May 2003 Progress Report: AFSC Pacific Cod Local Abundance Study

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Introduction

As part of the Steller Sea lion research initiative, the Alaska Fishery Science Center (AFSC) is conducting a field experiment on Pacific cod in the southeast Bering Sea. The objective of the study is to determine whether the winter trawl fishery in the vicinity of Unimak Pass has a measurable effect on local abundance of cod. Pacific cod is one of the three groundfish species managed by NOAA Fisheries for which localized depletion has been suggested as a possible mechanism whereby the fishery may impact food availability for endangered Steller sea lions. Because the winter trawl fishery for cod is fairly concentrated in both space and time, this fishery provides a good opportunity to conduct field studies on localized depletion. The study area is on the northeast side of Unimak Pass in an area that is consistently fished for cod during the winter season. The 10 nm no-trawl zone instituted around Cape Sarichef in 2002 provides an opportunity for a comparative treatment-control experiment, with pot fishing sites located in similar depths inside (control) and outside the no-trawl zone (treatment). The experiment is designed to measure the change in local abundance of cod in a before/after design, with one field survey performed before the start of the winter trawl season and a second survey immediately following the period of heaviest fishing. Pot catch of Pacific cod is used as an index of local abundance. Details of the study design may be found at *www.stellersealions.noaa.gov*.

The study design was presented at the fall 2002 meeting of the North Pacific Fishery Management Council (Council), and was reviewed by both the Scientific and Statistical Committee and the Advisory Panel. At this meeting, the AFSC requested a special two-week closure of the study area outside the no-trawl zone for March 15-31 of 2003-2006, in order to facilitate the "after" leg of each experiment. The Council granted this special closure, but asked that a progress report be submitted in spring 2003. This document is an interim report summarizing progress of the study during the 2003 field season and providing preliminary data analyses. All data presented in this report should be considered provisional, pending completion of data entry and analyses during summer 2003.

Summaries of Cruise Activity for the 2002-2003 Field Season

Abundance Experiment "Before" Cruise: Dec 28, 2002 – Jan 12, 2003 F/V Pacific Star

The objective of this cruise was to collect local abundance data in the Cape Sarichef experimental area (Figure 1) prior to the January 2003 opening of the cod trawl fishery. This cruise was intended as the "before" leg of the "Before/After" experimental design; pre-cruise targets were to pot-fish 60 pot positions within the no-trawl zone and 60 positions outside the no-trawl zone at a rate of 30-40 pot sets per day. Positions to be fished were set up according to a systematic design with random start (Figure 1).

This cruise was the first full use of AFSC's new research pots. During the final gear feasibility trial in October 2002, it was discovered that the research pots, which are slightly larger than the commercial pots normally used by the Pacific Star, would not fit properly on the Star's pot launcher. The pots sit on the launcher and can be launched and emptied, but the "pot dogs" that clamp the pot firmly in the launcher would not extend far enough to accommodate the research pots. A new launcher table that can accommodate the research pots was ordered for the Star, but was not delivered in time to install before the scheduled departure date. As a result, the pots could be fished, but without the added safety provided by the pot dogs.

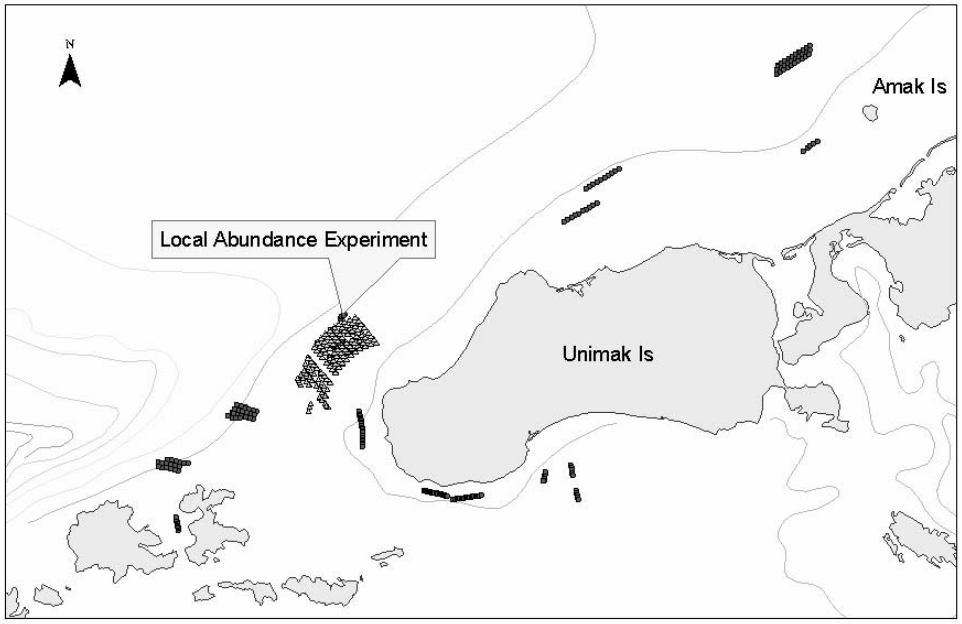
Execution of the intended sampling plan was severely hampered by bad weather and mechanical problems. Problems with the main lifting crane delayed departure form the dock. Fishing began with a run of eight pots on the evening of December 29 and a full set of 40 pots on Dec 30-31. Weather in the study area was rough and became rougher as the work progressed. The Captain and the field party chief together determined that seas were too rough to fish on Dec 31. Another full set of 40 pots was set on January 1. As these pots were being retrieved, rough seas shifted pots in the launcher several times; on two occasions, pots came completely free of the launcher. The combination of rough seas and the lack of pot dogs raised safety concerns and fishing was suspended. For Jan 2-3 the vessel moved to the south side of Unimak Island (in the lee of the weather) and tagged cod in the vicinity of Unimak Bight (Figure 1). On Jan 4 we returned to the study area and fished a full set of 40 pots. After this set, worsening seas and forecasts for gale winds caused the vessel to seek shelter in Akutan harbor. On Jan 7, winds finally abated enough to attempt fishing again. Upon leaving Akutan harbor, mechanical problems forced shutdown of one of the two main engines on the vessel. Because of safety concerns with reduced maneuverability of the vessel and the lack of pot dogs, the decision was made to return to Dutch Harbor and attempt repairs. When it was discovered that three main cylinders in the engine needed to be replaced, the charter was terminated on Jan 9.

