A Recommendation for Determining the Efficacy of Weight Removal Estimates for the Pacific Cod Longline CDQ Fishery

Anna L. Furniss
Utah State University

Follow this and additional works at: https://digitalcommons.usu.edu/gradreports

Part of the Applied Mathematics Commons, and the Mathematics Commons

Recommended Citation

This Report is brought to you for free and open access by the Graduate Studies at DigitalCommons@USU. It has been accepted for inclusion in All Graduate Plan B and other Reports by an authorized administrator of DigitalCommons@USU. For more information, please contact digitalcommons@usu.edu.
A RECOMMENDATION FOR DETERMINING THE EFFICACY OF WEIGHT REMOVAL ESTIMATES FOR THE PACIFIC COD LONGLINE CDQ FISHERY

by

Anna L. Furniss

A Plan B paper submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE in

Industrial Mathematics

UTAH STATE UNIVERSITY
Logan, Utah
2002
A Recommendation for Determining the Efficacy of Weight Removal Estimates for the Pacific Cod Longline CDQ Fishery

Technical Report

(Plan B)

Anna L. Furniss
Master of Science, Industrial Mathematics
Department of Mathematics and Statistics
Utah State University
Logan, Utah 84322-3900

Prepared for

North Pacific Groundfish Observer Program
Alaska Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
7600 Sand Point Way, NE
Seattle, Washington 98115-0070

February 2002
ABSTRACT

In January 2000, the Alaska Department of Community and Economic Development contacted the National Marine Fisheries Service (NMFS) regarding concerns over the methods used to determine catch estimates for the Pacific Cod Community Development Quota (CDQ) fishery. Currently, NMFS determines catch estimates for the Pacific Cod CDQ fishery based on the data collected by observers from the North Pacific Groundfish Observer Program (NPGOP).

Observer estimates for catch are based on the random sampling methods for a longline fishing vessel as described in the North Pacific Groundfish Observer Manual. These sampling methods provide an official total catch (OTC) estimate for each haul, or set (longline vessel) made by a CDQ vessel. Once a vessel reaches its individual yearly quota for Pacific Cod—based on the aggregate of the observer’s OTCs—it is no longer allowed to retain the species.

The Pacific Cod CDQ groups are concerned that the observer OTC estimates are over-estimating the catch of Pacific Cod, resulting in individual vessels being prematurely eliminated from the CDQ fishery. The CDQ groups have proposed that round weight estimates (RWEs), calculated from product recovery rates (PRRs), be used in lieu of observer OTC estimates for determining total catch of Pacific Cod on an individual longline vessel—primarily catcher/processor vessels.

Before NMFS can consider the new accounting method proposed by the CDQ groups, it must first be shown that the new method is as good or better than the current method. To be as good or better, the new method must estimate as accurately or more accurately than the current method, the total removal of Pacific Cod for an individual CDQ vessel.

The observer OTC estimate not only accounts for the removal of Pacific Cod, but also for the removal of all bycatch species from the fishery. Should a new accounting method be adopted, it must also be able to estimate the mortality of all species taken in by a vessel. Total removal numbers of both target and bycatch species enable NMFS to make yearly stock assessments and to set future fishery limits. These limits are critical to furthering the primary mission of NMFS—sustainable fisheries.
ACKNOWLEDGMENTS

I would like to express my profound gratitude to Dr. Dan Ito of the North Pacific Groundfish Observer Program for his cooperation and support of this project. I would also like to thank NMFS fisheries biologists Shannon Fitzgerald, Troy Martin, and NMFS observer Kevin Redslob for their data collection efforts at sea. And, to Douglas Limpinsel, also a NMFS fisheries biologist with the North Pacific Groundfish Observer Program, my deepest appreciation for his suggestions, invaluable insight, and time spent helping me with the details of this project, and for his work collecting the data used in this project.

From the University of Washington, Dr. Ed Melvin for granting NMFS permission to encroach upon the sea bird research cruise on such short notice, and to research assistants Kim Dietrich, Gillian Stoker, and Suzanne Romaine for their data collection efforts.

From the longline fishing industry, vessel and company representatives from the Gulf Mist Fishing Company, The Mariner Limited Partnership, and the Prowler Fisheries for accommodating additional NMFS personnel aboard their vessels.

Finally, thanks to my supervising committee at Utah State University; Dr. Joseph Koebbe, Mathematics and Statistics; Dr. Keith Criddle, Economics; and Dr. Richard Culter, Mathematics and Statistics, for their support of and assistance with this project—especially the survey design.
TABLE OF CONTENTS

ABSTRACT ........................................................................... i

ACKNOWLEDGMENTS .......................................................... ii

LIST OF FIGURES ............................................................... v

1.0 INTRODUCTION .............................................................. 1

1.1 NOAA and Its Mission ....................................................... 1
1.2 The North Pacific Groundfish Observer Program .................... 2
1.3 The Community Development Quota Program ....................... 2
1.4 Objectives of this Study .................................................... 4

2.0 THE OBSERVER OFFICIAL TOTAL CATCH ESTIMATE .......... 5

2.1 Procedure for Obtaining the Observer OTC Estimate on Longline Vessels . 5

2.1.1 Estimating Total Hooks in a Set ...................................... 6
2.1.2 Estimating Total Hooks in a Sample ................................. 7
2.1.3 Estimating Total Weight of Fish in a Sample ....................... 8
2.1.4 Determining the OTC for a Set ...................................... 8

2.2 Biases Associated with an Observer OTC Estimate ................ 9

3.0 ROUND WEIGHT ESTIMATES AND PRODUCT RECOVERY RATES ... 11

3.1 Procedure for Obtaining an RWE Based on PRRs .................... 11
3.2 Biases Associated with an RWE ......................................... 13

4.0 ANALYSIS OF EXISTING DATA ....................................... 15

4.1 Estimate Comparisons ..................................................... 15
4.2 Actual PRRs vs. Published PRRs ....................................... 18
4.3 Examination of Skate by Skate Totals for Pacific Cod ............... 21

