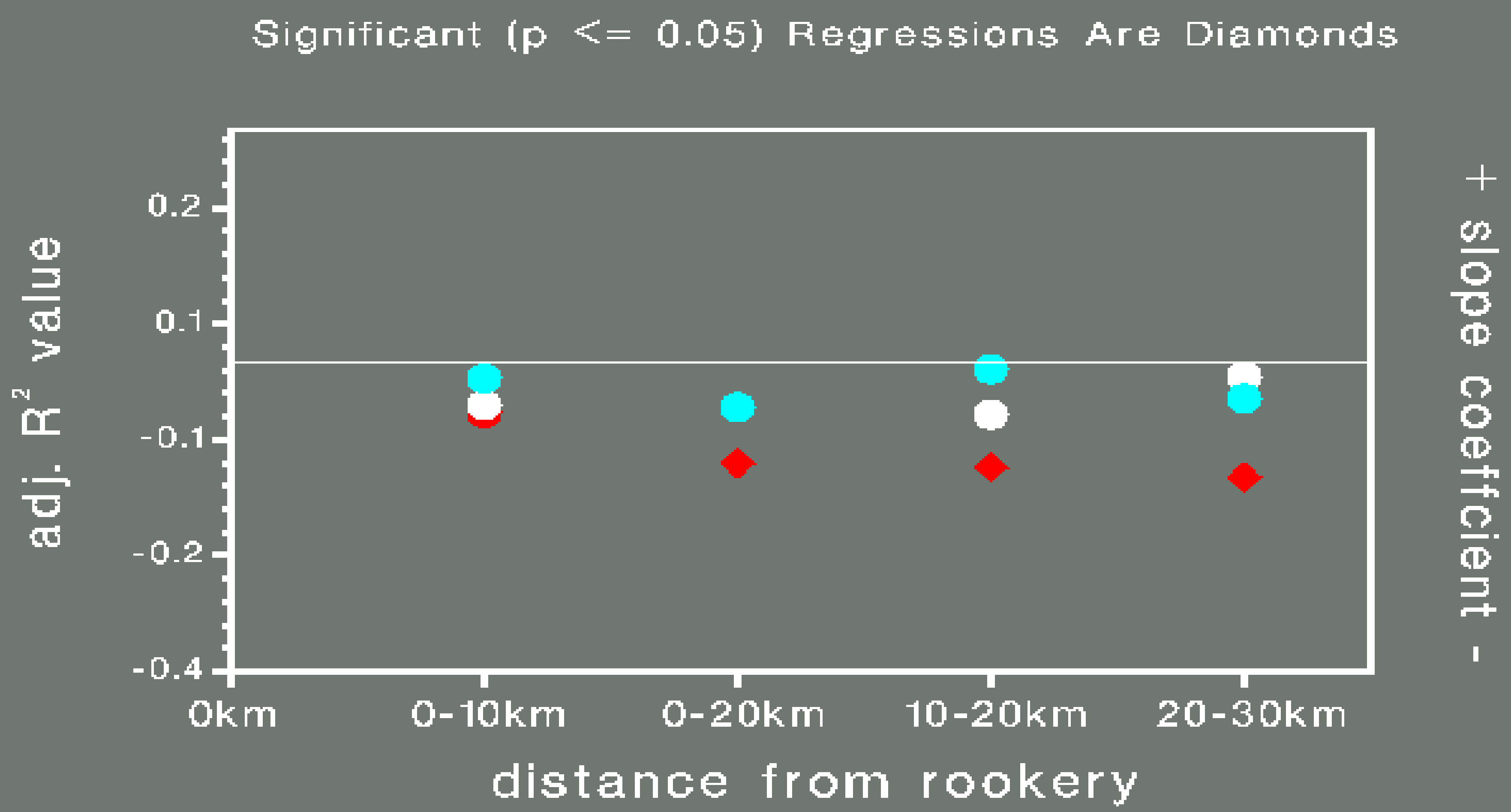
vs.

1977 – 1991 Fishing Activity

Results

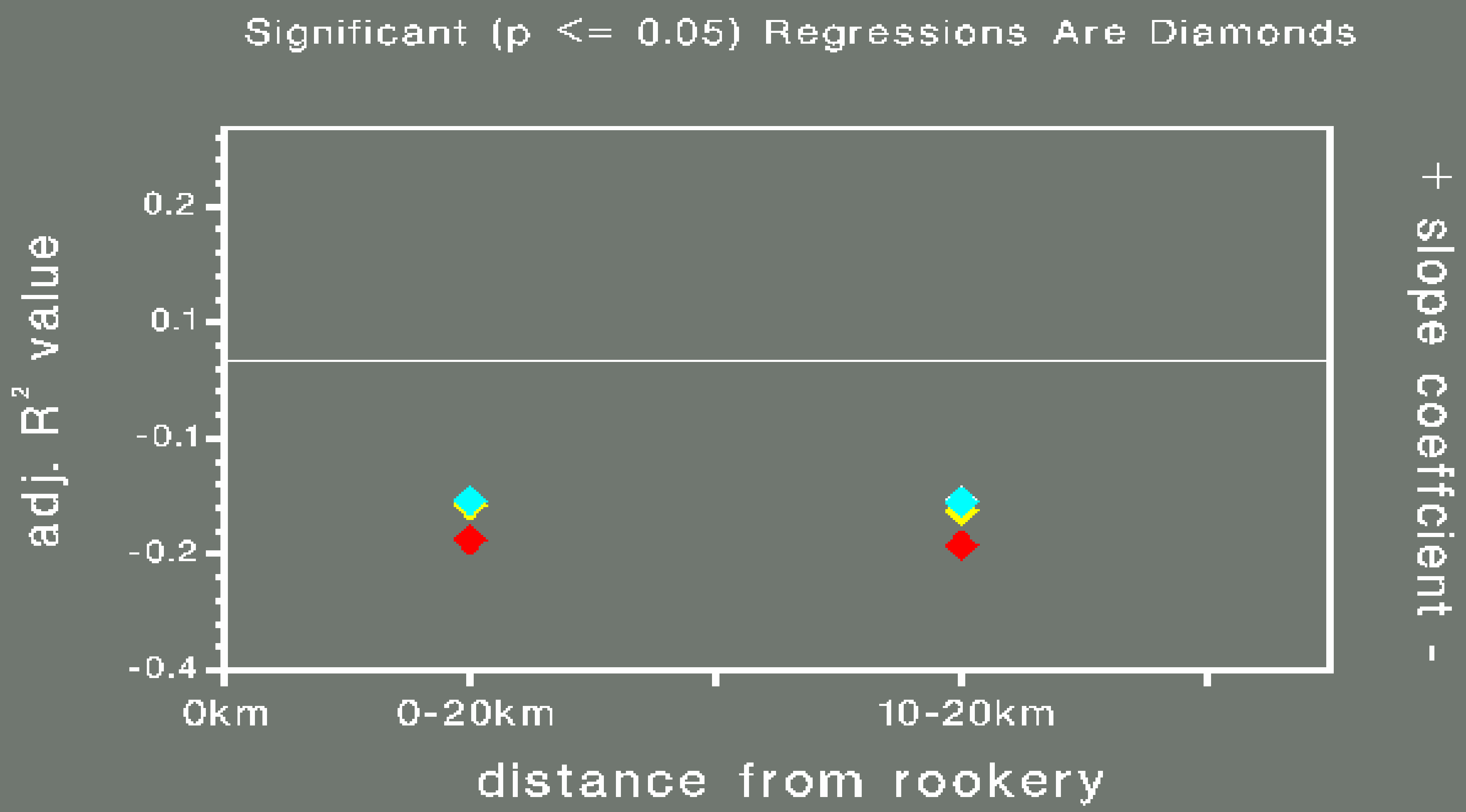
1977 – 1991 Growth Rate vs. Ranked 1977 – 1991 Fishing

Activity variables only: NM, SM, DUR



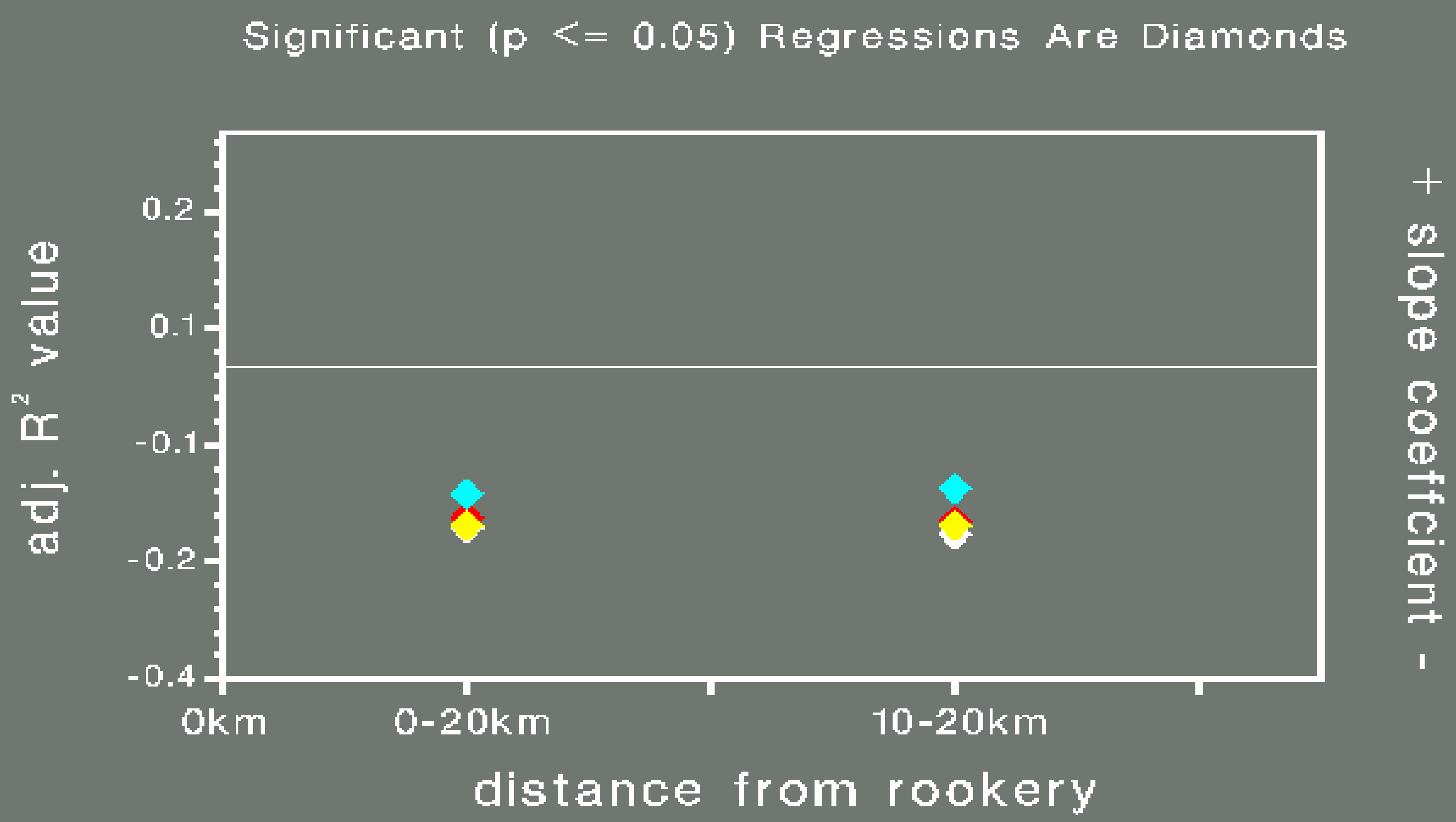
Results

1977 – 1991 Growth Rate vs. Ranked 1977 – 1991, Summer, Pollock, Small/Non-Pelagic Trawl Fishing. Activity variables only: NM, SM, IND, DUR



Results

1977 – 1991 Growth Rate vs. Ranked 1977 – 1991, Summer, Pacific Cod, Small/Non-Pelagic Trawl Fishing. Activity variables only: NM, SM, IND, DUR



Results

- Negative relationship between 1977 – 1991 fishing activity variables and 1977 – 1991 SSL population growth rate

Comparisons

1991 – 2001 SSL Population Growth Rate

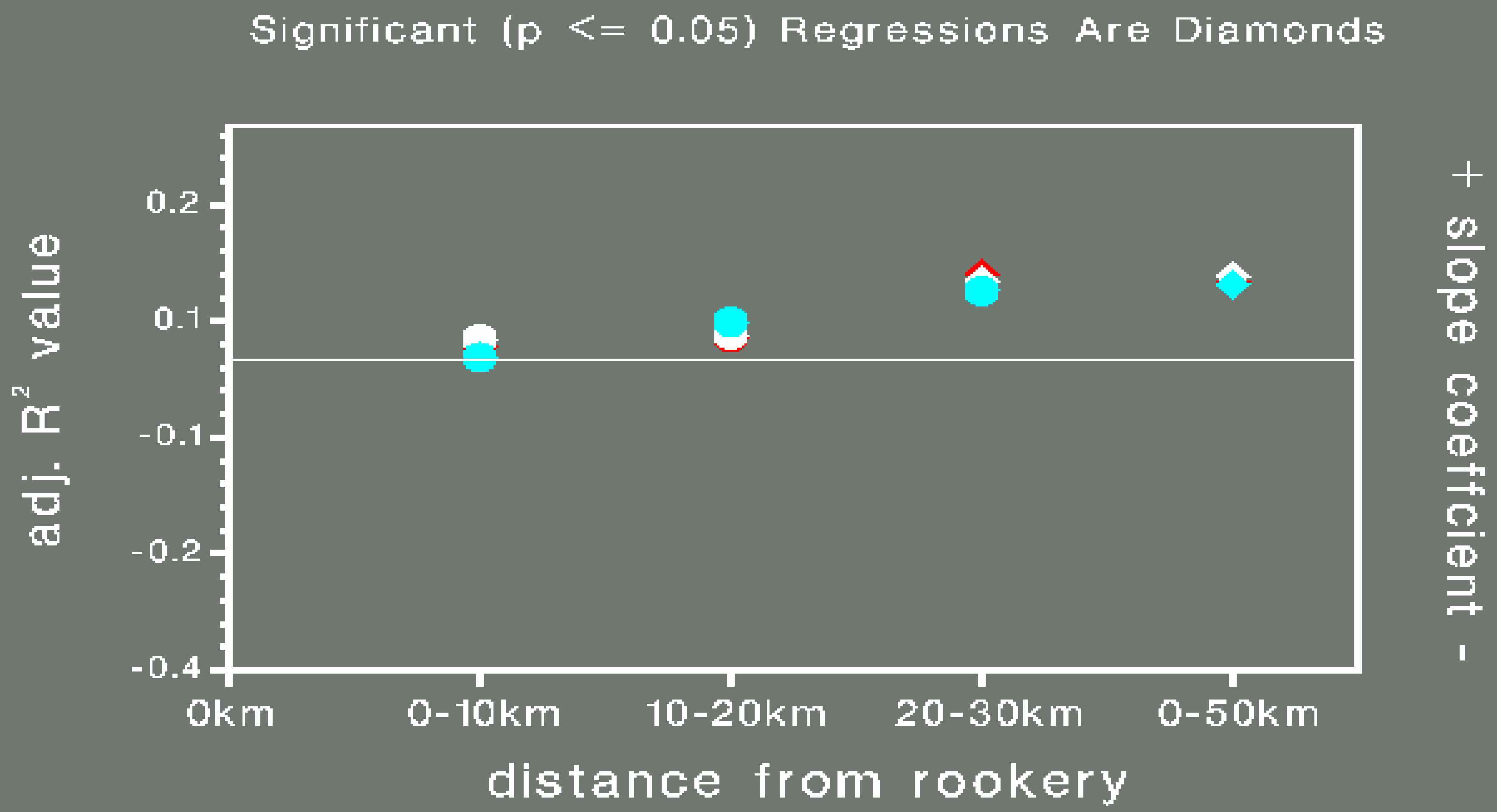
vs.