Overall, this cruise leg fished 127 pots in the local abundance study area. An additional seven pots were fished near the study area and 16 pots south of Unimak Island for collection of cod for tagging (Figure 1). A total of 10 data recording tags and 470 orange spaghetti tags were released. A total of 2,736 Pacific cod and a scattering of other species were collected (Table1). Approximately 35% of the cod collected were examined for individual lengths, sex, and maturity class. Fifty-nine cod were dissected for collection of biological specimens and genetic tissue samples.

Table 1. Total catch by species for AFSC cod pot cruises, winter 2002/2003.

Cruise:	**Dec-January**		**February**		**March**		**Combined Total**	
Species Name	**Num**	**Kg**	**Num**	**Kg**	**Num**	**Kg**	**Num**	**Kg**
Pacific Cod	2736	12970	7490	26315	4647	13633	14873	52917
Yellow Irish Lord	53	46.4	749	649.5	319	212.0	1121	907.8
Octopus	5	80.3	26	387.4	11	88.0	42	555.8
Wolffish					19	117.1	19	117.1
Starfish			662	103.9			662	103.9
Atka Mackerel	1	1.1	86	89.4	11	10.6	98	101.1
Tanner Crab (*Bairdi*)	46	1.9	153	89.9	77	7.7	276	99.5
Walleye Pollock	9	13.7	27	27.7	16	16.2	52	57.5
Halibut	2	4.0	9	32.3	5	10.9	16	47.2
Yellowfin sole			69	32.1	12	8.9	81	41.0
Great Sculpin	4	20.2			4	20.2	8	40.5
Snails	3	0.8	142	7.5			145	8.3
Northern Rockfish			9	8.2			9	8.2
Prowfish	1	0.6	3	6.0			4	6.6
Searcher			10	5.5	1	0.6	11	6.0
Sculpin spp.			5	5.1			5	5.1
Kelp Greenling			2	1.8	2	2.3	4	4.1
Hermit crab	8	1.3					8	1.3
Butter sole					1	0.8	1	0.8
Lyre Crab			9	0.6	30	0.0	39	0.6
Telmessus Crab			1	0.2			1	0.2
Arrowtooth Flounder	1	0.2					1	0.2
Fusi tritons					4	0.0	4	0.0
Cruise Total	2865	13120	9452	27763	5159	14128	17476	55011

Figure 1. Location of pots fished for Pacific cod, winter 2002/2003 Abundance experiment (triangles) and tagging (squares)



"Before" Abundance Experiment Retry and Tagging Cruise: Feb 5- 16, 2003, F/V Pacific Star

The intent of the second Pacific cod cruise, originally scheduled for mid-February, was to conduct tagging studies to observe seasonal and small scale movement of Pacific cod. Due to problems experienced during the January cruise, the start date was moved forward for a second attempt at the "Before" abundance experiment. Industry representatives were contacted and efforts were made to minimize gear conflicts with the cod trawl fleet as the new time frame would put research on the fishing grounds during the trawl season. AFSC scientists realized that research pot gear would impede trawling, and that if trawl fishing efforts were high during the cruise, attempts to work around the fishing fleet would likely fail. Upon arriving to the grounds researchers found the pollock trawl presence to be extensive. On Feb 5 -7 pots were fished at experimental sites within the no-trawl zone while trawl activity was observed. After three days, it was clear that setting pots outside the no-trawl zone was not feasible; abundance experiment fishing was abandoned and the research focus was switched back to tagging studies.

Fish for tagging were collected with the same research pots used in the local abundance experiment. Abundance experiment protocols for setting distance between pots and bait weight were used for all tagging pots, but soak times varied. Pots fished for tagging were hauled back as slowly as equipment allowed, in order to reduce pressure trauma to the fish. Pacific cod were tagged in three separate locations near Unimak Pass to look for: 1) movement northeast along the north west coast of the Aleutian chain, 2) deep to shallow movement, 3) movement from no-trawl zones into trawl zones. Figure 1 shows the areas where tags were released and Table 2 shows the number of tagged fish released at each location.

Table 2. Numbers of spaghetti tags released during AFSC cod studies (preliminary).

Cruise	Location	No. Tags
April 02	Akun	77
	Sarichef	1552
	Amak	108
Dec 02 - Jan 03		470
Feb 03	Akun	2392
	Sarichef	1144
	Slime Bank	394
	Amak	969
Mar 03		140
Total		7246

In addition to released fish, 500 cod were used in tag mortality studies, 600 were examined for sex and maturity class, 300 were dissected for biological specimens and genetic tissue samples. Length was collected on all tagged and specimen fish. Total catch for the cruise is shown in Table 1.