5.0 SURVEY DESIGN ........................................................... 25

5.1 Target Population .......................................................... 25
5.2 Sampling Units ....................................................................................... 25
5.3 Degree of Acceptable Precision for Survey ....................................... 27
5.4 Sampling Frame ..................................................................................... 27
  5.4.1 Number of Vessels ............................................................................ 28
  5.4.2 Number of Hooks ........................................................................... 28
  5.4.3 Spatial and Temporal Considerations ........................................... 29
5.5 Survey Design Summary ....................................................................... 30

6.0 SURVEY DESIGN ALTERNATIVE ...................................................... 32
  6.1 Statement of Problem ......................................................................... 32
  6.2 Proposed Survey Design Alternative ............................................... 32
  6.3 The Research Survey ......................................................................... 32
  6.4 Spatial and Temporal Considerations ............................................. 34
  6.5 CDQ Observer Selection .................................................................. 35
  6.6 Research Survey Summary ............................................................... 35

7.0 CONCLUSION ......................................................................................... 37

8.0 REFERENCES .......................................................................................... 38

APPENDICES
  A Commonly Used Abbreviations .......................................................... A-1
  B Definitions of Key Terms ..................................................................... A-2
  C Fishing Activity by Federal Reporting Area then Month ..................... A-3
  D Fishing Activity by Month and Federal Reporting Area .................... A-4
LIST OF FIGURES

2.1 Determining Hook Count for a Set .................................................. 7
2.2 Determining the Average Weight for Pacific Cod .......................... 8
2.3 Formula for Determining the OTC .................................................. 9
3.1 Product Recovery Rates for Pacific Cod ....................................... 11
3.2 Determining a total RWE, based on the Western (head) Cut PRR .... 12
3.3 Factory Layout on a Longline Vessel ............................................. 14
4.1 100% Tally Estimates vs. Observer OTC Estimates: Bering Prowler 15
4.2 Observer OTC Estimates vs. Vessel Estimates: Alaska Mist .......... 16
4.3 Comparisons of Three Estimates: Bering Prowler ......................... 17
4.4 Comparisons of Three Estimates: Alaska Mist ............................... 18
4.5 Actual PRRs vs. Published PRR (Eastern Cut): Bering Prowler .... 19
4.6 Actual PRRs vs. Published PRR (Eastern Cut): Frontier Mariner .... 19
4.7 Actual PRRs vs. Published PRR (Western Cut): Bering Prowler .... 20
4.8 Actual PRRs vs. Published PRR (Western Cut): Frontier Mariner .... 20
4.9 Coefficient of Variation for the Number of Pacific Cod: Bering Prowler 22
4.10 Coefficient of Variation for the Number of Pacific Cod: Frontier Mariner 23
4.11 Coefficient of Variation for the Number of Pacific Cod: Alaska Mist 23
5.1 One-stage Cluster Sample ............................................................ 26
5.2 Pacific Cod CDQ Fishery Activity ................................................. 28
1.0 INTRODUCTION

1.1 NOAA and Its Mission

In 1970, the National Oceanic and Atmospheric Administration (NOAA) was created to provide a rational and systematic approach to understanding, protecting, developing and enhancing the nation’s total environment. In addition to a specific responsibility for the development and conservation of marine fisheries, NOAA was to lead the development of a consolidated national oceanic and atmospheric research and development program and provide a variety of scientific and technical services to other Federal agencies, private sector interests, and the general public.¹

NOAA is comprised of several agencies to oversee the many facets of the environment. NOAA Fisheries is charged with the management and protection of the nation’s ocean environment. Its strategic plan contains three goals.

1) Rebuild and maintain sustainable fisheries
2) Promote the recovery of protected species
3) Protect and maintain the health of coastal marine habitats²

Understanding the first goal and its purpose in the management of United States fisheries is crucial to understanding the intention of this study—determining the most appropriate catch accounting method for the Pacific Cod longline CDQ fishery; one that insures sustainable fish stocks in the Eastern Bering Sea are maintained, while providing economic benefit to the fishing communities there.

The NOAA Fisheries mission statement further reads:

NOAA Fisheries Service is dedicated to protecting and preserving our nation's living marine resources through scientific research, fisheries management, enforcement, and habitat conservation. NOAA Fisheries is a leading voice for commercial and recreational fisheries and continues to focus its efforts on sustaining our marine resources as we face the challenges that the new millennium brings. Marine fisheries provide an important source of food for the nation, as well as thousands of jobs and a traditional way of life for many coastal communities. From the Gulf of Maine, to the Gulf of Mexico, and to the


² NOAA Fisheries: Conserving Our Nation’s Living Oceans, (NOAA Fisheries promotional pamphlet, 1996).
NOAA Fisheries Services, also known as the National Marine Fisheries Service (NMFS), manages 3.4 million square miles of ocean and coastal areas belonging to the United States. The Alaska Fisheries Science Center (AFSC), a division of NMFS, manages the stock levels of groundfish in the north Pacific ocean, primarily the Gulf of Alaska (GOA) and the Bering Sea/Aleutian Islands (BSAI) region. A primary method for collecting data for stock assessment of the GOA and BSAI groundfish fisheries is through the North Pacific Groundfish Observer Program (NPGOP), under the umbrella of the AFSC.

1.2 The North Pacific Groundfish Observer Program

In 1973, NMFS began placing observers on foreign fishing vessels in an effort to manage groundfish stocks in the north Pacific ocean. In 1976, after passage of the Magnuson Fishery Conservation and Management Act, the U.S. declared management authority over all fish resources within 200 nautical miles of its shores—the Exclusive Economic Zone (EEZ). Additionally, the Magnuson Act established eight regional councils to manage the nation’s fisheries. The North Pacific Fisheries Management Council (Council) was one such council established and given jurisdiction over the 900,000 square miles of ocean off the coast of Alaska.

By 1991, all foreign commercial fishing within the EEZ was terminated, leaving an entirely domestic fishery. Subsequently, the Council created the North Pacific Groundfish Observer Program (NPGOP) in an effort to collect, maintain, and distribute data for scientific, management, and regulation compliance purposes in the GOA and the BSAI region. The program deploys nearly 400 certified groundfish observers each year on a variety of commercial fishing vessels. These observers, in turn, provide the program with nearly 35,000 data collection days annually.