1991 – 2000 Fishing Activity

Results

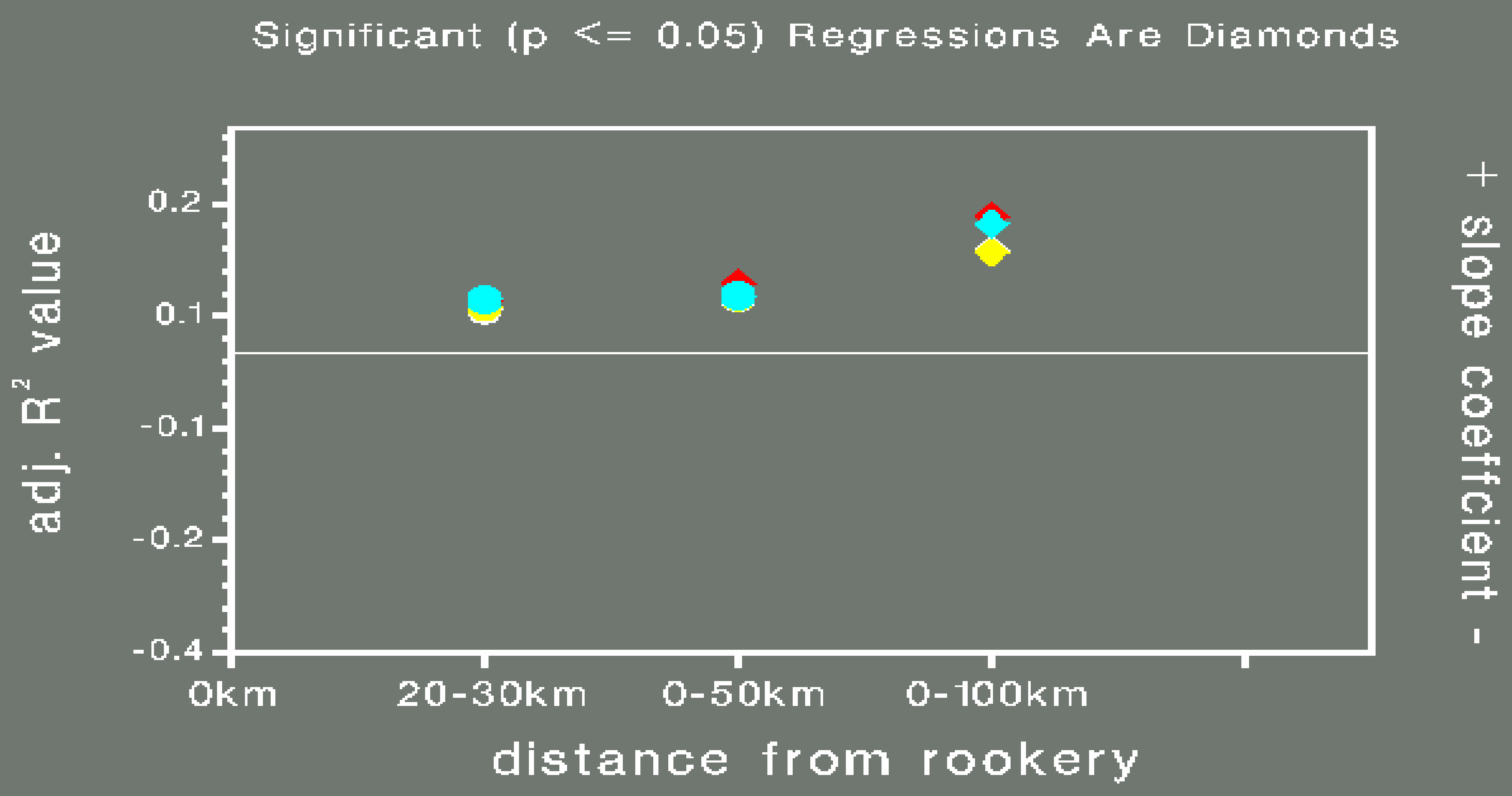
1991 – 2001 Growth Rate vs. 1991 – 2000 Ranked Fishing

Activity Variables Only: NM, SM, DUR



Results

1991 – 2001 Growth Rate vs. Ranked 1991 – 2000, Spring, Small/Non-Pelagic Trawl, Pacific Cod Fishing. Activity Variables Only: NM, SM, DUR, IND



Results

- Positive (offshore) relationship between 1991 – 2000 fishing activity variables and 1991 – 2001 SSL population growth rate

	Before 1991	After 1991
SSL vs. Fishing Activity	(-)	(+)
SSL vs. Fish Abundance	(-)	0

	Before 1991	After 1991
SSL vs. Near-shore Fishing Activity	(-)	0
SSL vs. Offshore Fishing Activity	0	(+)

	Before 1991	After 1991
SSL vs. Summer and Fall Fishing Activity	(-)	0
SSL vs. Winter and Spring Fishing Activity	0	(+)

	Before 1991	After 1991
SSL vs. Small/Non-Pelagic Trawl Fishing Activity	(-)	(+)
SSL vs. Large/Pelagic Trawl Fishing Activity	0	(+)

Discussion

- Clear negative relationship between fishing variables and SSL population growth before 1991.
  - Negative relationship is strongest near shore, using summer and fall small/non-pelagic trawl fishing variables.
- There is positive association with offshore fishing *activity* after 1991.
  - The relationship is strongest using winter and spring trawl fishing variables.

Conclusions

- Slowing of the decline rate was coincident with a complex of SSL protections.
- Higher decline rates in the 1980's, before protections went into effect, were spatially correlated with measures of fishing activity.

Questions

- What particular aspect (if any) of the commercial fisheries in the Bering Sea and Gulf of Alaska in the 1980’s was the mechanism contributing to the SSL decline?

Daniel Hennen, Biometrician, Alaska SeaLife Center

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Publication

- Hennen, D.R. 2006. Associations between the steller sea lion decline and the

  Gulf of Alaska and Bering Sea commercial fisheries. *Ecological Applications. 16(2) pp.704-717.*

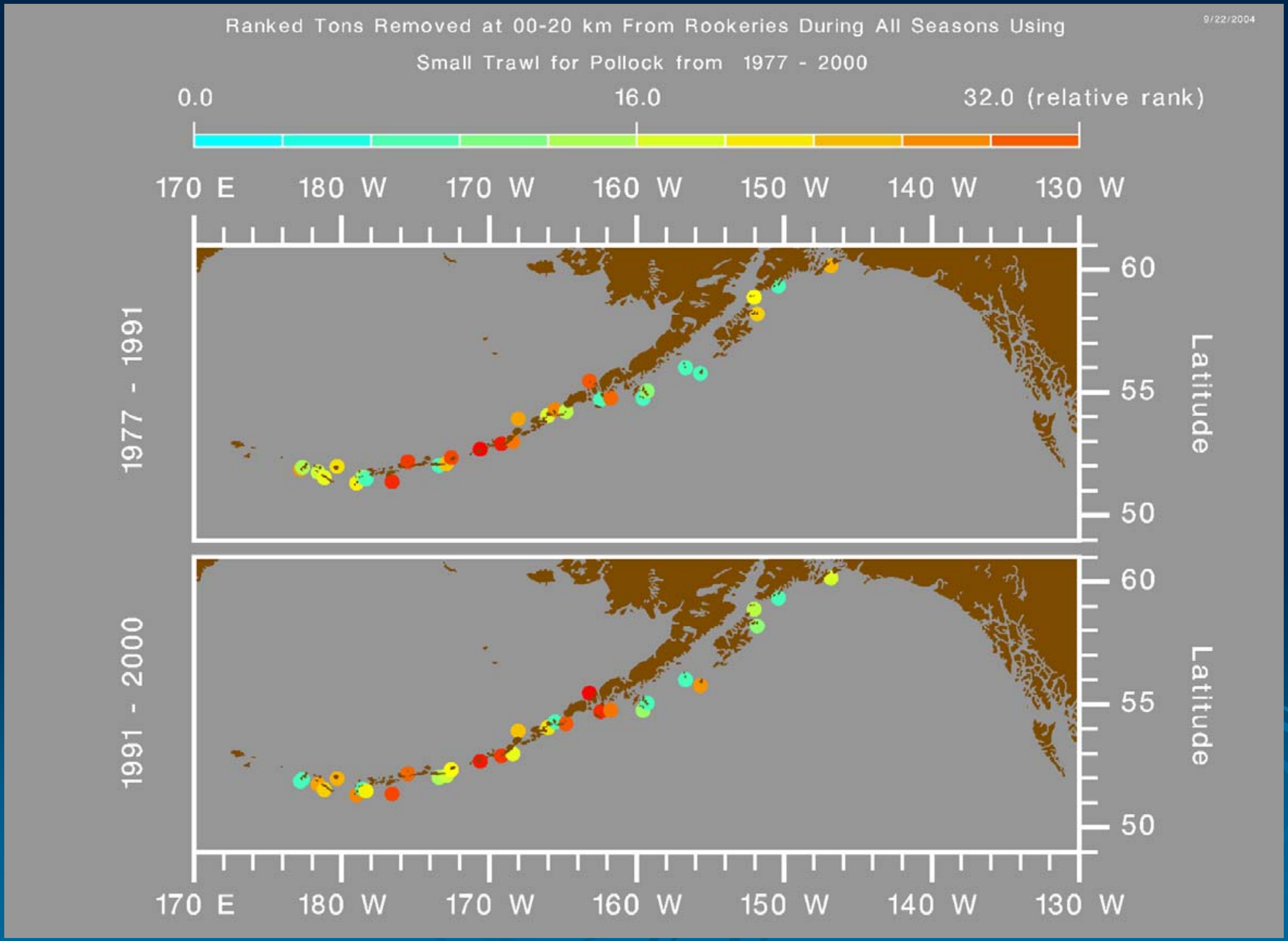
What Changed?

- SSL Population Trend Estimates Compared

	Mean	Std.Dv.	N	Diff.	t	df	p
S1_with_50s	-0.101	0.056					
S2_with_50s	-0.078	0.116	32	-0.024	-1.019	31	0.316
S1_no_50s__	-0.116	0.048					
S2_no_50s__	-0.069	0.113	32	-0.046	-2.196	31	0.036
S1_77______	-0.126	0.039					
S2_77______	-0.065	0.115	31	-0.061	-2.970	30	0.006

What Changed?