Abundance Experiment "After" Cruise: March 14 – April 2, 2003, F/V Pacific Star

The objective of this cruise was to collect local abundance data in the Cape Sarichef experimental area (Figure 1) after the period of heaviest cod trawling. The cruise was originally intended to be the "after" leg of the "before/after" experimental design, in which stations fished prior to the cod trawl fishery were sampled again. We adhered to the "before/after" construct but we also modified the experimental design somewhat, concentrating on the 80 stations in the northeastern two thirds of the original 120 stations (Figure 1), 40 within the no trawl zone and 40 outside the no trawl zone. We did this for three reasons:

1. Comparisons of research catches from before and after the trawl fishery were likely to be inconclusive due to the low sample size and attendant uncertainty in the "before" data. In short, there was nothing to jeopardize by deviating slightly from the sampling structure of the "before" leg.
2. The difficulties of the first leg taught us that the "worst case" scenario was worse than we had anticipated and that we needed to define primary goals that could be attained in very few fishing days. We were not sure if it was better to have fewer stations and more replication at each station, or *vice versa*. We chose to reduce the station number and preserve or increase replication at each station since the data collected under that scheme could be used to evaluate the question of allocation of field effort among stations and station replication *per se* in the "before/after" construct.
3. Once we had decided to reduce the station number from 120 to 80, those in the northeastern portion of the original station pattern were preferred because all had been fished at least once during the "before" leg.

To best arm ourselves for bootstrap simulations we decided to fish on those 80 stations as many times as possible. Thus, if smooth operations and favorable weather permitted, we were willing to deploy a pot as many as 7 or 8 times at each station. (Had the "before" data been more fully realized then our primary and secondary goals would have been to provide corollary "after" data as completely as possible. Under such circumstances we would not have fished more than three times at any station until the "before" data had been fully matched with "after" data.)

The scheduled charter dates for this cruise were March 14 through April 2, 2003. This period encompassed the temporary closure to fishing in the vicinity of the Cape Sarichef experimental site. Severe weather hampered operations in this cruise, just as it had for the "before" leg. Initial departure from Dutch Harbor was delayed until 18 March because flights from Anchorage to Dutch Harbor were cancelled for over a week due to high winds, stranding all of the vessel's crew and part of the field party in Anchorage. Once embarked, operations were suspended for March 23 - 25 due to seas built up by a northeasterly that blew 50 to 70 knots throughout that time. Despite time lost to weather, we were able to launch and retrieve pots at least 5 times on almost all 80 stations.

On this cruise 425 pots were launched and retrieved as part of the "before/after" experiment. During the period of bad weather, another 53 pots were deployed to capture cod for tagging studies in the vicinity of Scotch Cap/Arch Point/Seal Cape in Unimak Pass and near Lost Harbor in Akutan Bay. Trigger sensors were deployed on pots in the "before/after" experiment and additional deployments were dedicated to collecting trigger sensor data independently of the experiment.

Over all of the pot deployments in this cruise, a total of 4647 cod and a scattering of other species were collected (Table 1). All cod were measured individually for length. Other than those released as part of tagging research, all cod were examined individually for gender and gonad maturity was evaluated. 163 specimens were dissected for more detailed biological sampling. Tissue was collected from approximately 1,500 cod as part of a genetics investigation.

Preliminary Results and Data Analyses from 2003 Cruises

Definition of Catch Measures and Comparisons

This experimental design uses pot catch of cod as an index of local abundance. This section describes how pot catches are used to compare the rate of change in local abundance between treatment (trawled) and control (untrawled) parts of the study area. Catch of cod by weight and numbers was strongly correlated and analysis using either measure would give similar results; the analyses presented here are based on numbers of cod caught in each pot.

Prior to the start of the 2003 field season, 120 possible study sites were selected according to a systematic design with random start (see Figure 1). A "site" is a particular location specified by Latitude/Longitude coordinates that can be fished several times over the course of the study. This layout of study sites is symmetric across the no-trawl zone boundary, so that half

the sites are within the no-trawl zone (control area) and half outside the boundary in the treatment area. The goal of the field effort is to measure cod catch at each site three or more times during each two-week survey ("before" in Dec-Jan and "after" during March). For each site, an average catch rate for the survey (X_{Before} or X_{After}) is calculated.

The "before" and "after" catch rates at each site are used to calculate a percentage change in abundance (delta) over the period between the two surveys:

$$\delta \equiv \left(\left(X_{After} - X_{Before} \right) \Big/ X_{Before} \right)$$

This quantity will be near zero if the catch rate is the same at a given site during both the before and after surveys, positive if the catch rate increases, and negative if the catch rate decreases over the season. For example, a δ of -0.50 would represent a 50% decrease in catch rate, and a δ of +1.00 would represent a 100% increase. Hypothesis testing for the presence or absence of a fishing effect is based on comparing the set of deltas measured in the treatment zone to the set of deltas measured in the control (untrawled) zone. Our assumption is while the absolute abundance of cod may vary both between sites and over time, the percentage change in abundance due to natural causes should be consistent over the entire study area. If the trawl fishery is creating localized depletion in the treatment area, we would expect the percentage change to be lower in the treatment group than in the control group (Figure 2).