1.3 The Community Development Quota Program

The fishing industry is organized into a number of associations, based either on vessel and gear type or by location, and is made up of either offshore or inshore fishing vessels and onshore processing.

---


4 NOAA Fisheries: Conserving Our Nation’s Living Oceans, (NOAA Fisheries promotional pamphlet, 1996).

plants. Vessels are defined as catcher, catcher/processor (C/P), or motherships and the gear used is non-pelagic trawl, pelagic trawl, hook and line (longline), pots, or jig/troll.⁶

Many groups in the fishing industry have agreed to take part in the Western Alaska Community Development Quota (CDQ) Program. The CDQ Program allocates a percentage of all Bering Sea and Aleutian Islands quotas for groundfish, prohibited species, halibut, and crab to eligible communities. The purpose of the CDQ Program is to provide the means for starting or supporting commercial fisheries business activities that will result in an ongoing, regionally based, fisheries-related economy in Western Alaska.⁷ To be eligible to participate in a CDQ fishery, each community must meet all of the following requirements:

1) the community must be located within 50 nautical miles of the Bering Sea
2) must be a native Alaskan community
3) have residents who conduct more than half of their commercial or subsistence fishing in the Bering Sea
4) have no previous processing or harvesting capability beyond small boat commercial fishing.⁸

Observer coverage varies in CDQ fisheries depending on the size, class, and operating hours of the vessel. For longline catcher/processor vessels, two observers (one lead NMFS-CDQ certified observer and one NMFS certified observer) must be on board the entire time the vessel is fishing within the CDQ fishery.⁹

Experience requirements for NMFS-CDQ observer certification are more stringent than those for regular NMFS observer certification. A CDQ certified observer must have

1) at least 60 days of data collection experience with a minimum rating of 1 or 2 from their most recent debriefing (job review) and
2) successfully completed the CDQ observer training course.

---

As well, a lead CDQ certified observer for a longline vessel must also have successfully completed at least two cruises (one cruise is limited to 90 days) and sampled at least 60 hauls/sets on a longline vessel.10

1.4 Objectives of this Study

The main objective of this study is to recommend an approach for determining the best accounting method for estimating total catch (total mortality/removals) from the Pacific Cod CDQ longline fishery in the Eastern Bering Sea.

Two current methods for determining catch quotas in the Pacific Cod CDQ fishery are

- observer estimates for official total catch (OTC) (total mortality)
- round weight estimates (RWEs) based on product recovery rates (PRRs)

The background and procedures involved with each of the two existing accounting methods will be examined as well as their associated biases. Some insight into the accuracy of the two methods can be drawn from existing data, but the available data is from three experimental cruises and is not a representative sample of the Pacific Cod CDQ longline fishery. Therefore, the primary purpose of this study is to construct a survey design that could be implemented to provide a representative sample from this fishery. The data from the sample could then be analyzed to provide a scientific basis for determining the accuracy of the OTC estimate and RWE.

---

2.0 THE OBSERVER OFFICIAL TOTAL CATCH ESTIMATE

In the Pacific Cod CDQ longline fishery, catcher/processor vessels operate on a continual 24-hour schedule, making observation of the entire catch formidable. However, for CDQ longline catcher/processor vessels, NMFS requires two certified CDQ observers to be on board monitoring the catch the entire time the vessel is fishing within the CDQ fishery. NMFS certified CDQ observers have had extra training—above that of a regular NMFS certified observer—and are seasoned in calculating OTC estimates on longline vessels.

2.1 Procedure for Obtaining the Observer OTC Estimate on Longline Vessels

Each year, the Council and NMFS set a total allowable catch (TAC) limit (in metric tons) for all groundfish fisheries in the GOA and BSAI regions. The Pacific Cod CDQ fishery is allotted a percentage (usually <10%) of the TAC for Pacific Cod for a given calendar year. Each vessel participating in the CDQ fishery purchases a portion of the overall CDQ quota for Pacific Cod and is allowed to fish for its quota at anytime during the two CDQ seasons (A or B), which together encompass the entire calendar year.

Total weight of mortality, rather than the total number of Pacific Cod, is the determinant for a vessel’s catch limit. Although the vessel has purchased a quota for Pacific Cod, it must also stay within mortality weight limits for bycatch species, some of which are prohibited (e.g., salmon, crab, halibut). CDQ vessels are not allowed to retain prohibited species (unless they have a special permit to do so), but can retain non-prohibited bycatch species. The observers’ sampling efforts involve generating a weight estimate for total mortality (the OTC estimate), which includes the mortality weight of both target (e.g., Pacific Cod) and bycatch species.

The ideal procedure for generating weight estimates is for the CDQ observer to calculate the OTC estimate according to the gear used by the CDQ vessel. For each possible gear type (trawl, longline, pot/troll, etc.), there is a different sampling method for generating an OTC estimate. If circumstances arise that prevent an observer from obtaining an OTC estimate for a haul/set, they can use either the vessel’s estimate for haul/set weight or wait until the vessel is off-loading to a processing plant and obtain a weight estimate there. The latter provides an overall estimate of total mortality weight for the cruise rather than individual haul/set weights.

A longline catcher/processor vessel typically deploys several sets of hook and line fishing gear in the water at a time. A set of gear varies significantly between vessels, but usually consists of 50 to 100 hooks per skate and up to 100 skates per set. After several sets have been deployed and allowed to
soak, the vessel begins retrieving the gear. The retrieval of one 10,000 hook set can take up to five
hours, under ideal conditions (i.e., weather, mechanical, etc.). Once the retrieval process begins, gear
comes on board continually until the vessel’s fishing effort is complete, making it necessary for the two
observers to take turns monitoring the catch in twelve hour intervals.

To calculate an OTC estimate for one set (equivalent to a haul on a vessel using different fishing
gear) on a longline vessel, several factors are involved:

- the total number of hooks in the set
- the total number of hooks in a sample of the set
- the total weight of fish in a sample of the set

A CDQ observer has been trained to estimate each of these factors using scientific sampling methods
for a longline vessel, as described in the North Pacific Groundfish Observer Manual. Used in
combination, these individual estimates provide the OTC estimate for one set.