- Fishing Differences



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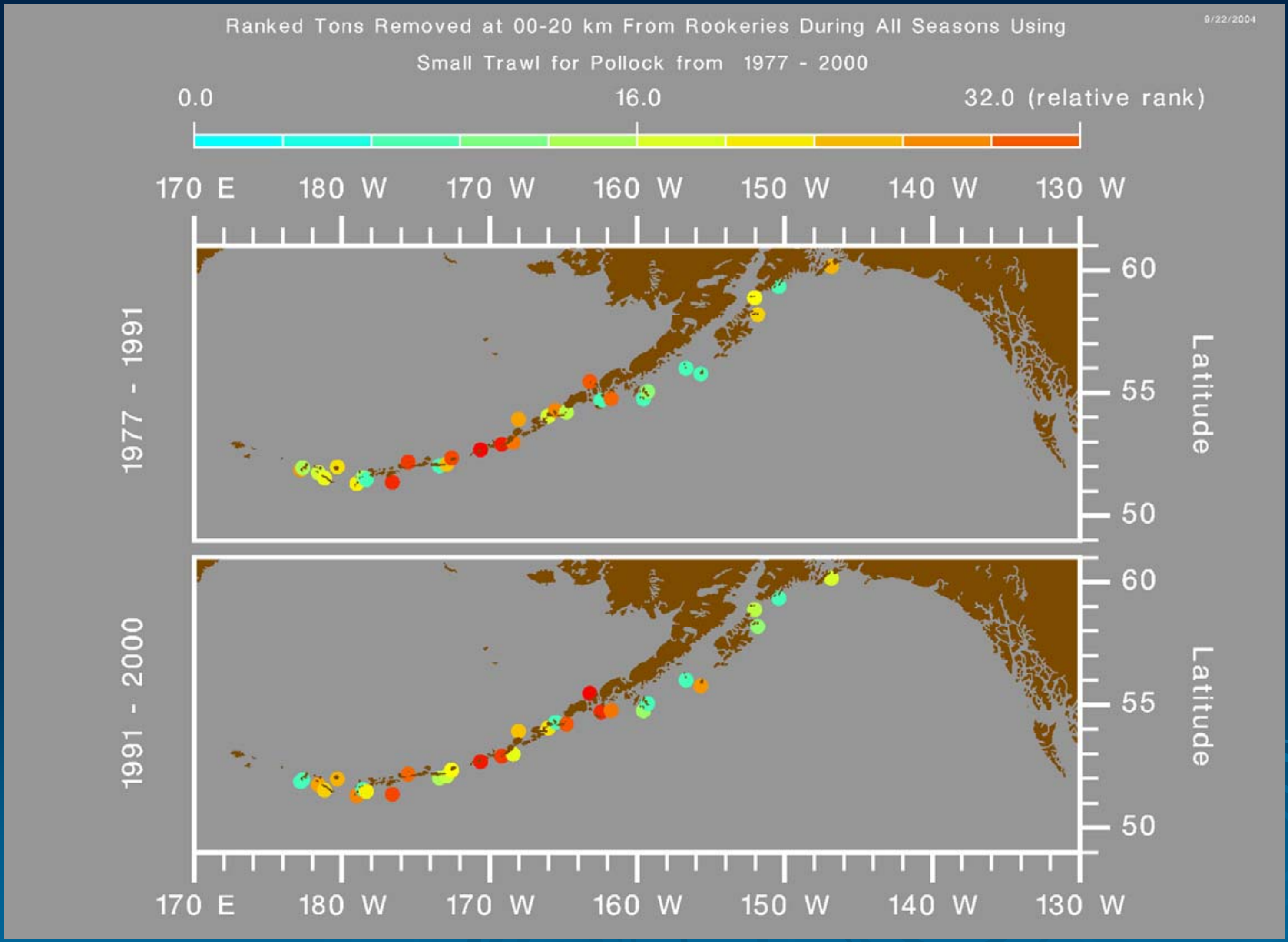
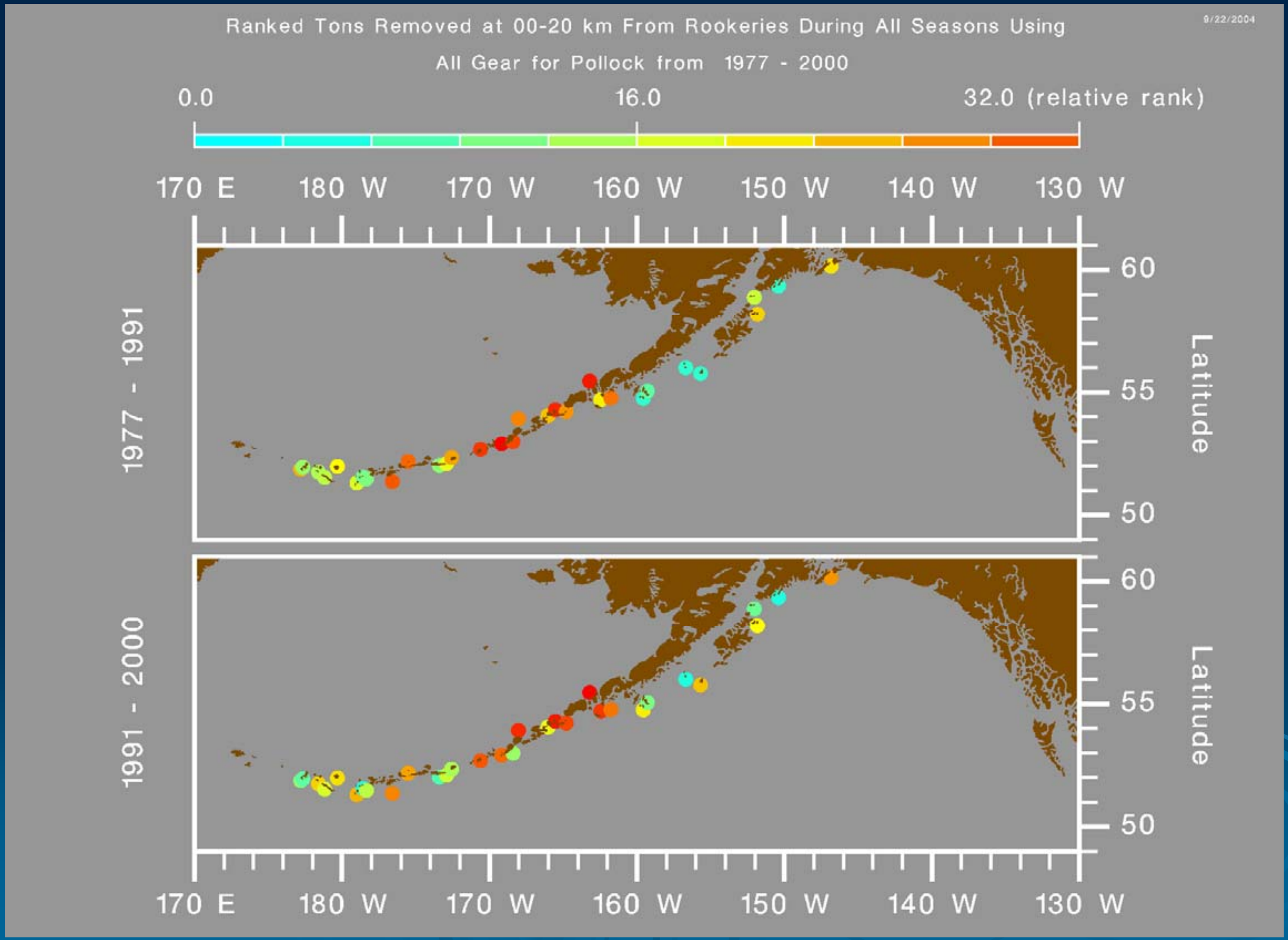


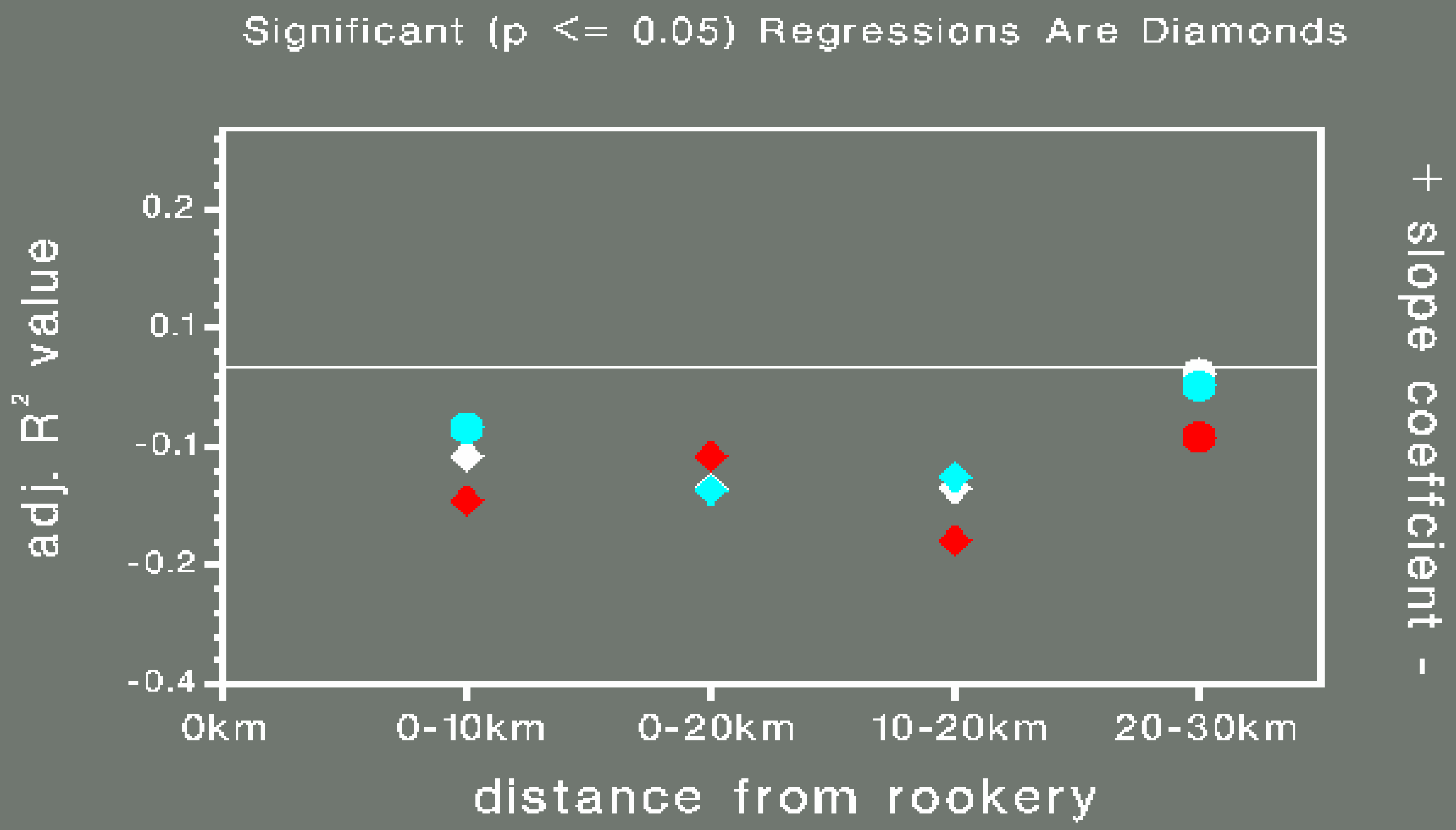
What Changed?

- Fishing Differences



Results

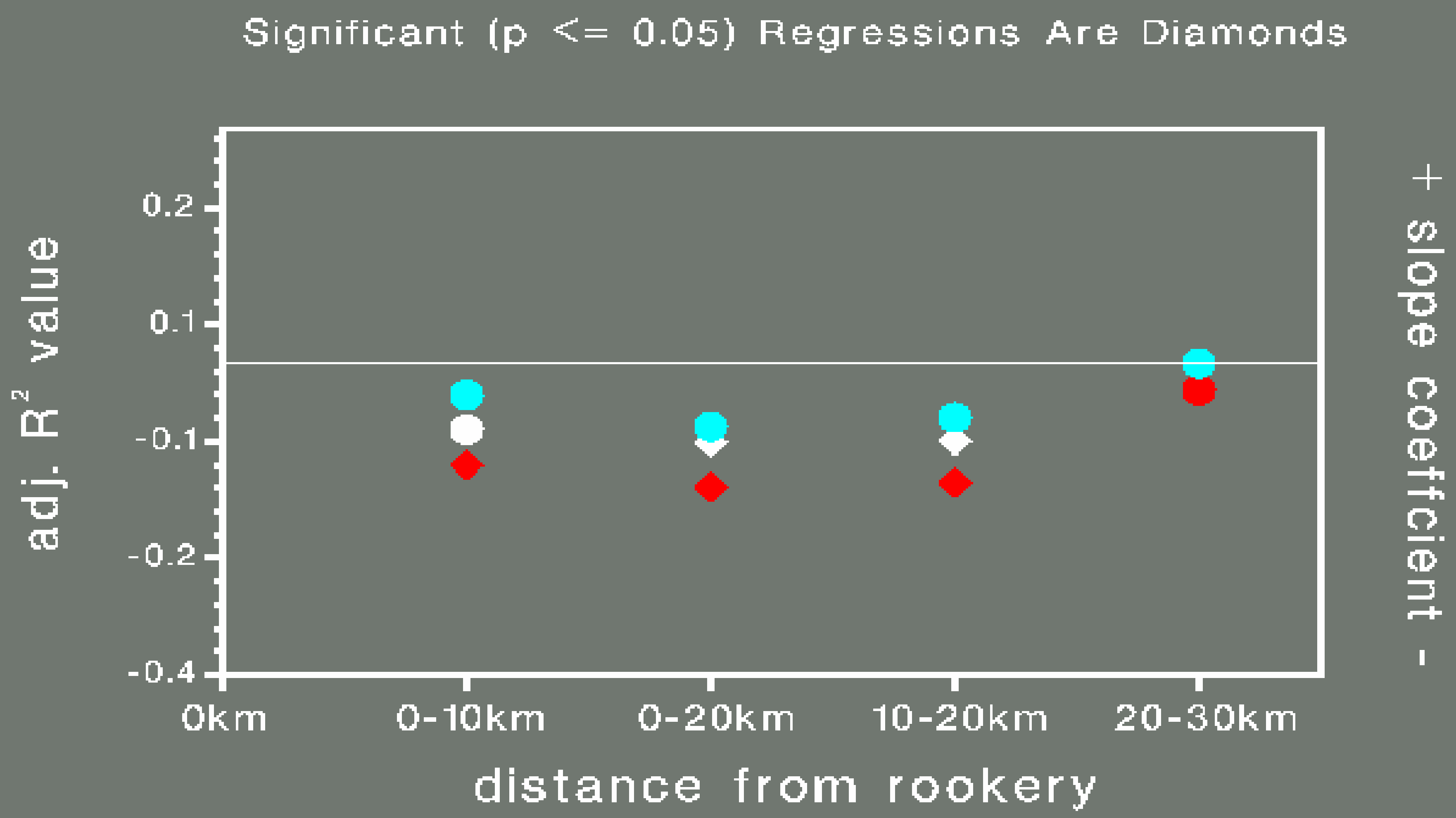
1956 – 1991 Population Trend vs. 1977 – 1991 Fishing



Results

1960 – 1991 Population Trend vs. 1977 – 1991 Fishing

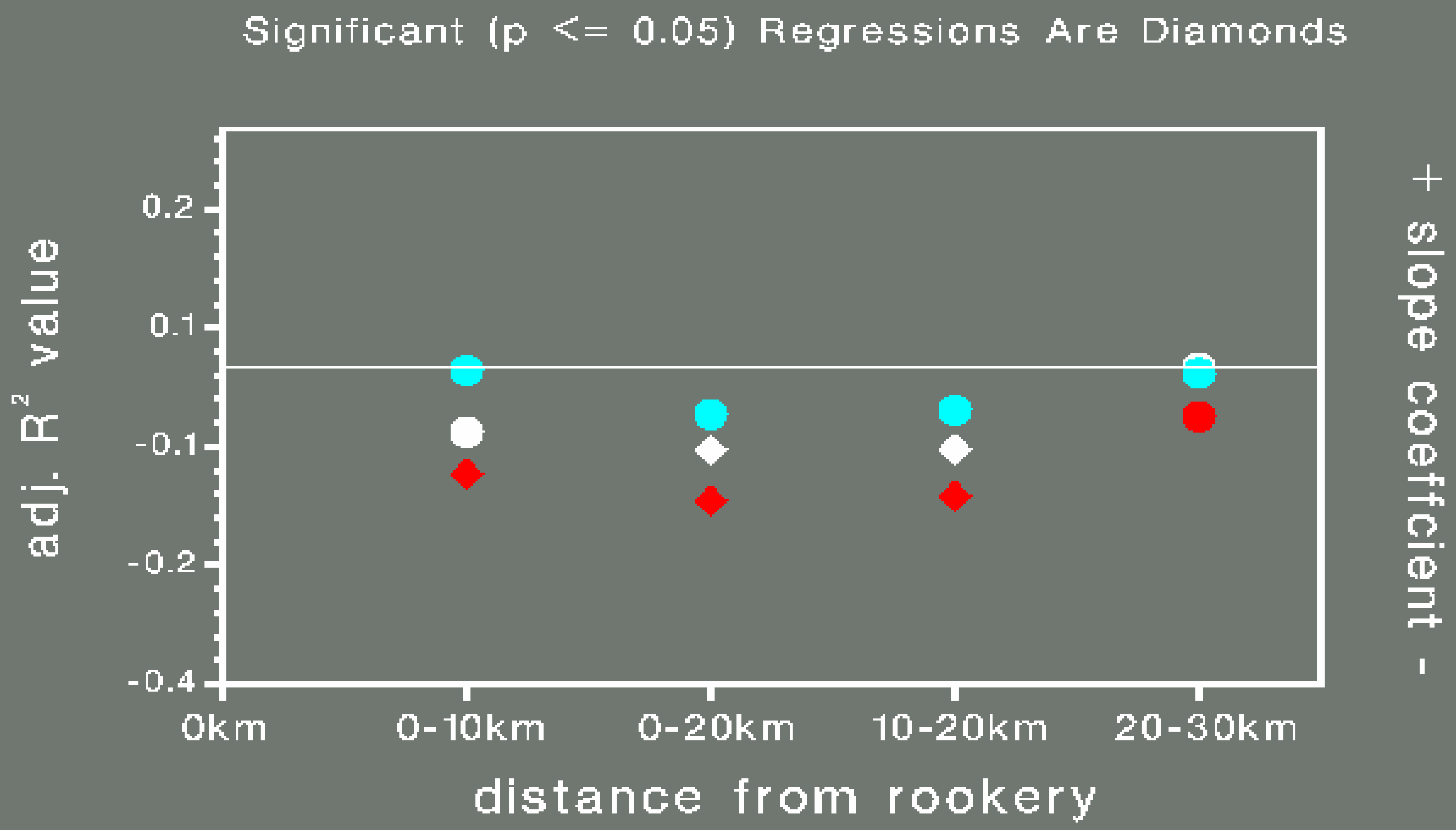
Activity variables only: NM, SM, DUR



Results

1977 – 1991 Population Trend vs. 1977 – 1991 Fishing

Activity variables only: NM, SM, DUR



Principal Components Analysis

The fishing data used were all the 10 – 20 km

pollock and cod,

summer and fall,

small/non-pelagic trawl variables.