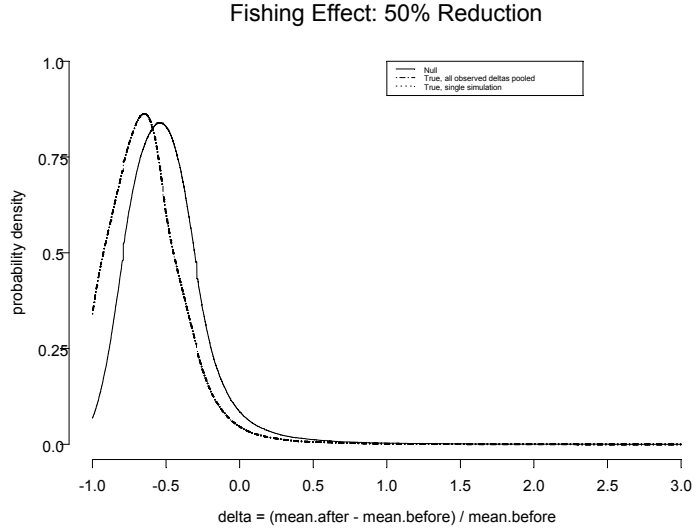


Figure 2. Example of the distribution of change in catch measure (delta) in the absence of any fishing effect (solid line) and under a 50% reduction in the mean "after" catch rate (dotted line). Distributions are based on bootstrap simulations from winter 2002/2003 data, as described below.

Results – Catch Data

The catch of cod continued to look like a reasonable index of local cod abundance (Figure 3). Using the research pots with a 4-8 hour soak period, there was no evidence of gear saturation and only a few empty pots. There were no immediately evident patterns in catch with pot location (North-South or East-West), depth, soak time, or time of day; more detailed analysis of the catch data will be conducted over the next few months. There were strong variations in catch over both seasonal and short-term time scales (Figure 3, Table 3). Catches in the experimental area declined strongly from January to March; this pattern is evident both in the overall distribution of catches and at the majority of the individual pot sites. Preliminary analyses of catch data also show substantial day-to-day variations in catch rates, especially during the March cruise. Variations in the average length and weight of fish caught per day (especially during March) indicate that different groups of fish move into and out of the study area over time spans of days. Length-frequency distributions for different locations and time periods will be compared as part of the full data analysis.

Results – Measures of Change in Catch Before/After

Because of the bad weather and mechanical problems encountered, the sample size for the Dec/Jan "Before" survey was much smaller than the target level. Instead of fishing each station three or more times, many stations were fished only once during this cruise. A larger number of stations were fished in March with three to six replications at each station. For calculation of the percentage change over the season, however, only the sites that have January data on catch rates can be used. There are two data sets that can be examined for change in catch. These data sets are used to illustrate the computations for hypothesis testing according to the experimental design for the study. Because of the small sample size in 2003, tests constructed from these data are expected to have low power and be difficult to interpret. A simulation study and discussion of the overall power of the procedure is included in a later section of this report.

The first data set calculates the percentage change in abundance (delta) at each site based on one day of fishing in each survey. A total of 56 sites were fished once during the period of Jan 1-4 and once during the period March18-20, 2003. Half of these sites were inside the no-trawl zone, and half in the treatment area. The second, much smaller data set calculates the change in catch over the season by using the average of three pot sets at each site during each survey. There are 16 sites available for this comparison, ½ of which are treatment and ½ control.

When the change in catch was calculated from a single pot catch in each survey, we observed values of δ ranging from -1.00 to +3.36. The median value for single-catch changes in

2003 was -0.65 for stations in the control zone and -0.66 for stations in the treatment area. A non-parametric Wilcoxon Rank-Sum test indicates that there was no statistically significant difference in the change in catch between the treatment and control groups for 2003 (p-value of 0.95). When the *X* for each survey was composed of an average over three pot sets, the percentage changes ranged from -0.37 to -0.84, with medians of -0.0.62 for the treatment sites and -0.57 for the control. The rank sum test also indicated no significant difference between the two groups based on this measure (p-value of 0.51). A pooled frequency distribution for all sites from the single-pot data set is shown in Figure 4. Exploratory analysis of the change-in-catch measures did not show any consistent trends with depth, position (E-W), or soak time.

Results – Tagging Studies

Feasibility studies for research on cod movements by tagging were also conducted in 2002 and 2003. Tagging work included development of capture and handling methods for cod using pot gear, development of tagging procedures and data formats, release of cod tagged with archival data-storage tags and standard spaghetti tags, and preliminary tagging mortality studies. The goal of this effort is to collect information on both seasonal migration patterns and small-scale cod movements during the spawning season. Some of these movement questions are important to the interpretation of the local abundance study. The February tagging cruise released tagged fish at a series of four locations along the 100m depth contour north of Unimak Pass (see Figure 1) in order to assess the degree of east-west movement through the study area. Fish were also tagged at deep offshore locations and within the no-trawl zone to try to assess movement from deep to shallow areas during the spawning season and across the no-trawl zone boundary. Bad-weather days during both the January and March cruises were used opportunistically to tag and release fish on the south side of the Pass to look for movement between the Bering and GOA. In total, 295 archival tags and over 7,000 spaghetti tags have been released (Table 2). The return rate on tags released in April 2002 has been excellent (>20% so far), and tags released in 2003 have already started to come in. The AFSC has appointed a post-doctoral scholar for the cod tagging program who will be starting in June 2003.