2.1.1 Estimating Total Hooks in a Set

When the observers board a longline vessel, their first tasks are to calculate the number of skates
(also referred to as magazines) per set and the average number of hooks per skate. Prior to departure,
one of the observers must ask a crew member which gear, and how much of it will be used by the
vessel during the cruise. They also need to know what is used as the skate indicator (i.e., a knot in the
line, a weight block, c-rings, flourescent tape, etc.). The observers then count all of the skates in each
of the active set lines prior to the deployment of the gear. For verification, the observers again count all
of the skates in the active sets as the gear is being retrieved. Usually, a catcher/processor vessel will
only use up to four set lines during one cruise, so counting all skates that will be used is feasible.

Once the number of skates per set has been calculated, the average number of hooks per skate is
determined. It would be impossible to count every hook in each set, even with two observers, so a
sample of hooks from each set is counted. An observer counts thehooks from one-fifth of the skates in
a set, calculates an average number of hooks for that set, and applies that average to the total number
of skates in the set. Figure 2.1 shows an example.
Figure 2.1 - Determining Hook Count for a Set

30 skates in the set: \( \frac{1}{5} \times 30 = 6 \)

All hooks on 6 randomly chosen skates are counted

- skate 1 = 48 hooks
- skate 2 = 49 hooks
- skate 3 = 45 hooks
- skate 4 = 47 hooks
- skate 5 = 50 hooks
- skate 6 = 46 hooks

Average hook count for the 6 skates: 47.5

Total number of hooks for the set: \( 47.5 \times 30 = 1425 \)

Hook counts are done on all sets that will be used during the vessel’s cruise and must be re-verified twice a week to account for the loss of hooks during the fishing process or the replacing of hooks to the line by crew members.\(^{11}\)

2.1.2 Estimating Total Hooks in a Sample

The total number of hooks in a sample is determined by observing, or sampling, one-third of the skates in a set. An observer has several sampling protocols to choose from; spatial, temporal, or a combination of both. For example, if an observer chooses to sample spatially, he or she would sample (or observe) one-third of the skates in the set. Using the previous example, the observer randomly selects ten skates from the thirty using NMFS certified random number tables to choose the skates that will be sampled (e.g., the random number tables indicate that skates 1, 2, 5, 9, 12, 17, 18, ... are to be sampled). This selection process helps guarantee the sample will include a fair and random representation of all parts of the set (i.e., front, middle, end). The temporal sampling frame works similarly but is based on the number of hours it will take to bring in a set. The observer samples (or observes) for one-third of the total time it will take to retrieve the set, using the skate indicators to determine specific start and stop points.\(^{12}\) The time the observer spends sampling a set, whether spatially or temporally, is known as the sampling period.

Sampling a set means that the observer tallies every fish brought up by the vessel (whether it is retained or not) and counts the number of empty hooks that occur during the sampling period. The


observer’s tally station is usually very near the point where the line is coming out of the water and into the vessel (typically one level up). This insures that the observer will have a clear view of the line. At the end of the sampling period, the observer has a total number of fish for each species caught during the sampling period, as well as a tally for the number of empty hooks. The total number of fish tallied and the total number of empty hooks provides the total number of hooks for the sample.

2.1.3 Estimating Total Weight of Fish in a Sample

The total weight of fish in a sample is estimated from the information gathered during the sampling period. It is virtually impossible to weigh every fish brought on board during the sampling period, therefore, the observer randomly selects only 50 specimen of the target species (e.g., Pacific Cod) to weigh. Once the 50 have been selected, the observer weighs all 50 specimen and calculates an average weight. That average weight is then applied to the total number of target species tallied during the sampling period. Figure 2.2 shows an example.

Figure 2.2 - Determining the Average Weight for Pacific Cod

| Pacific Cod tallied during sampling period | 352 |
| 50 randomly selected cod are weighed      | 50  |
| weight of 50 cod = 198.51 kg             |     |
| Average weight of cod: 198.51 ÷ 50 = 3.9702 kg | |
| Total weight of Pacific Cod in sample: 352 x 3.9702 = 1397.51 kg |

Weight for non-target species (i.e., everything other than Pacific Cod) works similarly. However, because of time constraints, only up to 15 specimen are weighed for predominant bycatch species and an average weight is calculated for them using the same procedures as for the target species. Typically, however, fewer than 15 specimen of any bycatch species are caught during the sampling period, so an actual weight can be calculated for most bycatch species.

The total sample weight is the sum of the weights for all species tallied during the sampling period.

2.1.4 Determining the OTC for a Set
Once the total weight of fish (target and bycatch) is determined for a sample, the final OTC estimate for the set can be calculated. The OTC estimate is found by using the ratio relationship between the total sample weight and the total number of hooks for the sample versus the total set weight and the total number of hooks for the set (Figure 2.3).

**Figure 2.3 - Formula for Determining the OTC**

\[
\frac{\text{Total Sample Weight}}{\text{Total Hooks in the Sample}} = \frac{\text{Official Total Catch (OTC)}}{\text{Total Hooks in the Set}}
\]

Solving the equation for OTC,

\[
\frac{\text{Total Sample Weight} \times \text{Total Hooks in the Set}}{\text{Total Hooks in the Sample}} = \text{OTC}
\]

The final recording for the OTC is in metric tons. The OTC represents a total mortality weight for all fish brought in for one set. All sample information, such as numbers and weights for individual species, hook counts, and the OTC for all sets are sent daily to the NPGOP in Seattle, Washington, via NMFS satellite computer program ATLAS. Each CDQ vessel is required to have a computer on board with the ATLAS program and satellite linking capabilities. The observer should be able to access the computer at least once a day. These daily updates allow NMFS to monitor each vessel’s CDQ quota for Pacific Cod, bycatch, and prohibited species. Although, the total accumulated mortality weight for Pacific Cod is not calculated by the observer, the ATLAS program can extrapolate this information from the data sent in by the observer.