Eigenvalue	% of Total Variation
16.53	71.00%
1.882	8.10%
1.612	6.90%
1.009	4.30%
0.651	2.80%
0.425	1.80%
0.375	1.60%
0.228	1.00%

Principal Components Analysis

YFC (50's) - 1991 SSL decline			
Variable(s)	Slope coefficient (β)	p-value	adj R^2
PC1	**-0.535**	**0.001**	**32.32%**
PC4	-0.273	0.071	
YFC (no 50's) - 1991 SSL decline			
Variable(s)	Slope coefficient (β)	p-value	adj R^2
PC1	**-0.533**	**0.001**	**26.69%**
PC4	-0.160	0.298	
1977 - 1991 SSL decline			
Variable(s)	Slope coefficient (β)	p-value	adj R^2
PC1	**-0.466**	**0.003**	**34.32%**
PC3	**0.404**	**0.009**	

Principal Components Analysis

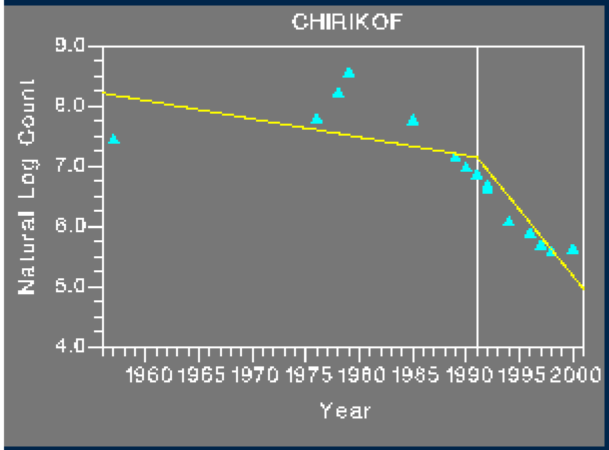
PC1	PC3	PC4	variable
0.212	-0.165	0.089	num1, pl_wt, summer , smtrl, 10-20 km
0.218	-0.192	0.084	sum1, pl_wt, summer, smtrl, 10-20 km
0.214	-0.196	0.006	dur1, pl_wt, summer, smtrl, 10-20 km
0.184	-0.227	0.177	CPU1, pl_wt, summer, smtrl, 10-20 km
0.213	-0.075	-0.26	num1, pl_wt, fall, smtrl, 10-20 km
0.215	-0.12	-0.195	sum1, pl_wt, fall, smtrl, 10-20 km
0.213	-0.101	-0.263	dur1, pl_wt, fall, smtrl, 10-20 km
0.192	-0.264	-0.001	CPU1, pl_wt, fall, smtrl, 10-20 km
0.215	-0.065	0.21	num1, cd_wt, summer, smtrl, 10-20 km
0.217	-0.086	0.203	sum1, cd_wt, summer, smtrl, 10-20 km
0.219	-0.03	0.181	dur1, cd_wt, summer, smtrl, 10-20 km
0.195	-0.144	0.219	CPU1, cd_wt, summer, smtrl, 10-20 km
0.213	-0.093	-0.233	num1, cd_wt, fall, smtrl, 10-20 km
0.22	-0.099	-0.15	sum1, cd_wt, fall, smtrl, 10-20 km
0.211	-0.099	-0.193	dur1, cd_wt, fall, smtrl, 10-20 km
0.209	-0.141	-0.105	CPU1, cd_wt, fall, smtrl, 10-20 km
0.185	0.342	-0.246	num1, am_wt, summer, smtrl, 10-20 km
0.195	0.353	-0.15	sum1, am_wt, summer, smtrl, 10-20 km
0.181	0.265	-0.253	dur1, am_wt, summer, smtrl, 10-20 km
0.188	0.318	-0.186	CPU1, am_wt, summer, smtrl, 10-20 km
0.192	0.283	0.22	num1, am_wt, fall, smtrl, 10-20 km
0.197	0.244	0.315	sum1, am_wt, fall, smtrl, 10-20 km
0.193	0.267	0.21	dur1, am_wt, fall, smtrl, 10-20 km
0.198	0.202	0.338	CPU1, am_wt, fall, smtrl, 10-20 km

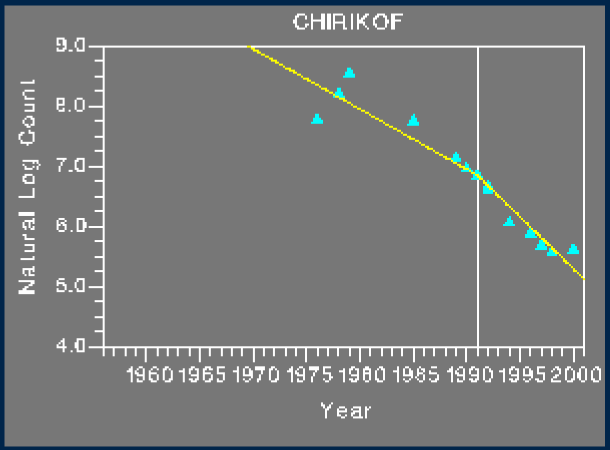
SSL Data

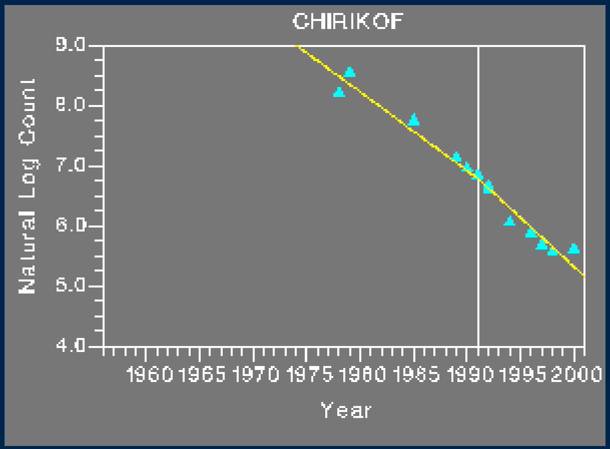
- Surveyed at least three times in June or July, in the period from 1977-1991 or 1991-2001

SSL Data

- 3 different time periods were tested
- 1956 – 1991 – 2001
- 1960 – 1991 – 2001
- 1977 – 1991 – 2001



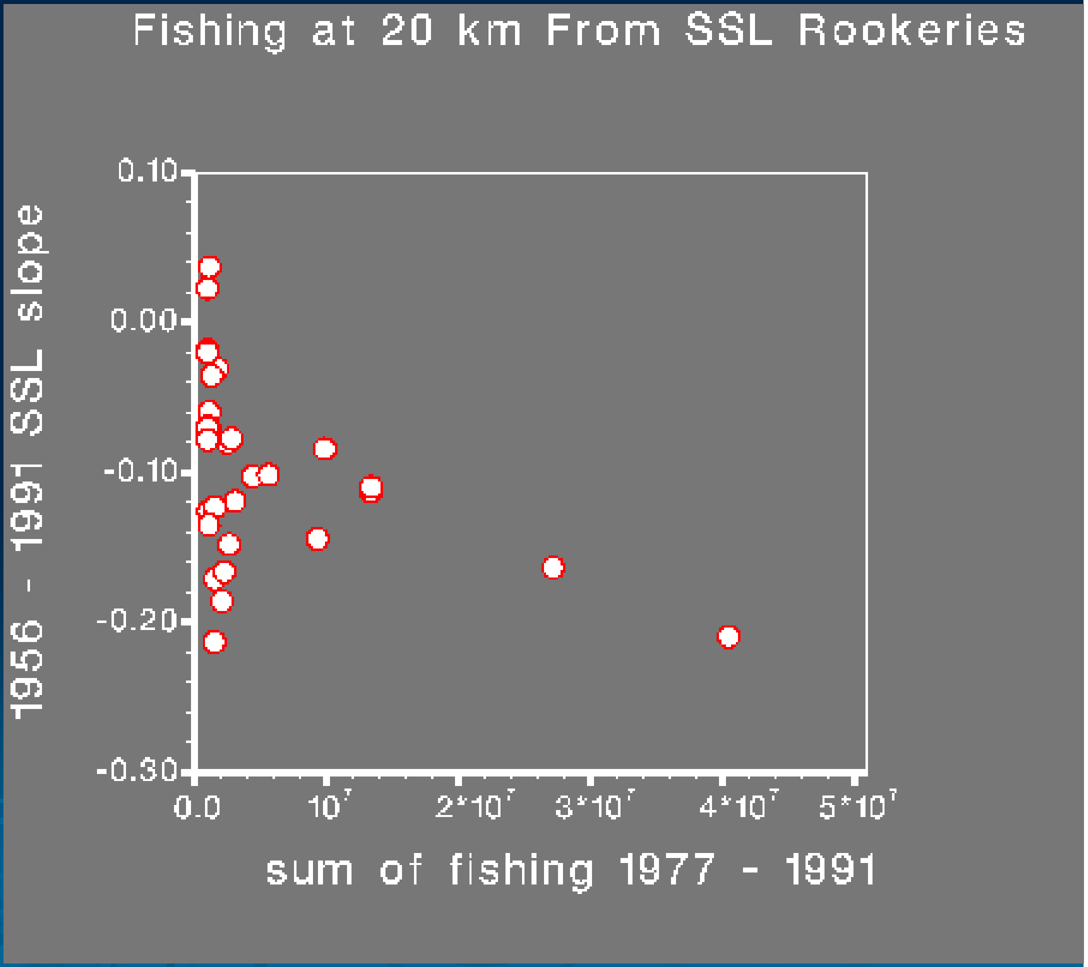




	1956 - 2001	1960 - 2001	1977 - 2001
YFC - 1991 Slope	-0.031	-0.100	-0.130
1991 Intercept	7.156	6.859	6.805
1991 - 2001 Slope	-0.219	-0.172	-0.164