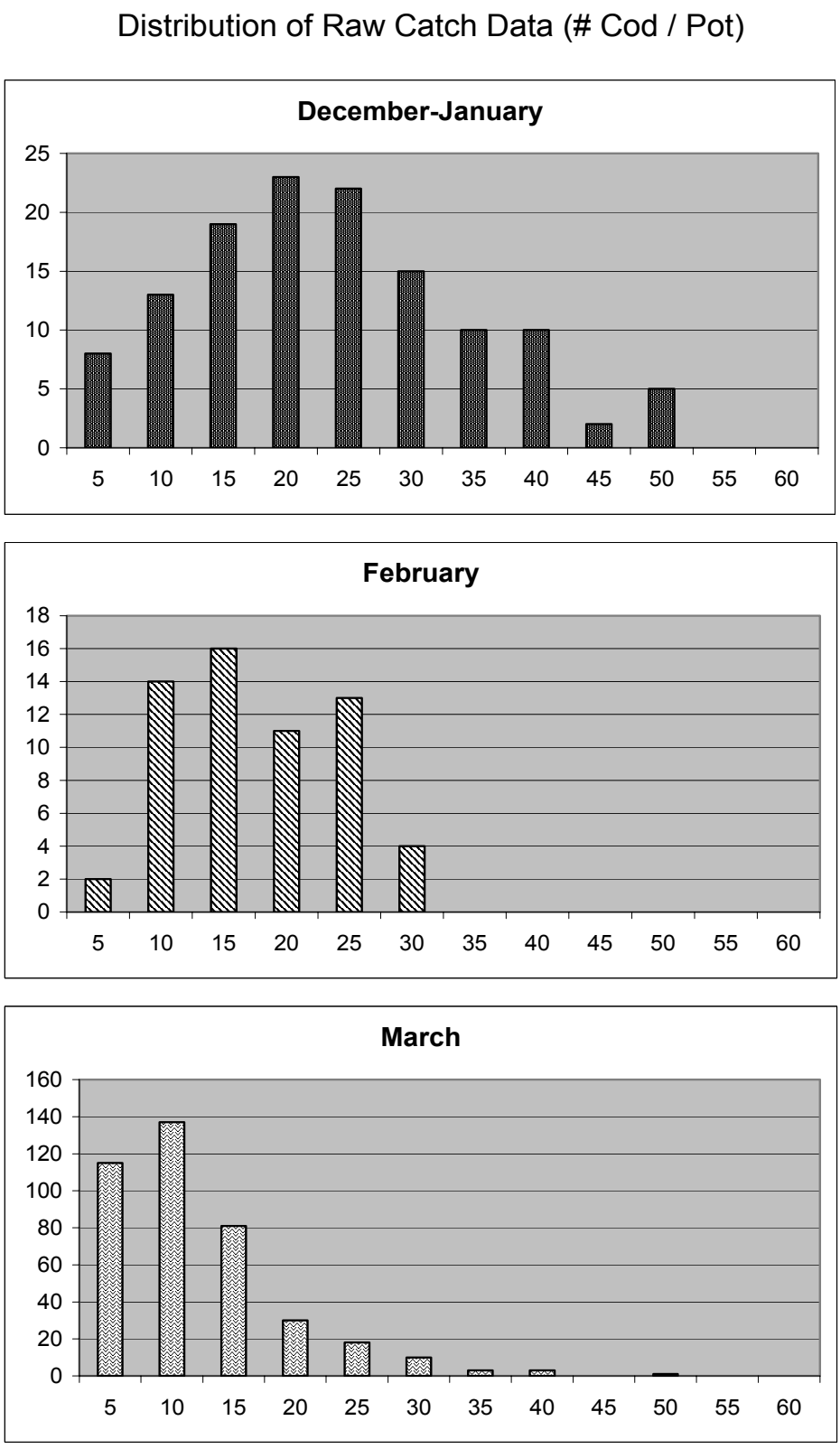


Figure 3. Frequency distribution of raw catch data (in numbers of cod per pot) from the cod local abundance experiment off Cape Sarichef.

Table 3. Daily variation in catch at the Cape Sarichef local abundance experimental area, for the three winter 2002/03 cruises.

		Number	Number	Weight	Daily Averages		
		of Pot	of Cod	of Cod	Number	Weight	Weight
Cruise	Date	Hauls	Caught	Caught (Kg)	per Pot	per Pot	per Fish
Jan	12/29	8	136	685	17.0	85.7	5.04
	12/30	40	581	2,846	14.5	71.2	4.90
	1/1	40	818	3,612	20.5	90.3	4.42
	1/4	40	1201	5,826	30.0	145.7	4.85
Feb							
	2/5	20	184	706	9.2	35.3	3.84
	2/6	20	384	1,671	19.2	83.5	4.35
	2/7	20	368	1,399	18.4	69.9	3.80
March	3/18	16	133	453	8.3	28.3	3.40
	3/19	40	912	2,919	22.8	73.0	3.20
	3/20	41	340	1,219	8.3	29.7	3.58
	3/21	40	292	975	7.3	24.4	3.34
	3/22	41	334	1,115	8.1	27.2	3.34
	3/26	25	202	696	8.1	27.8	3.44
	3/27	40	276	768	6.9	19.2	2.78
	3/28	45	299	642	6.6	14.3	2.15
	3/29	45	283	638	6.3	14.2	2.26
	3/30	40	444	1,439	11.1	36.0	3.24
	3/31	41	604	2,122	14.7	51.7	3.51