### 2.2 Biases Associated with an Observer OTC Estimate

The biases that may affect the observer’s OTC estimate are often fewer on CDQ vessels than on open access fishing vessels. CDQ vessels are required to have NMFS certified observer sampling stations and a motion-compensated platform scale, which provides more accurate weight measurements than standard hanging Salter scales used by observers in open access fisheries. These requirements help eliminate two major problems most observers encounter—obscured view of the incoming catch and potentially inaccurate scales.\(^\text{13}\) Regardless of these factors, there are still obstacles

\(^\text{13}\) Todd M. Loomis, *The Role of the North Pacific Groundfish Observer Program in the Community Development Quota Program*, (NPGOP quarterly report, April/May/June 2000): 5.
an observer must work around in order to generate a reliable OTC estimate. Some major problems that can create a bias in the OTC estimate are

- **Inclement weather.** Visibility can be severely impaired during a storm on the Bering Sea. Likewise, rough seas can make standing for hours at a time tallying fish almost impossible.

- **Health.** Even the most seasoned observer can become very ill during a cruise, whether from sea sickness or other common maladies. Working while sick can affect the quality of the work by an observer, and therefore, the reliability of the OTC estimate.

- **Crew co-operation.** Although this is not as prevalent a problem in the CDQ fisheries, it is still a problem that occurs on CDQ vessels. Crew members will sometimes interfere with the different processes of the observer’s work, making it difficult for the observer to do his or her job effectively. Incidences of interference are recorded by the observer in their log books and reported to NMFS and can result in a vessel losing its CDQ permit.

- **Measurement error.** All of the measurements that comprise an observer OTC estimate are themselves estimates. Although CDQ observers are experienced in calculating OTC estimates on longline vessels, calculation error can happen. Observers must follow a tight protocol when calculating an OTC estimate, but at times for various reasons, the protocol is not, or can not be followed. Observers must watch for vessel interaction with mammals and halibut while sampling, which can cause distraction and introduce calculation error. Logistics on a vessel, such as mechanical difficulties, can create incidences where the process of calculating an OTC estimate is interrupted or altered. Anytime this happens, a sampling error occurs. This may cause individual OTC estimates to be either an underestimate or an overestimate of actual set weight. However, when individual OTC estimates are averaged over many sets, these errors are minimized and the resulting average is a reliable estimate of average set weight for a cruise.
3.0 ROUND WEIGHT ESTIMATES AND PRODUCT RECOVERY RATES

The round weight estimate (RWE) is sometimes used to calculate an estimate of total catch weight in the GOA and BSAI groundfish fisheries. Vessels that estimate catch weight with RWEs, often calculate the RWE on a daily basis—generally at the end of a factory shift or a twenty-four hour period—and report it to NMFS. However, there is currently no standard method among the various types of fishing vessels for calculating an RWE.

3.1 Procedure for Obtaining an RWE Based on PRRs

Longline catcher/processor (C/P) vessels have factories on board which make finished product out of the fish as it is brought on board. At no point during the factory process are whole fish weighed, so product recovery rates (PRRs) are used to back calculate whole product weight from the finished product weight.

A PRR is simply the proportion of a specimen left after it has been processed. The processing of a fish on a longline C/P vessel involves the fish being headed and gutted, panned, then frozen. At the end of a cruise, most longline C/P vessels will deliver packaged (in the form of frozen cases) frozen fish to transport vessels; or in some cases, to off-shore or on-shore processing plants. Fish not suitable for finished product or that has no commercial value is made into fish meal.

Each of the groundfish target species has several PRRs. NMFS has published standard PRRs—based on measurements developed over the years by the fishing industry—for the different heading procedures for each target species. Vessels generally use the NMFS published PRRs to determine an RWE, as opposed to estimating it based on an actual PRR calculated for a species as it is being processed. Pacific Cod is generally processed with either the eastern head cut or the western head cut. Figure 3.1 shows the NMFS published PRRs for these processes.

Figure 3.1 - Product Recovery Rates for Pacific Cod

<table>
<thead>
<tr>
<th>Pacific Cod</th>
</tr>
</thead>
<tbody>
<tr>
<td>Western (head) Cut</td>
</tr>
<tr>
<td>PRR = 0.57</td>
</tr>
<tr>
<td>Eastern (head) Cut</td>
</tr>
<tr>
<td>PRR = 0.47</td>
</tr>
</tbody>
</table>
Each species (target and predominant bycatch) sold as finished product is placed into freezer pans after processing. At this point, an RWE is usually calculated. One method for determining an RWE is by average pan weights. Other methods are used throughout the fishing industry, however, the average pan weight method is commonly used on longline C/P vessels.

With this method, an average pan weight is determined for each species. The average pan weight is divided by the corresponding PRR (based on the heading procedure used and the species) to obtain an average pan RWE. The total RWE for a species is calculated by multiplying the average pan RWE to the total number of pans for that species. If the vessel’s daily report to NMFS is based on RWEs (as opposed to vessel estimates, i.e., the vessel’s best guess of weight removal), it will include the total RWE for each species that has been made into finished product.

Figure 3.2 shows how to calculate an RWE for Pacific Cod using the average pan weight method and the PRR for the western head cut.

**Figure 3.2 - Determining a total RWE, based on the Western (head) Cut PRR**

```
| Total number of pans of finished product: 20 |
| average pan weight: 15 kg |
| average pan RWE: \( \frac{15}{0.57} = 26.3158 \text{ kg} \) |
| total RWE for Pacific Cod (western cut): |
| \( 20 \times 26.3158 = 526.32 \text{ kg} \) |
```

Theoretically, the daily totals from the vessel should match the sum of the observer OTC estimates for the same period of time. However, one question that has surfaced in this project is how many fish embody each total. Factories are processing continually around the clock and have very little communication with the observers. The question of concern, then, is how many fish comprise an RWE, and is it close to, or the same as, the number of fish that would comprise an equivalent observer OTC estimate? In order to make valid comparisons of these two estimates—whether it be daily comparisons or set by set comparisons—each estimate must include the same (or very close to the same) number of fish. This question cannot easily be answered without a more in-depth study of these two estimates.
3.2 Biases Associated with an RWE

As with the observer OTC estimate, there are several biases associated with the RWE.