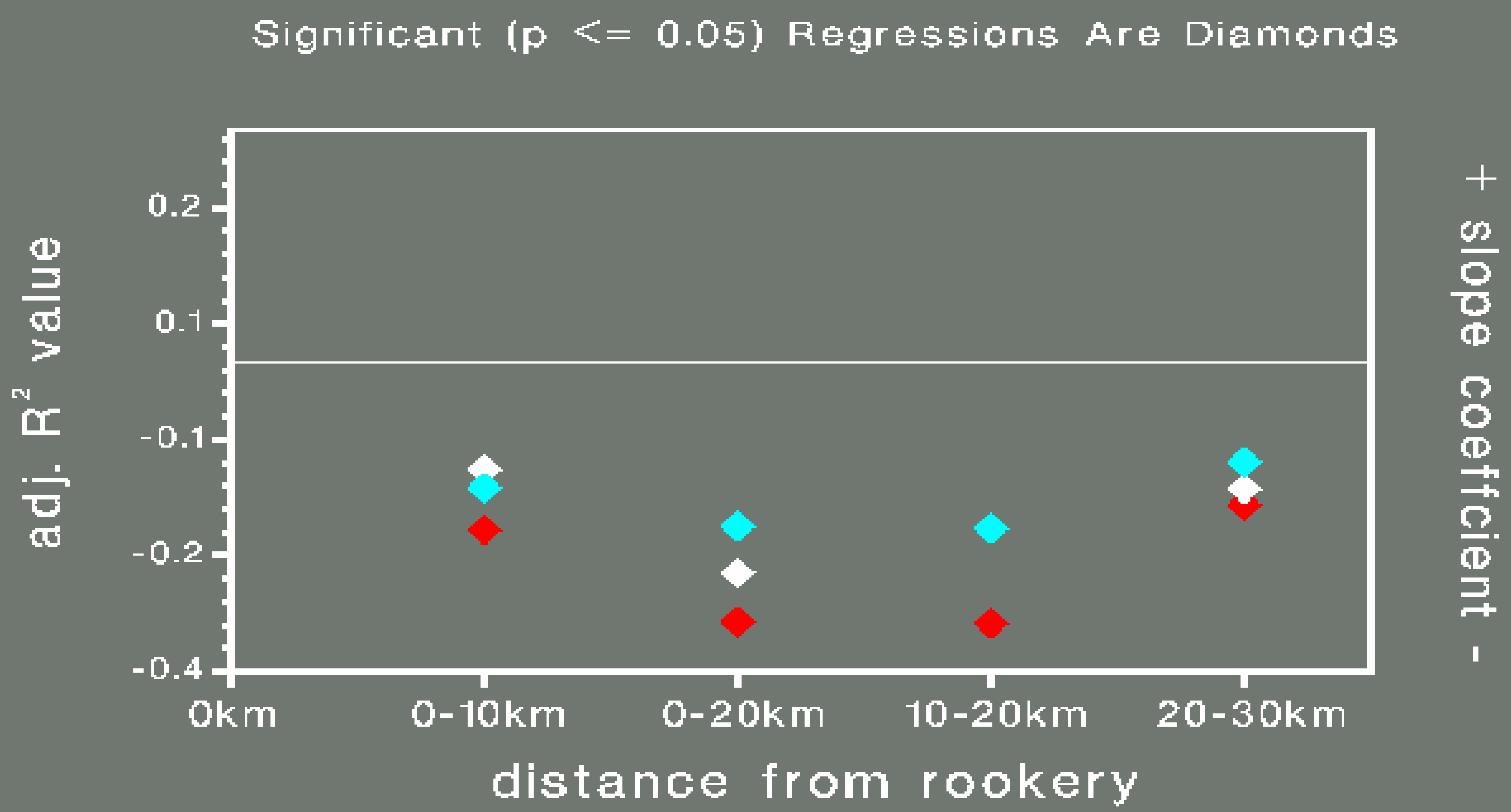
Methods

- Regression of raw variable values



Results

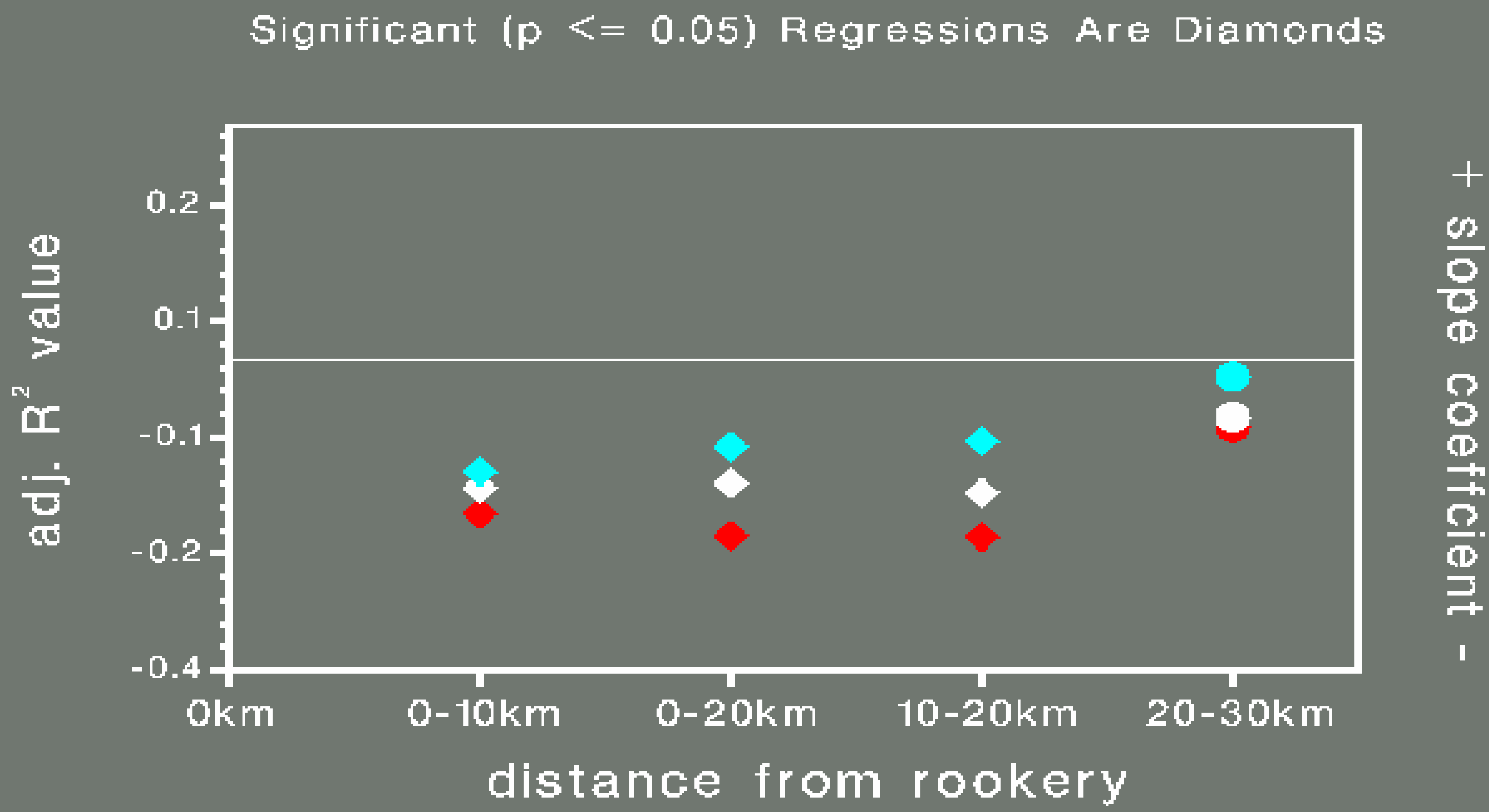
1956 – 1991 Population Trend vs. Ranked 1977 – 1991
Fishing Activity variables only: NM, SM, DUR



Results

1960 – 1991 Population Trend vs. Ranked 1977 – 1991 Fishing

Activity variables only: NM, SM, DUR



Fisheries Data

- Further stratified by gear type
- 1977 – 1990
  - Mothership
  - Small trawl
  - Large trawl
  - Pot and trap
  - Longline
- 1991 – 2000
  - Non-pelagic trawl
  - Pelagic trawl
  - Pot and trap
  - Longline

Fisheries Data

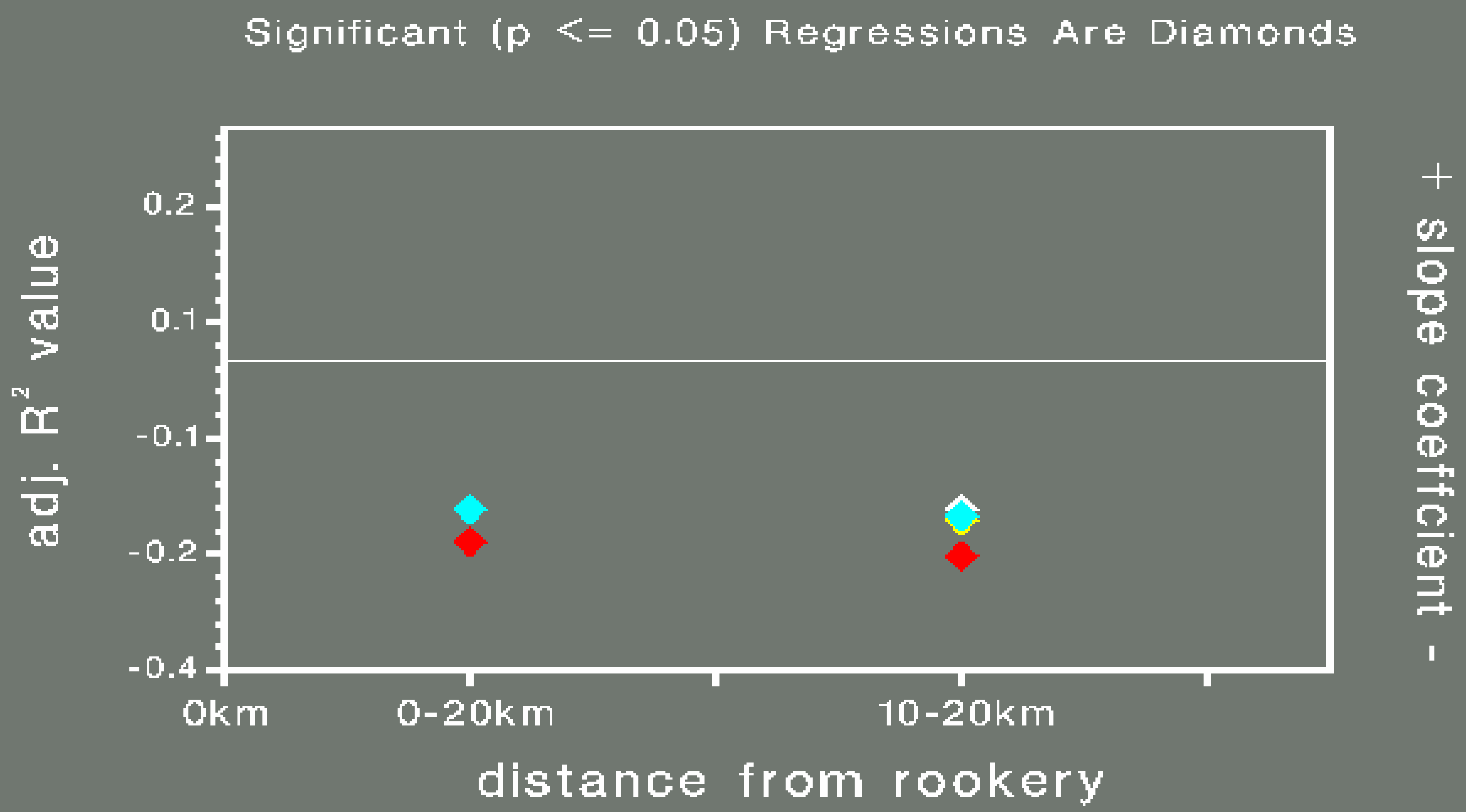
- Seasons
  - Months 12, 1 and 2 = Winter
  - Months 3, 4 and 5 = Spring
  - 6, 7 and 8 = Summer
  - 9, 10 and 11 = Fall

Fisheries Data

- Species, includes a new variable ‘ind’
  - Pollock
  - Pacific cod
  - Atka Mackerel

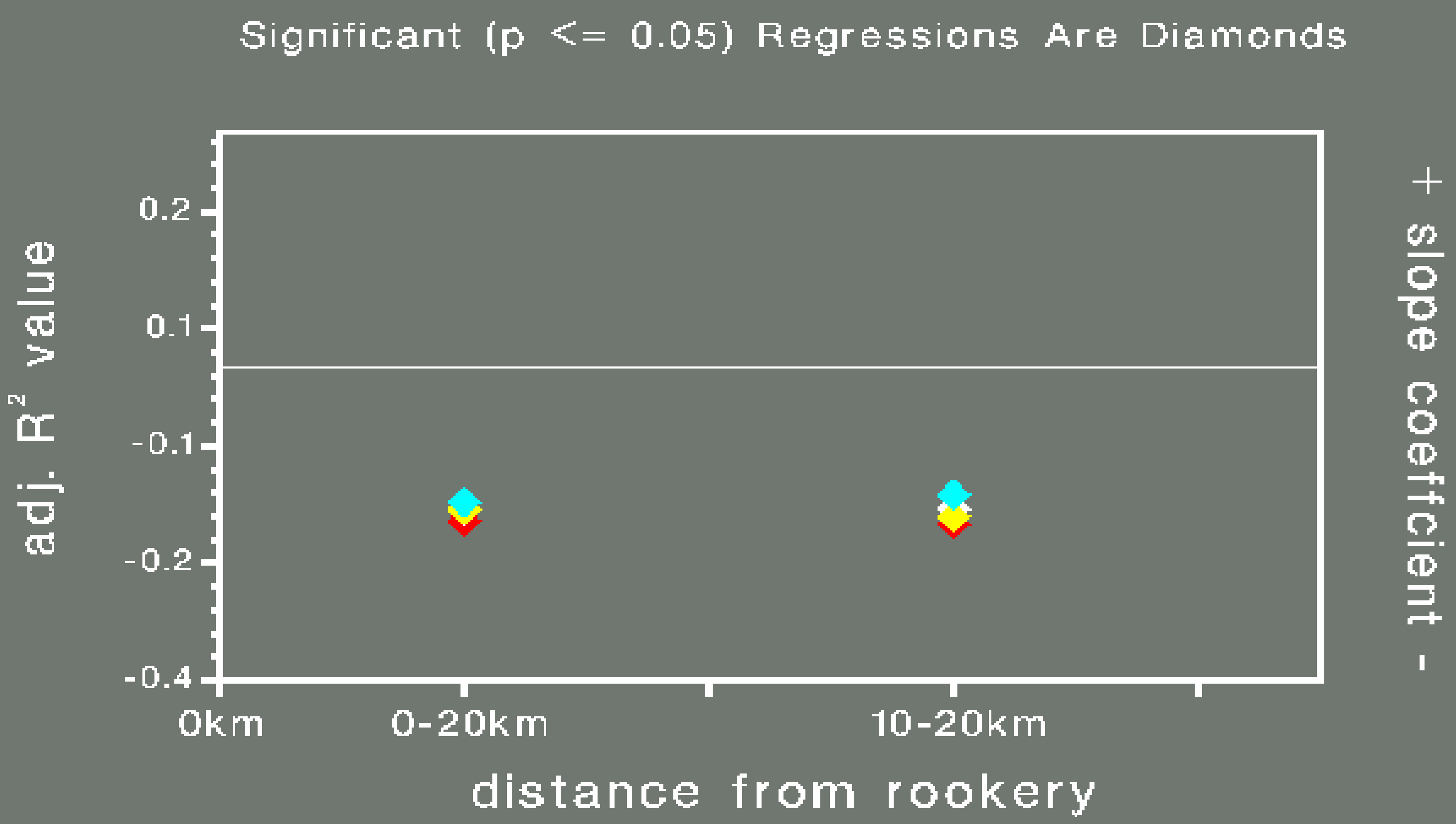
Results

1956 – 1991 Population Trend vs. Ranked 1977 – 1991, Summer, Pollock, Small/Non-Pelagic Trawl Fishing. Activity variables only: NM, SM, IND, DUR