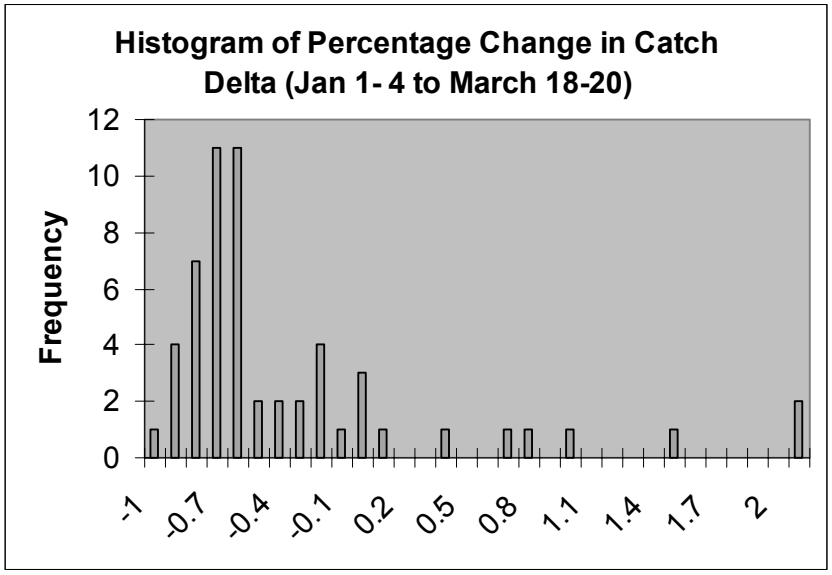


Figure 4. Frequency distribution of percentage change in catch (all stations), Jan-March 2003.

Results - Biological Data Collection

The main focus of the AFSC cod pot studies is the local abundance experiment, but these studies also provide a platform for the collection of important information on cod movement and spawning biology. AFSC staff was accompanied on 2003 cruises by a University of Alaska graduate student whose work focuses on fecundity of cod and effects of age and water temperature on fecundity. Maturity and fecundity of specimens collected during the pot cruises will be compared to cod specimens collected from the Gulf of Alaska (Kodiak). Specimen samples were also collected for laboratory histology, in order to collect high-quality data on the age at 50% maturity, which is an important parameter in the cod stock assessment model. Paired samples of otoliths and vertebrae were collected for the AFSC Age and Growth laboratory, which is working on improved methods for aging Pacific cod. Fish sampled for lengths were also given a gross maturity code based on visual inspection of the gonad; the frequency distribution in these maturity classes give valuable information about sex ratios and the timing of spawning within the three-month winter season. Finally, tissue samples were collected for genetic analysis, in support of studies by the NMML genetics laboratory on population genetics and stock structure of cod.

Results - Gear Development

The local abundance study has also provided the opportunity for development of pots as research fishing gear. The experimental pots developed for this study have triggers that can be fit with sensors that record when fish entered the pot. A small number of these sensors were used in 2002 and 2003 studies while the best sensor configuration was being worked out. If funding can be obtained, a larger number of pots will be equipped with trigger timers for 2004 and later work. Data from these sensors in winter 2003 shows patterns that suggest pot catch rates are strongly affected by tide, as has been observed by many pot skippers. Because pots depend on the scent plume from the bait to attract fish, the direction and strength of bottom currents is expected to be an important factor in catch efficiency. The AFSC is working on developing a ‘sensor pot’ that includes a Doppler current sensor and can be launched and retrieved along with standard pot gear. With direct means of measuring bottom currents and trigger timers, it may be possible to account for much of the variance in pot catch. Plans for the future also include development of water quality instrumentation, so that we can track oceanographic features (fronts, mixing of Pacific and Bering Sea water masses) that may be important to cod abundance and/or catch efficiency. Funding for gear development work in the current 2003/2004 project budget is limited; additional funding sources for this work are being investigated.

Simulation – Power of Experiment, based on winter 2003 Data

The data collected in these cruises affords us our first opportunity to evaluate the experimental design directly, especially with regard to sample size and the power of the test. The "after" leg provided sufficient and properly configured data to permit simulations of a "before/after" experiment, employing the measure of trawling effect described earlier in this report. Bootstrap methods (resampling the data, with replacement) were used to simulate 1000 experiments under a variety of sampling constraints. The following algorithm was used:

1. Compute mean catch in the "before" data, $\overline{C}_{Before}$, ignoring trawled and untrawled categorizations.

2. Compute mean catch in the "after" data, $\overline{C}_{After}$, ignoring trawled and untrawled categorizations.

3. Compute the seasonal effect observed in the "before" and "after" legs (the underlying change in abundance from before the fishery to after the fishery due to all factors *other* than removals by a trawl fishery.)

$$\hat{S} = \frac{\overline{C}_{Before}}{\overline{C}_{After}}$$

4. Randomly select X stations, with replacement, from the stations visited in the "after" leg, ignoring trawled and untrawled categorization.

5. For each station selected in Step 4, randomly select m_{Before} catches, with replacement, from the catches made at that station during the "after" leg.

6. Multiply each catch selected in Step 5 by the factor representing seasonal change, $\hat{S}$ (computed in Step 3). These simulated data constitute the "before" leg of a simulated "before/after" experiment.

7. For each station selected in Step 4 randomly select m_{After} catches, with replacement, from the catches made at that station during the "after" leg.

8. Of the stations selected in Step 4, assign one half of them (the second half) to the trawled category.

9. For the stations assigned to the trawled category and for catches selected for them in Step 7, impose a fishing effect, F, a constant factor representing the fraction remaining after removals by a trawl fishery. For example, if 20 percent of the cod were harvested in the trawled area, the factor F would be 0.8.