- **Unretained species.** CDQ vessels are primarily concerned with retaining the target species, such as Pacific Cod. Non-target (bycatch) species caught will often be discarded by the rollerman (the person standing at the point where the line is coming out of the water and into the vessel), unless there is market for it. For example, pollock and skate are two species that have markets for finished product, therefore, some vessels will retain those species and turn them into product, along with the target species. If there isn’t a market for a species, such as rock fish, the vessel may discard the fish. This is, potentially, the main reason for variance between the observer OTC estimate and the RWE; the OTC estimate is accounting for the mortality of all species caught by the vessel whether they are retained or not.

- **Measurement error.** The RWE is an estimate and therefore will have an associated error as well. NMFS published PRRs may vary significantly from actual PRR measurements, as will be shown in section 4.3. This may be due to seasonal variation in fish weight (e.g., spawning vs. non-spawning times) or a bias which has naturally developed over time. Using published PRRs, rather than actual PRRs, may either over estimate or under estimate actual fish weight.

- **Factory discards.** The nature of longline fishing creates an environment for predation from sand fleas, snails, crabs, and other fish. After the line has been set, it will sometimes take up to twelve hours before the vessel retrieves it. Because of this extended amount of soak time, predators have ample time to “eat” away at the fish caught on the line. These fish have little or no market value and are often discarded by the rollerman or during the factory process. Other unwanted bycatch species and undersized target species are commonly discarded as well, since larger fish garner higher prices. Discard is an area of increasing concern for NMFS because it can be a primary source for the discrepancy between the OTC estimate and the RWE, since all fish caught by the vessel—whether whole or partial—are included in the OTC estimate. Figure 3.3 shows a typical layout for a factory on a longline vessel with areas noted where potential discard may occur.
Observers have been minimally trained to watch for discard, either by the rollerman or in the processing area. Regardless, the observers still record on their forms their "best guess" estimate for the percentage of a species that is retained by the vessel. However, because it is just a guess, NMFS does not consider it a reliable estimate of retention, but rather general information.

To date, there has been no accurate accounting—either by the observer or the vessel—of species retention on Pacific Cod longline CDQ vessels. In order to accurately compare the RWE to the observer OTC estimate, actual retention must be known.
4.0 ANALYSIS OF EXISTING DATA

In the summer of 2000, staff members from the NPGOP participated in three experimental cruises on longline vessels in the Eastern Bering Sea to gather information for future research cruises. The data from these cruises is not a representative sample of the Pacific Cod CDQ fishery, and therefore, the results from the analysis of the data cannot be used to make inferences about the Pacific Cod CDQ fishery as a whole. However, information from these cruises has offered insight to the accuracy of the observer OTC estimate and the published PRRs, and consequently the accuracy of the RWE.

4.1 Estimate Comparisons

An important question that can be answered by the data from these cruises is how the different estimates compare to each other. During the cruise on the Bering Prowler in September 2000, a 100% tally estimate was conducted on several sets. Two different people, a NMFS fisheries biologist and a CDQ observer, each counted the fish on fifty percent of a set. Each person then calculated the weight for the fish on their half of the set according to the methods described in section 2.1.3. In theory, the 100% tally estimate should be more accurate than the observer OTC estimate because the average weight of cod for the entire set is based on the actual weight of 100 fish instead of 50. This doubling of the number of fish used for the average weight of cod reduces the error associated with the estimate. Figures 4.1 shows how the 100% tally estimates compare to the regular observer OTC estimates for various set from this cruise.

Figure 4.1 - 100% Tally Estimates vs. Observer OTC Estimates: Bering Prowler
This comparison shows very little variance between the two estimates. The average observer OTC estimate was 4.5% higher than the average 100% tally estimate.

Another question of interest is how does the observer OTC estimate compare with the vessel’s estimate? Figure 4.2 shows the comparison of the vessel’s estimates vs. the observer OTC estimates from the cruise on the Alaska Mist in August 2000.

**Figure 4.2 - Observer OTC Estimates vs. Vessel Estimates: Alaska Mist**

As with the previous comparison (Figure 4.1), this comparison hints of little overall difference between the vessel’s estimate and the observer OTC estimate. In fact, the average OTC estimate from this cruise was only 1% higher than the average vessel estimate. It must be noted here that the vessel’s estimate is not the same as the RWE for a set. The vessel’s estimate is often a “best guest” estimate by someone from the vessel’s crew—usually the captain. The more seasoned a captain is, the more accurate the estimate. The vessel’s estimate is usually recorded daily in the vessel’s log book, and can be referenced by the observer for his or her records.

During the cruises on the Bering Prowler and the Alaska Mist, a NMFS staff member was able to conduct actual PRR measurements on many of the sets. Looking at what the RWE would be when using the actual PRR measurement, instead of the published PRR for a set provided valuable information. Figure 4.3 shows the comparison of three estimates; the RWE based on actual PRRs, the RWE based on the published PRR, and the observer’s OTC estimate.
Again, the overall difference in these three estimates is minimal. The average RWE based on published PRRs was 9% higher, and the average observer OTC estimate was 6% higher than the average RWE based on actual PRRs.

A similar comparison (Figure 4.4) can be shown for the data collected on the Alaska Mist. However, instead of RWEs based on published PRRs, the vessel’s estimate was used. Also, these comparisons were for fewer sets—which consequently increases the variance between the averages of the estimates—because the vessel’s estimate of weight for a set was not always available on this cruise.
The average observer OTC estimate was 5% higher, and the average vessel estimate was 3% higher than the average RWE based on actual PRRs.

In all of the above comparisons, the RWE, whether based on actual or published PRRs, was always lower than the other estimates. A reason for this could be discard. The NPGOP staff members watched for discard during these cruises and recorded their “best” guess at the amount of fish retained for each set. Most of the recordings for retention were less than 100%, varying between 93% and 97%.

4.2 Actual PRRs vs. Published PRRs

The accuracy of the RWE is very dependant upon the published PRR. Knowing how accurate the published PRR is will help answer how accurate the RWE is. Again, because the data from these experimental cruises is not a representative sample of the Pacific Cod CDQ fishery, it is impossible to conclude statistical accuracy of the PRR rates. However, a positive bias can be detected through straight comparisons of actual PRRs to published PRRs.