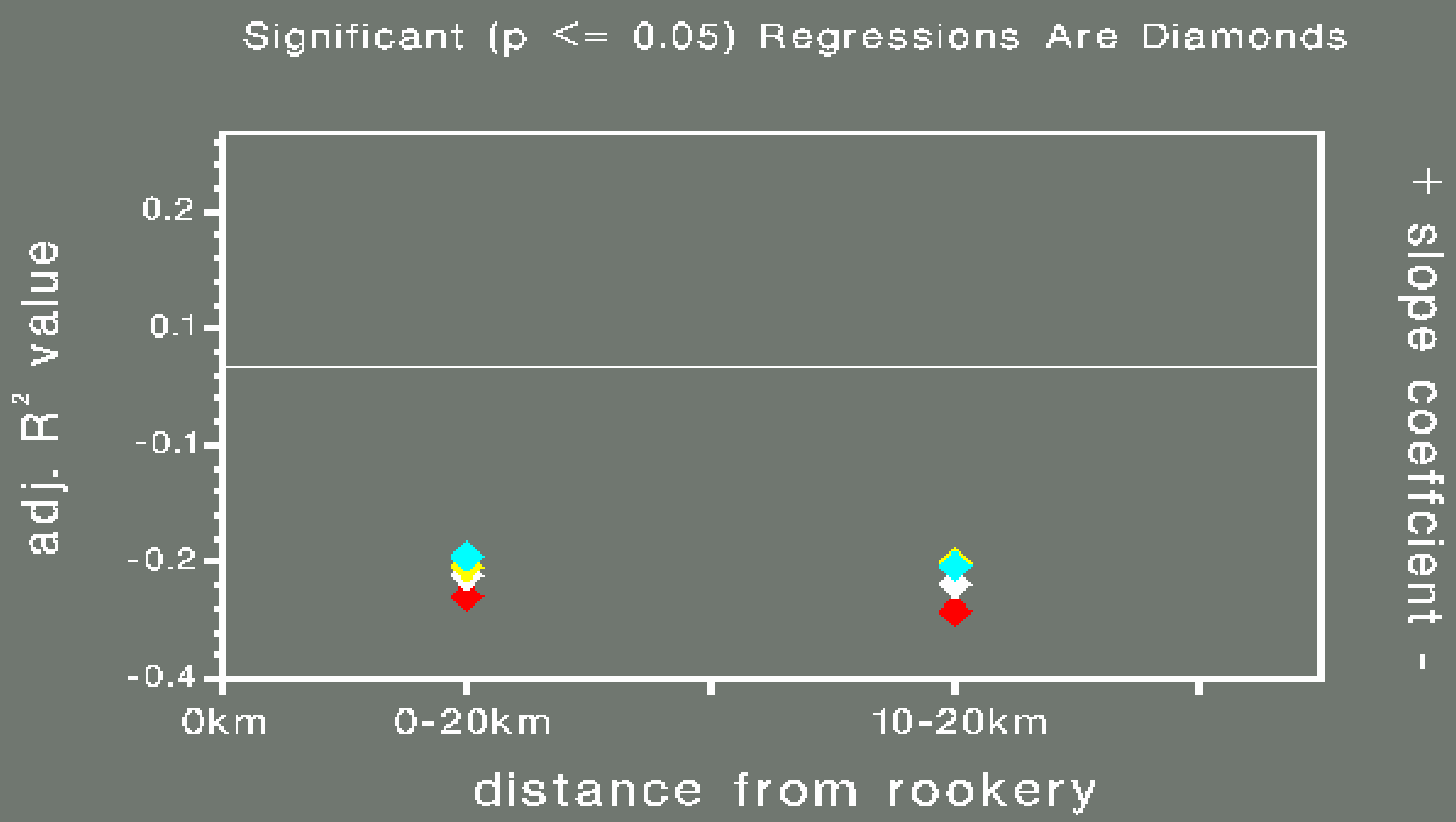
Results

1960 – 1991 Population Trend vs. Ranked 1977 – 1991, Summer, Pollock, Small/Non-Pelagic Trawl Fishing. Activity variables only: NM, SM, IND, DUR



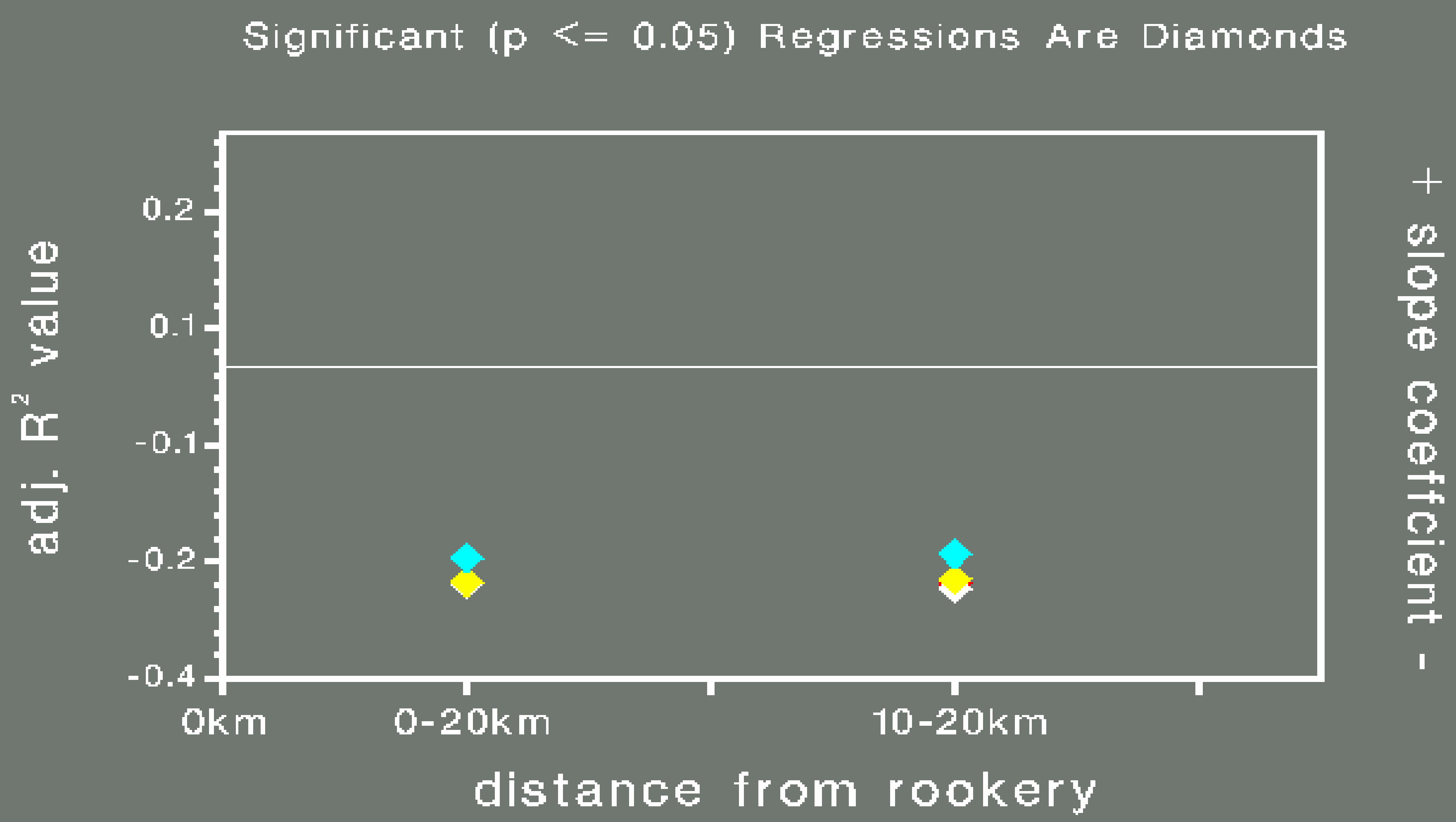
Results

1956 – 1991 Population Trend vs. Ranked 1977 – 1991, Summer, Pacific Cod, Small/Non-Pelagic Trawl Fishing. Activity variables only: NM, SM, IND, DUR



Results

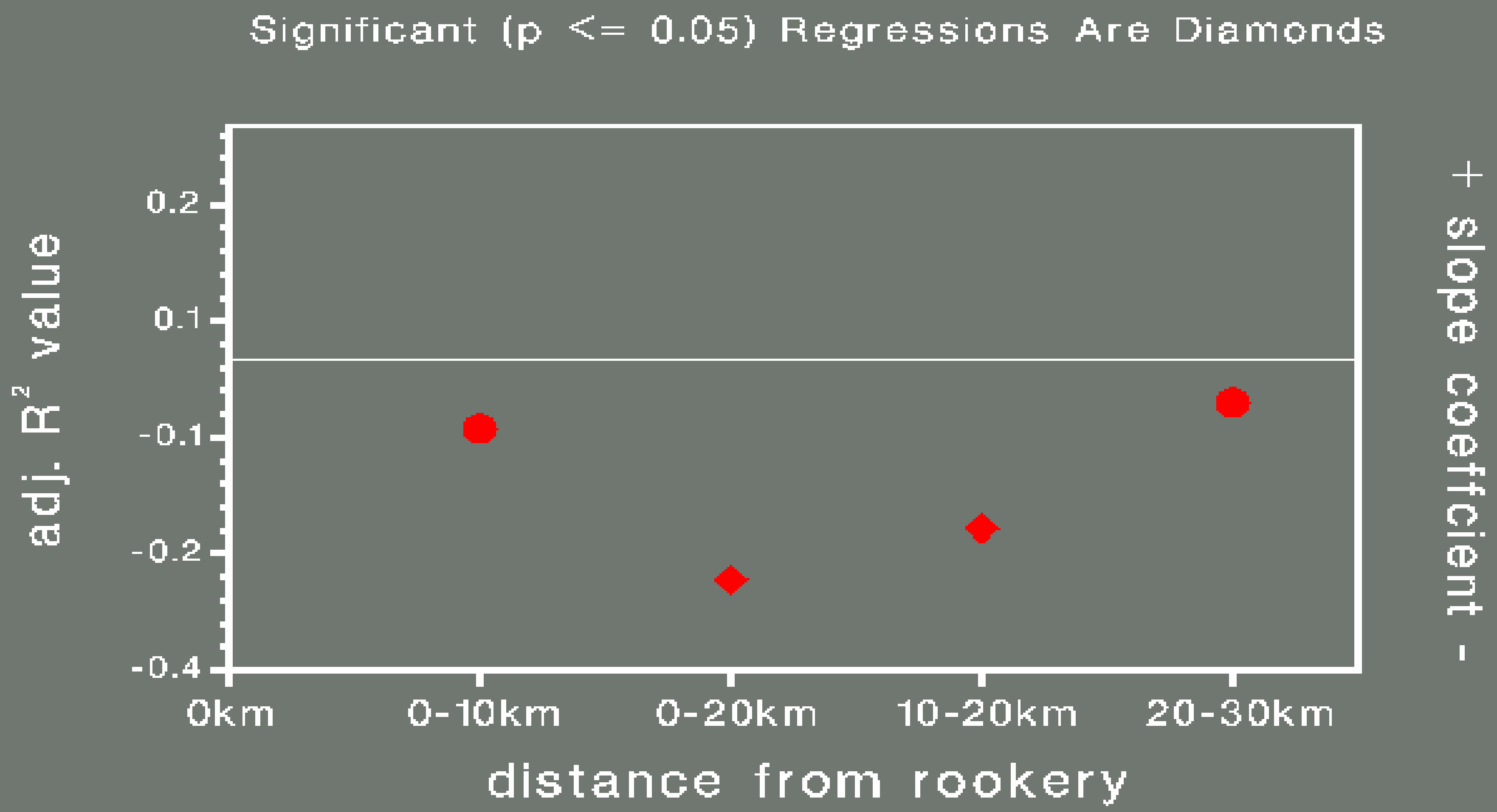
1960 – 1991 Population Trend vs. Ranked 1977 – 1991, Summer, Pacific Cod, Small/Non-Pelagic Trawl Fishing. Activity variables only: NM, SM, IND, DUR