10. For each station selected in Step 4 compute δ_i.

$$\delta_i = \frac{\overline{C}_{i,Before} - \overline{C}_{i,After}}{\overline{C}_{i,Before}}$$

where

$$\overline{C}_{i,Before} = \left(\frac{1}{m_{Before}}\right)\sum_{j=1}^{m_{Before}} C_{i,j},$$

$$\overline{C}_{i,After} = \left(\frac{1}{m_{After}}\right)\sum_{k=1}^{m_{After}} C_{i,k},$$

$C_{i,j}$ = the j^{th} of m_{Before} catches at station i prior to the simulated trawl fishery,

and

$C_{i,k}$ = the k^{th} of m_{After} catches at station i after the simulated trawl fishery.

11. Conduct the Wilcoxon Rank Sum test of the null hypothesis:

$$\delta_{Trawled} = \delta_{Untrawled}$$

where

$\delta_1, \delta_2, \ldots, \delta_{\frac{X}{2}}$ constitute the simulated δs within the no trawl zone,

and

$\delta_{\left(\frac{X}{2}\right)+1}, \delta_{\left(\frac{X}{2}\right)+2}, \ldots \delta_X$ constitute the simulated δs outside the no trawl zone.

This algorithm was repeated 1000 times for each of the combinations of sampling effort and trawling effect. The p-values computed in Step 11 were used to compute probabilities of rejecting the null hypothesis for $\alpha = 0.05$, 0.1, and 0.2 at each of the levels of sampling effort. The results are plotted in Figure 5.

Sample size (i.e. station number) was held constant at 80 stations because that represents two fishing days with one pot per station. (Forty pots can be deployed and retrieved on any day that weather permits fishing.) To achieve five replications per station at 80 stations would require 10 successful fishing days. This number of fishing days is achievable. Were it not for the mechanical difficulties of the first leg, the 2003 experiment would have had this sampling level in both legs, not just in the "after" leg.

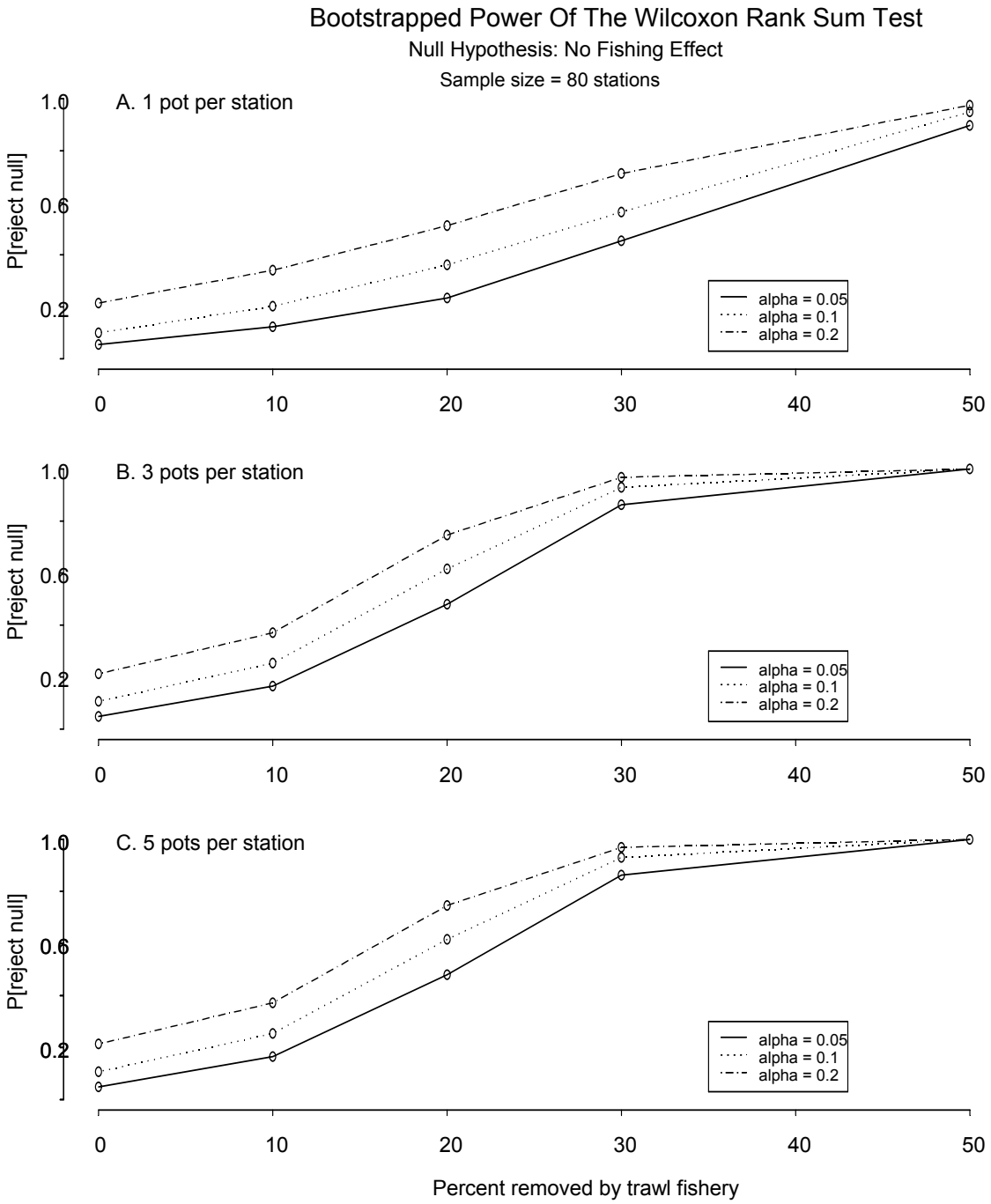


Figure 5. Power curves from simulation study based on 2003 data. Each graph shows the probability of rejecting the null hypothesis of no trawling effect when, in fact, a trawling effect of the size indicated on the x-axis exists. Top figure is one replicate of pot catch per station, middle figure is three replicates, bottom figure is 5 replicates. Each plot shows alphas of 5%, 10%, and 20%.