During the cruises on the Bering Prowler and the Frontier Mariner, actual PRRs were calculated for a number of sets. These measurements were done for the two main head cuts for Pacific Cod; the
eastern cut, or J-cut, and the western cut, or collar-on cut. Figures 4.5 and 4.6 are comparisons of the actual PRRs for the eastern cut vs. the published PRR for the eastern cut.

**Figure 4.5 - Actual PRRs vs. Published PRR (Eastern Cut): Bering Prowler**

**Figure 4.6 - Actual PRRs vs. Published PRR (Eastern Cut): Frontier Mariner**
Figures 4.7 and 4.8 show the comparison of the actual PRRs for the western cut vs. the published PRR for the western cut.

**Figure 4.7 - Actual PRRs vs. Published PRR (Western Cut): Bering Prowler**

---

**Figure 4.8 - Actual PRRs vs. Published PRR (Western Cut): Frontier Mariner**

---

20
There is evidence in these charts of a positive bias associated with the actual PRRs versus the published PRR for both cuts. With a positive bias in the actual PRRs, it suggests that the published rate used by the industry is over estimating round weight; by how much is yet to be determined. Although, Figure 4.3 showed the RWEs based on published PRRs was 9% higher than the RWEs based on actual PRRs. However, this result was for only one cruise and cannot be used to make inferences about the behavior of actual PRRs versus published PRRs for the population as a whole.

A PRR directly affects the validity of an RWE, therefore, the standard NMFS published PRRs should periodically be verified for accuracy, especially since RWEs are sometimes used by non-observed vessels to estimate catch weight. To check if there is an overall bias in the published PRRs, actual PRRs should be conducted during different cruises, during different times of the year—preferably in tandem with a scientific sampling of the Pacific Cod CDQ fishery—and verified with the published PRRs.

4.3 Examination of Skate by Skate Totals for Pacific Cod

Many of the comparisons shown in the previous sections indicate high variance between individual set estimates. Determining if this variance is occurring naturally will help in understanding how to deal with the variance between set weight estimates. If high variance exists naturally, it can affect the accuracy of individual set weight estimates, making it more effective to look at the average of set weight estimates rather than at individual set weight estimates. Averaging works to “smooth” over the high variability in the individual estimates to give a more reliable estimate of average set weight.

Staff members from NMFS focused on the most probable source of variability—the skates. During all three experimental cruises, the number of Pacific Cod was recorded for each skate, for each sampled set to determine if the high variability was occurring between skates. The skate by skate numbers for Pacific Cod were analyzed to determine the existence of high natural variability. Pacific Cod was the only species this was done for. Since it is the target species, its probability of occurrence on all skates was much higher than any other species.

A common measure of variance is the coefficient of variation. This measure is more informative for data taken over time than just the average and the variance. In measurements taken over time, the average and variance can be very different for different measurements, such as set totals on a longline vessel. The coefficient of variation is a relative measure of variance, measuring the variance in the data as a proportion of the average (i.e., the standard deviation divided by the average). For example, if the average number of Pacific Cod for one set was 100 and the standard deviation (the square root of the variance) was 10, the coefficient of variation would be 10%. This means that the individual measurements would lie within 10% of the average measurement. On the other hand, if the average number of Pacific Cod was 100 and the standard deviation was 20, the coefficient of variation would be 20%. This would indicate that the scatter of individual measurements about the average
measurement would be wider, or spread further away from the average, than with the previous example.

In order to detect any natural variability between skates, the coefficient of variation was calculated on a set by set basis. As a general rule, if the coefficient of variation is less than 5%, there is very little variability between individual measurements. If the coefficient of variation is greater than 10%, this indicates high variation between individual measurements. Subsequently, the greater the coefficient of variation the higher the variation between individual measurements. The coefficient of variation was calculated for the majority of sets on all three experimental cruises and is detailed for each cruise in Figures 4.9, 4.10 and 4.11.

Figure 4.9 - Coefficient of Variation for the Number of Pacific Cod: Bering Prowler

---

Figure 4.10 - Coefficient of Variation for the Number of Pacific Cod: Frontier Mariner

Figure 4.11 - Coefficient of Variation for the Number of Pacific Cod: Alaska Mist
As shown by these coefficient of variation charts, the variability in the number of Pacific Cod between skates is very high. For one set (Figure 4.10), the variability was as high as 65%. This suggests the likely scenario that one skate had a large amount of Pacific Cod, say 100, while another skate in the same set may have had as low as two Pacific Cod.

Because Pacific Cod is the predominant species caught by this fishery, it affects set weight more than any other species. Therefore, it can be concluded that the high variability between set weight estimates is caused by the naturally high variability in the number of Pacific Cod between skates. Apropos, if variability tests were run on other species, such as Pollock, it is very likely the results would be the same as for the Pacific Cod. In general, because of the nature of longline fishing and because of the natural pooling behavior of fish, most species would show high between skate variability.

The random sampling methods used by CDQ observers to obtain the OTC estimate are robust against high variability and should render reasonably accurate weight estimate for each set regardless. However, this high variability will make it unlikely for one weight estimate to be equal to another, especially when they are calculated differently. In other words, it isn’t logical to assume that the vessel’s estimate or RWE will equal the observer’s OTC estimate on every single set. But, when they are averaged over many sets, the average estimates are more apt to be close.
5.0 SURVEY DESIGN

The primary purpose of this project is to recommend an approach for determining how accurate the observer official total catch estimate (OTC) and round weight estimate (RWE) are. One scientific approach is to survey the Pacific Cod CDQ fishery through a statistical sample. Actual weight measurements of sets can be gathered through a sample to provide appropriate information for assessing the accuracy of the observer OTC estimate and the RWE.

5.1 Target Population

When considering the type of statistical sample to use, the main question to ask is which sampling method is the most feasible given the nature of the target population. The target population is defined as the group which is to be observed during the statistical survey. Because the entire population cannot be observed, due to the extreme expense involved with such a level of observation, a large enough sample of the target population will provide enough information to make valid assumptions about the population as a whole.