Results

1956 – 1991 Population Trend vs. Ranked 1977 – 1991 Fishing

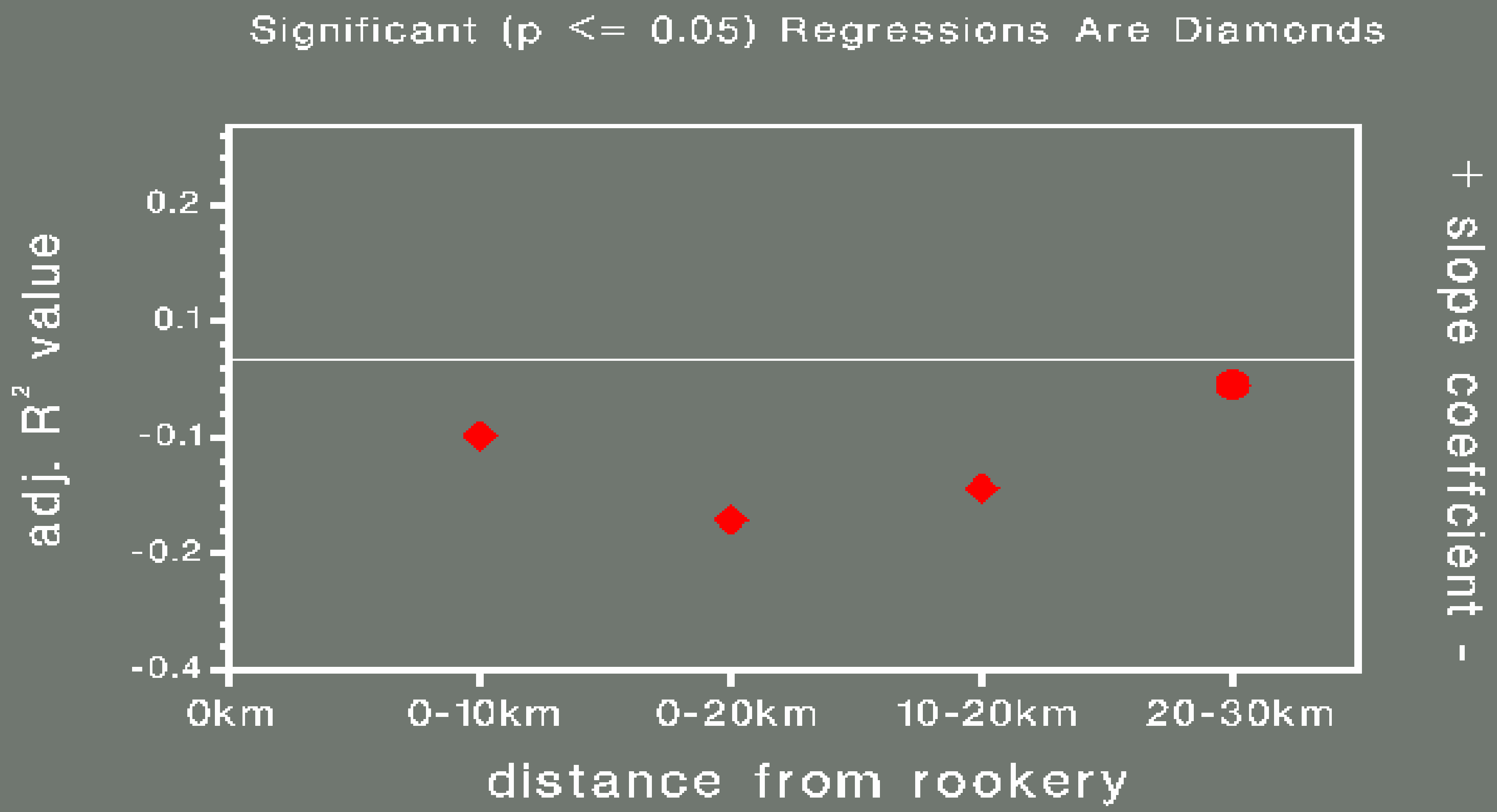
Abundance Variables Only: CPU



Results

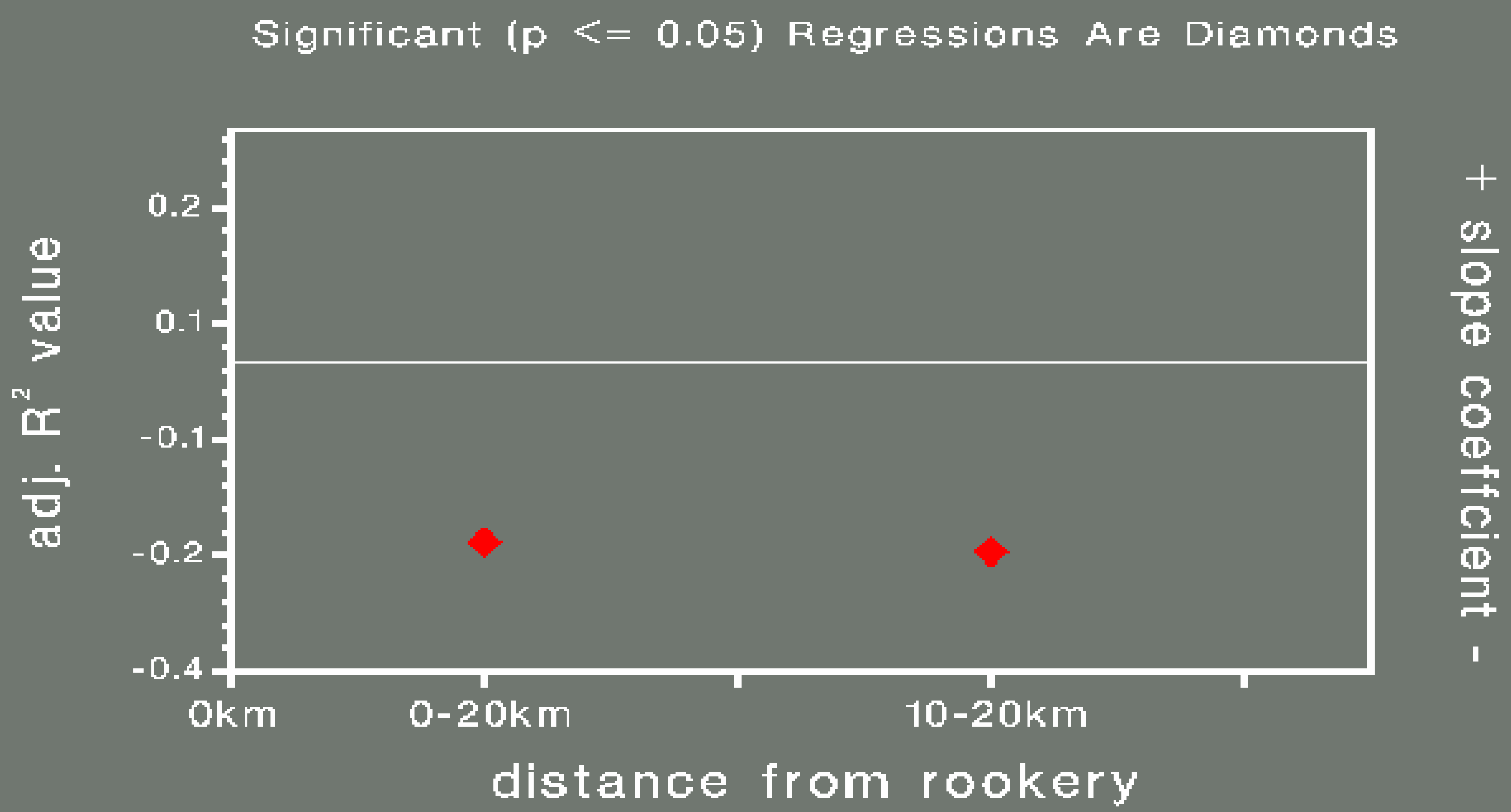
1960 – 1991 Population Trend vs. Ranked 1977 – 1991 Fishing

Abundance Variables Only: CPU



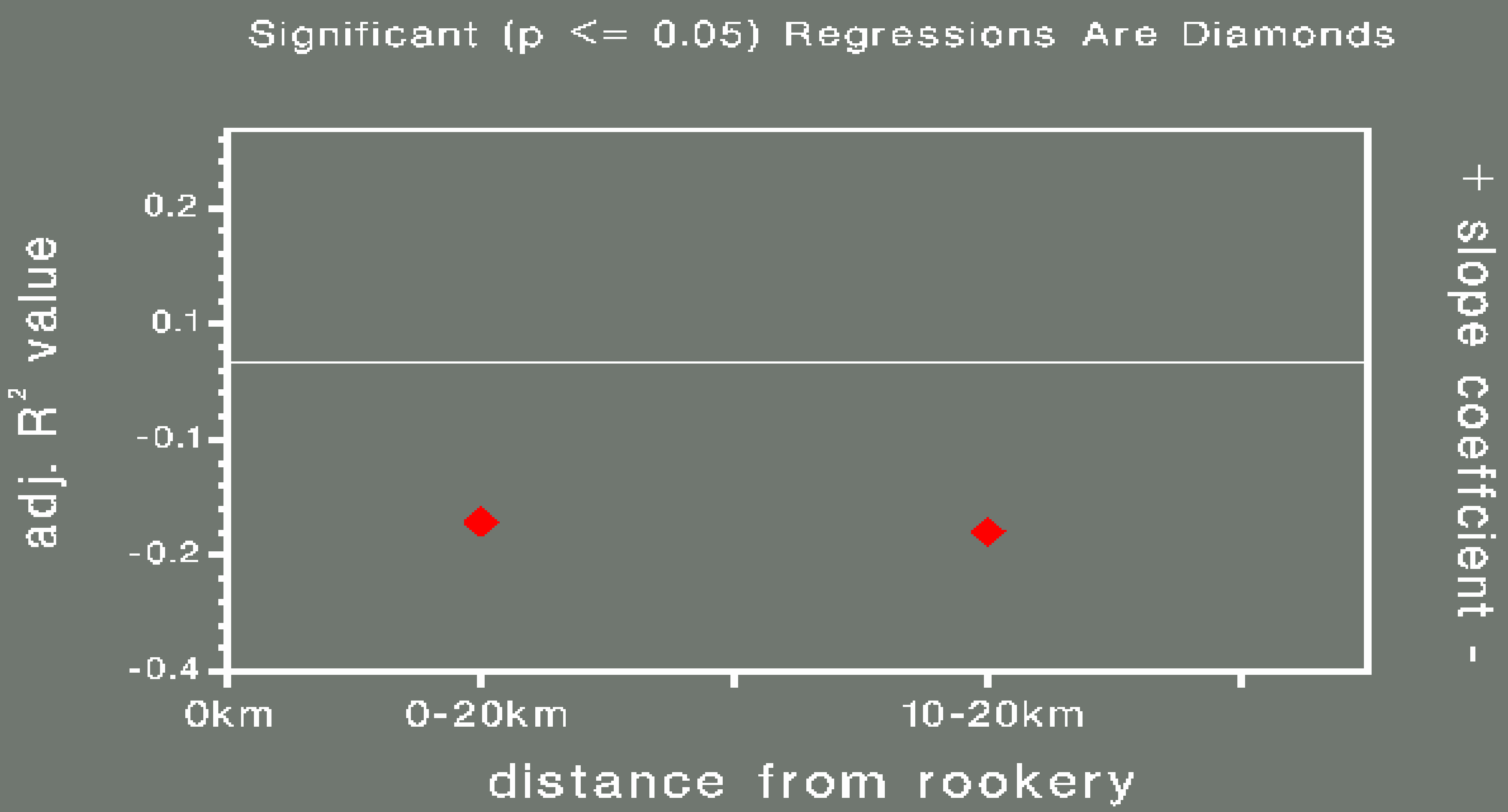
Results

1956 – 1991 Population Trend vs. Ranked 1977 – 1991, Fall, Small/Non-Pelagic Trawl, Pollock Fishing. Abundance Variables Only: CPU



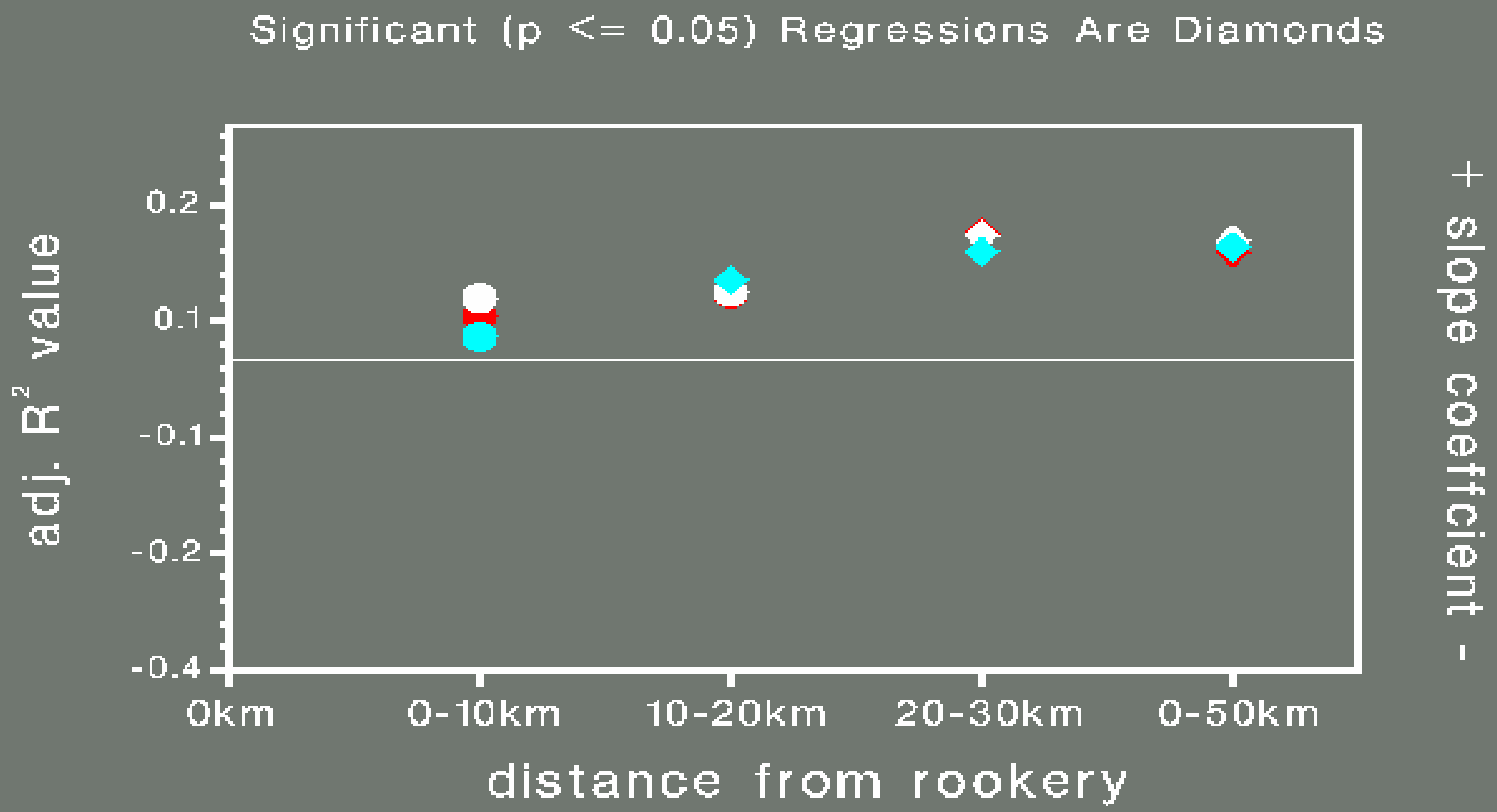
Results

1960 – 1991 Population Trend vs. Ranked 1977 – 1991, Fall , Small/Non-Pelagic Trawl, Pollock Fishing. Abundance Variables Only: CPU



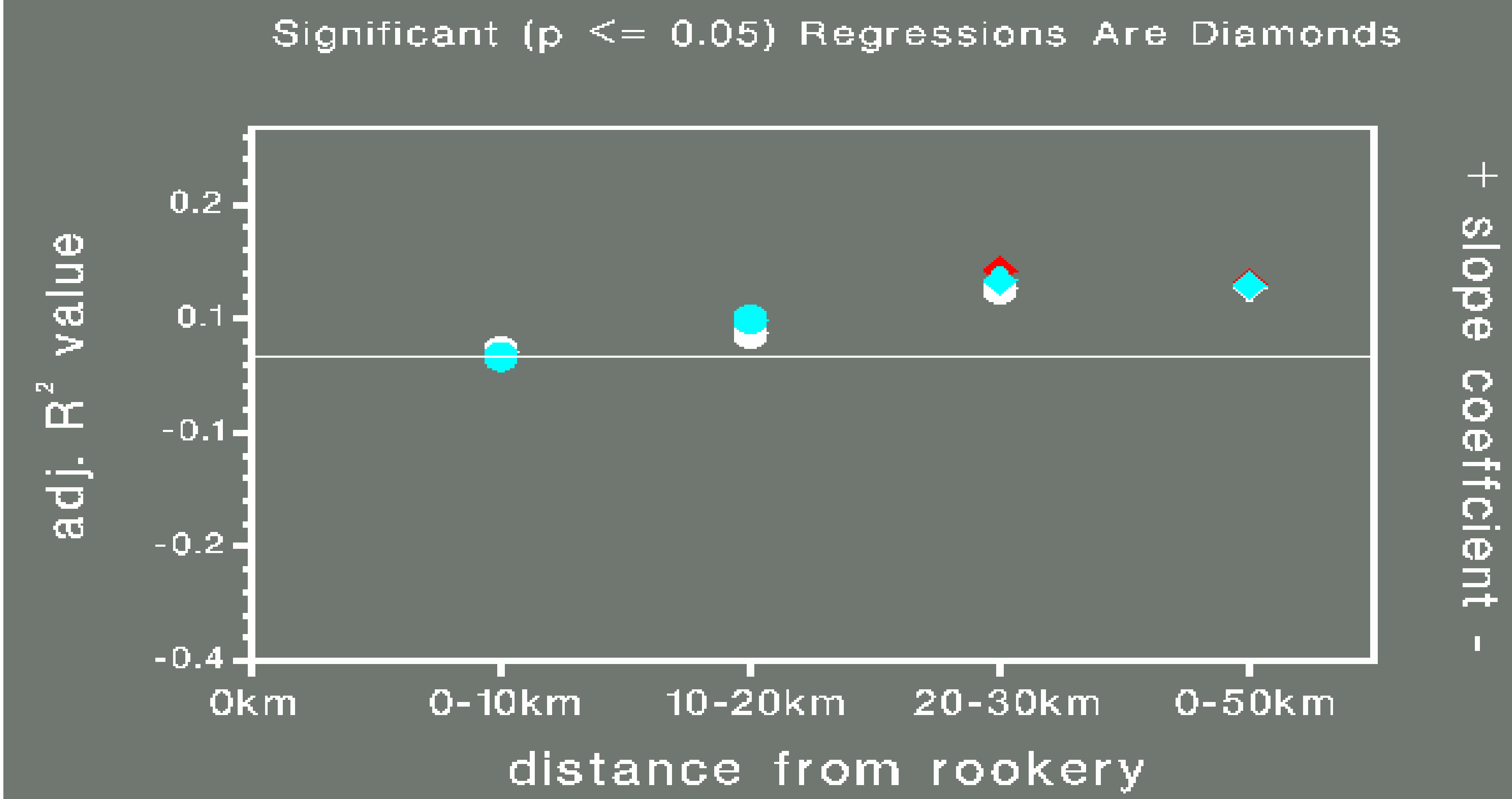
Results

1991 – 2001 Population Trend (50's) vs. 1991 – 2000 Ranked Fishing Activity Variables Only: NM, SM, DUR