Discussion

Hypothesis Tests for Fisheries Effect

Hypothesis tests on the available data from 2003 suggest that there is no measurable difference between the trawled and untrawled portions of the study area. These results should, however, be interpreted with caution. Because of the small sample size, the power of the tests for 2003 is low, and failure to detect a difference is not strong evidence that no effect exists. The simulation study shows that sampling once per survey at eighty stations would detect a 20% change in the mean less than 50% of the time. At this level of sampling, a fishery effect would have to approach a 50% reduction in catch rates before it could be reliably detected (Figure 5). The experiment will be repeated in 2004, and the results are expected to be more conclusive. Simulations suggest that if a sample size of eighty stations can be fished at least three times (approximately six fishing days) in each survey, it should be possible to reliably detect a fishing effect that produces a 25-30% reduction in local abundance.

Need for the Cape Sarichef Special Closure

Operations in February 2003 clearly demonstrated the need for the special closure of the study area for the March "after" leg of the experiment. The February tagging cruise was moved up in the hope that we could use the ship time to collect a larger set of "before" data than was obtained in January. The intent was to try to work around any active cod trawling in the study area, perhaps by setting experimental gear at night. When the charter vessel got on-site, however, the area outside the no-trawl zone was being actively trawled by several vessels, including Pollock trawlers that were working around the clock. It was clear that there was simply too much trawl traffic to risk putting fixed gear outside the no-trawl zone. During the March cruise, with the closure in place, there was no difficulty in working experimental gear at all of the study sites. Vessels were observed trawling along the outer side of the special closure area, but there were no problems with gear conflict. The continuation of the Cape Sarichef special closure in 2004 and later years is necessary to perform the experiment.

Suggestions for Modifications in 2004 and Beyond

The main improvement suggested by our 2003 experience is to increase the effort to get an adequate "Before" sample. While weather conditions cannot be predicted or avoided, the charter proposal for the winter 2004 work is being revised to provide the best opportunities possible for flexibility of schedule and ability to work in rough conditions. Issues of soak time and at-sea work schedule will be reviewed based on the 2003 data to see if there is any way to

increase the number of pots that can be fished in a day without compromising the study design. The simulation study suggests that it is highly beneficial to get at least three replicated acts of fishing at each station; fishing in 2004 will be oriented toward this goal. The simulation suggests that a reliable hypothesis test may be reached if at least six days of fishing can be attained in each survey.

Maturity code data collected in 2003 provided some interesting insights; we hope to develop this approach further and gain more knowledge about the timing of cod spawning. Biological specimen collection and cooperative research will continue. The initial work done with cod tagging suggests that this approach is highly feasible. Current plans for 2004 do not include vessel charter time especially devoted to tagging, but opportunistic tagging of fish during field studies will continue. Tag return data will be used to look at questions of small-scale movement around the study area that might affect the local abundance study. Efforts to continue the development of trigger timers and oceanographic instruments in conjunction with the pot studies will continue.

Conclusions

The effectiveness of the cod pot local abundance experiment for 2003 was severely limited by the high proportion of bad weather days and by serious mechanical problems. While a certain amount of weather and mechanical delay is expected on any cruise, the number of problems encountered this year was extraordinary. Many of the problems that arose would not, by themselves, have seriously affected the project. The close occurrence of one problem after another, however, restricted data collection on the December/January "Before" cruise to an extent that affected the entire project. A small sample size from the "Before" leg gives us only a small sample of "Before/After" measurement pairs, and makes hypothesis testing for 2003 inconclusive. An attempt to collect additional "Before" data in early February was unsuccessful due to the presence of the Pollock fleet in the study area. This attempt made it clear that the two-week special closure granted by the Council in 2002 is necessary to conduct the "after" leg of the local abundance study.

Data collected during 2003 did, however, provide important information on cod movement and catch characteristics in the study area, and allowed us to verify that the experimental design is effective in this setting. Raw catch data from all three cruises continued to indicate that pot catch is a reasonable index of local cod abundance, with considerably less variability than trawl data. The frequency distribution of the observed "change-in-catch" measures showed a shape and variance structure that should provide solid hypothesis testing, once a reasonable sample size is achieved. Simulations based on the observed data indicate that it should be possible to detect a fishing effect on the order of 25-30% with at least 80% accuracy, if at least six full fishing days can be worked during each phase of the experiment.

Biological specimens and corrolary data collected during the pot studies are also expected to provide 1) information on both seasonal migration and short-term movement patterns in Pacific cod that spawn in the study area, 2) an updated data set for measuring the "length at 50% maturity" parameter that is important in the cod stock assessment, 3) information on the timing of maturation and spawning within the season, 4) information on fecundity of cod at different ages and water temperatures, 5) genetic stock structure of Bering Sea cod, and 6) movement and catch patterns associated with tide, currents, and other oceanographic features.