Results

1991 – 2001 Population Trend (no 50’s) vs. 1991 – 2000 Ranked Fishing Activity Variables Only: NM, SM, DUR



Interpretations

- Fishing related activities contributed to the decline of SSL before 1991
- Since 1991, SSL are not declining as fast in areas of high offshore fishing activity

Comparisons

1977 – 1991 SSL Population Growth Rate

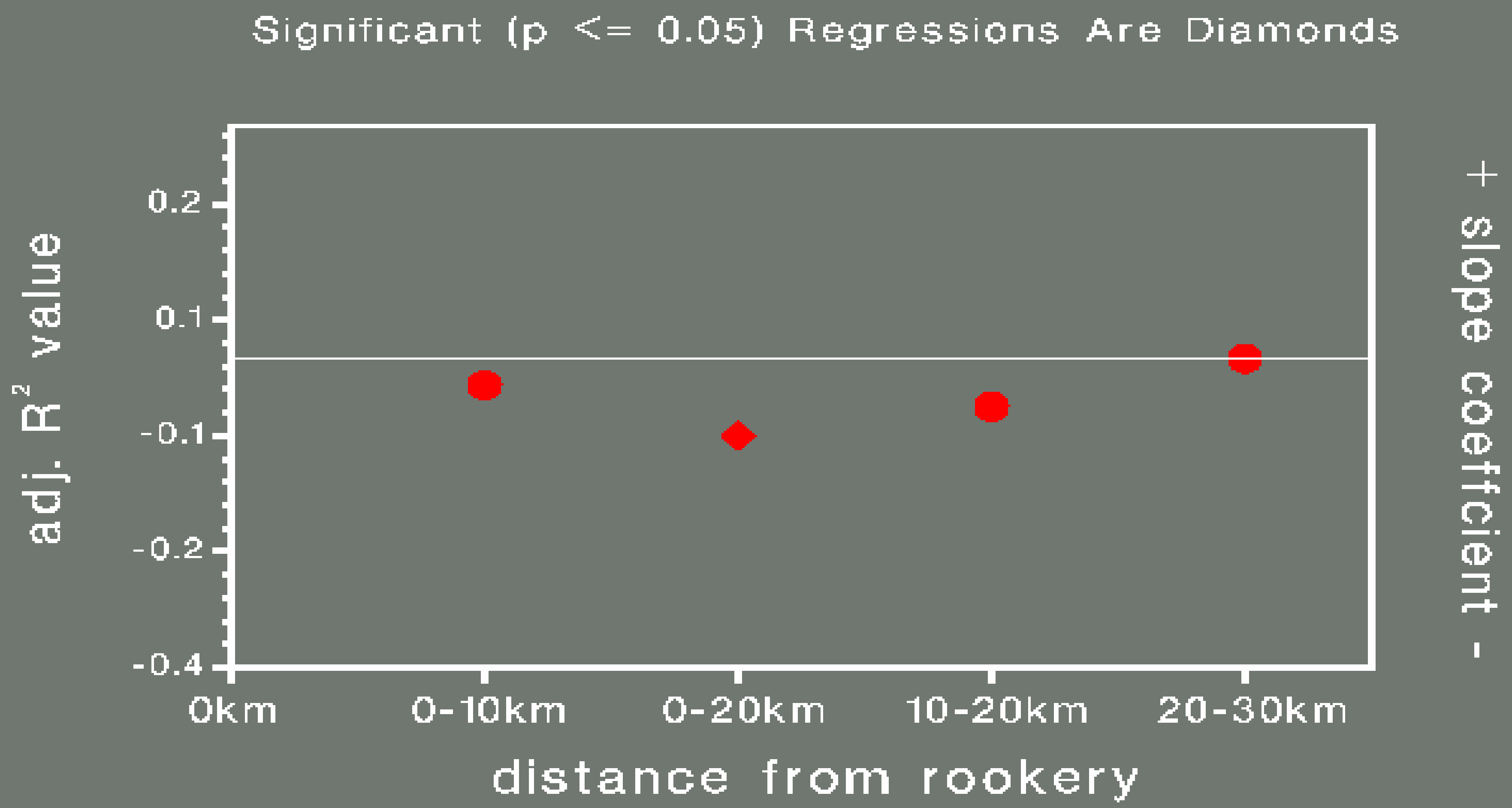
vs.

1977 – 1991 Fish Abundance

Results

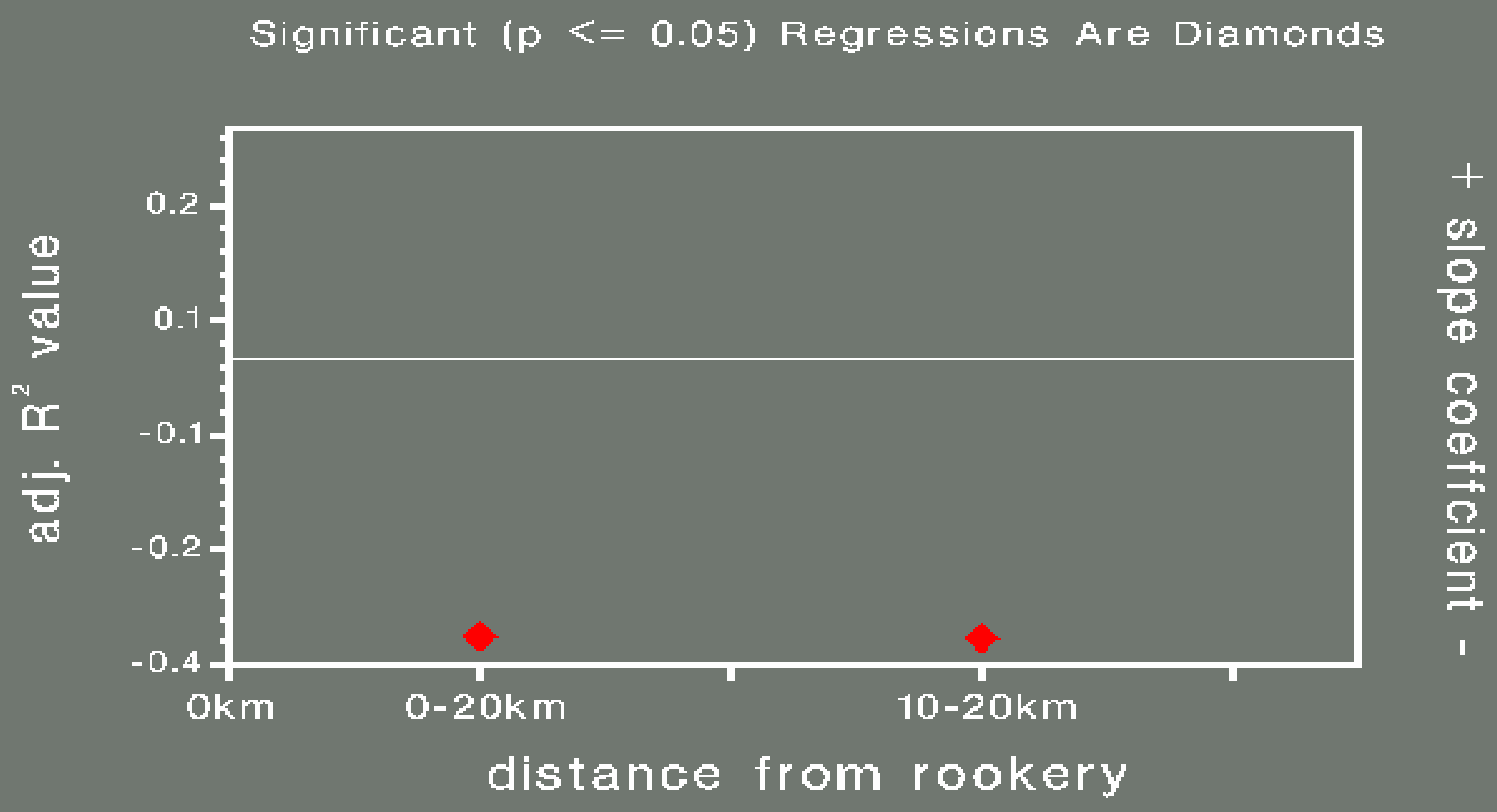
1977 – 1991 Growth Rate vs. Ranked 1977 – 1991 Fishing

Abundance Variables Only: CPU



Results

1977 – 1991 Growth Rate vs. Ranked 1977 – 1991, Fall , Small/Non-pelagic Trawl, Pollock Fishing. Abundance Variables Only: CPU



Results

- Negative relationship between 1977 – 1991 fish abundance variables and 1977–1991 SSL population growth rate

Comparisons

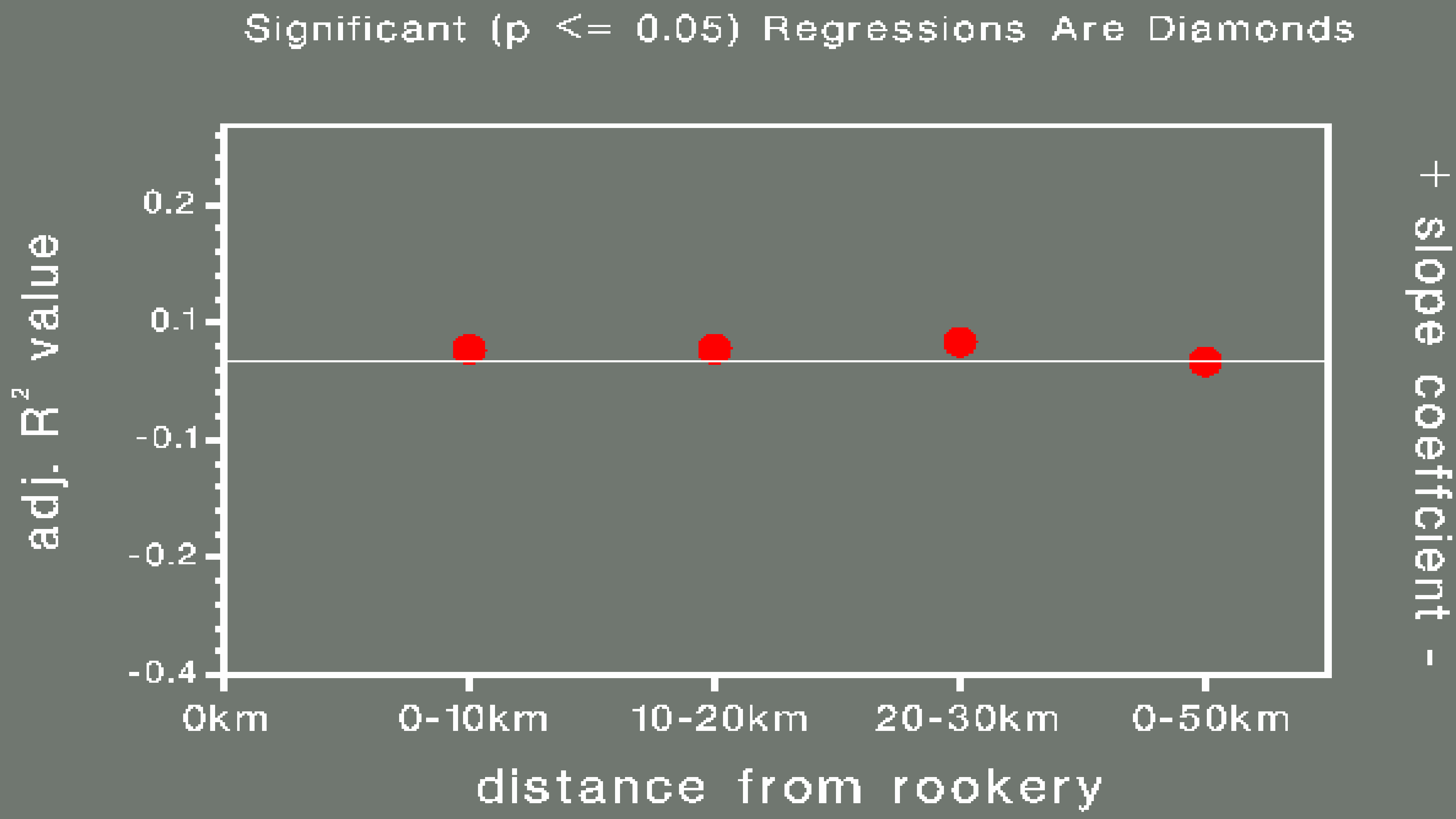
1991 – 2001 SSL Population Growth Rate

vs.

1991 – 2000 Fish Abundance

Results

1991 – 2001 Growth Rate vs. Ranked 1991 – 2000 Fishing Variables Abundance variables only: CPU



Results

- No clear relationship between 1991 – 2000 fishing abundance variables and 1991 – 2001 SSL population growth rate