For this survey, the target population is defined as all longline vessels fishing in the Pacific Cod CDQ fishery in a given calendar year (the number of vessels holding Pacific Cod CDQ permits varies from year to year). The main objective of the survey is to obtain critical information about the target population—in this case, actual set weights from the vessels fishing effort. During the survey, however, secondary tasks will be to gather observer OTC estimates and RWEs for each set and to conduct actual PRR measurements on Pacific Cod. With actual set weights, the accuracy of the observer OTC estimate and the RWE can be determined through comparisons of each to the actual set weights.

5.2 Sampling Units

The nature of the Pacific Cod CDQ fishery is such that a simple random sample would be impractical and very expensive. A more feasible and economical approach to surveying this population is through a one-stage cluster sample.

---

15 A simple random sample (SRS) is the simplest form of a probability sample. A sample size of \( n \) members is randomly selected from the target population, \( N \), and observed. Each member of the target population has the same chance of being selected for sample as the next.

16 A one-stage cluster sample is a cost effective sampling method that is used in cases such as this where the object to be observed (e.g., the weight of a set) is not easily sampled using simple random sampling methods. In a one-stage cluster sample, a portion of the target population is randomly selected and all elements (e.g., all sets) from the selected members are observed.
For a one-stage cluster sample, primary and secondary sampling units must be identified. The primary sampling unit (PSU) represents a randomly selected member from the target population. Together, the PSUs make up a randomly selected portion of the target population. In a one-stage cluster sample, all elements from each PSU are observed. These observed elements are the secondary sampling units (SSU) (Figure 5.1).\textsuperscript{17} For this survey these are defined as follows:

**Primary Sampling Unit (PSU):** a longline vessel from the Pacific Cod CDQ fishery  
**Secondary Sampling Unit (SSU):** all sets retrieved by a PSU vessel

**Figure 5.1: One-stage Cluster Sample**

\[
\begin{align*}
\text{Target Population: Pacific Cod CDQ Fishery} \\
&\quad M \text{ longline vessels holding current Pacific Cod CDQ permits} \\
&\quad \downarrow \\
&\quad \text{Primary Sampling Unit (PSU):} \\
&\quad \quad m \text{ vessels randomly selected for survey} \\
&\quad \downarrow \\
&\quad \text{Secondary Sampling Unit (SSU):} \\
&\quad \quad N \text{ (all) sets made by a PSU}
\end{align*}
\]

To be an eligible PSU for this survey, a vessel must hold a current CDQ permit for the Pacific Cod CDQ fishery for the year the survey is conducted. The vessel must also accommodate, during the designated survey cruise, at least three other staff member from NMFS in addition to the two required CDQ observers.

The SSUs are all sets retrieved by a PSU. However, the definition of what constitutes a set varies significantly between vessels. One vessel may retrieve four sets, per 24-hour period, with an average of 10,000 hooks per set, while another vessel will retrieve one long set of approximately 40,000 hooks during a 24-hour period. In order to equalize these differences between vessels, the sample size for the survey will be based on a total hook count and each PSU vessel will be required to retrieve a portion of that total. This should enable the PSU vessels to fish in the manner they are accustomed.

Actual set weight will be determined based on what the PSU vessel defines as a set. The two CDQ observers will perform regular OTC estimates for each of these sets, while a staff member from NMFS will oversee that an RWE is calculated for each set. In the end, there should be an actual weight, an

\textsuperscript{17} Sharon L. Lohr, *Sampling: Design and Analysis* (Duxbury Press, 1999), 131-133.
observer OTC estimate, and an RWE for all sets made by the PSU vessel during the designated survey cruise.

5.3 Degree of Acceptable Precision for Survey

The precision, or level of acceptable error in the survey data, will be relaxed for this initial survey. As more information is gathered about the logistical needs of the survey and about the target population, the precision can be tightened for subsequent surveys. For this initial survey, however, the precision measures are as follows:

\[ \alpha = 0.10, \text{ the acceptable limit for a statistical type 1 error}^{18} \]
\[ e = 0.05, \text{ the acceptable margin of error}^{19} \]

Both of these limits will be used in the calculation of the sample size.

5.4 Sampling Frame

Complete data for the activity of the Pacific Cod CDQ fishery is available for the calendar years 1999 and 2000 from the NPGOP. This data details the activity of the target population and has been used in the calculations of the sampling frame (Figure 5.1).

---

18 A statistical type 1 error is the probability that the null hypothesis will be rejected incorrectly during statistical analysis of the data. In this case, the null hypothesis would be rejected incorrectly 10 times out of 100. One minus the alpha level is how much confidence an analyst has that the actual population measure will fall within a certain interval, such as a confidence interval.

19 The margin of error can also be described as the sampling error. Sampling error is the measurement error that can result from sampling a portion of the population rather than the entire population. For example, if one sample of a population resulted in 51% of the voters favoring candidate A over candidate B, with a margin of error of plus or minus 3%, then the actual, or true population measure for those favoring candidate A may be as high as 54% or as low as 48%.
Figure 5.2 - Pacific Cod CDQ Fishery Activity

<table>
<thead>
<tr>
<th></th>
<th>1999</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Number of Vessels</td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td>Federal Reporting Areas Fished</td>
<td>14</td>
<td>13</td>
</tr>
<tr>
<td>Months Fished</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Total Sets</td>
<td>1,793</td>
<td>2,182</td>
</tr>
<tr>
<td>Total Hooks</td>
<td>21,213,908</td>
<td>19,723,867</td>
</tr>
<tr>
<td>Avg. Hooks/Set</td>
<td>11,832</td>
<td>9,039</td>
</tr>
<tr>
<td>Std. Deviation (hooks)</td>
<td>6,941</td>
<td>4,962</td>
</tr>
<tr>
<td>Coefficient of Variation (Std Dev/Avg) (hooks)</td>
<td>0.5866</td>
<td>0.549</td>
</tr>
</tbody>
</table>

5.4.1 Number of Vessels

To calculate the number of PSU vessels for the survey, the square root of the average number of vessels for 1999 and 2000 is taken:

\[ v = \sqrt{\frac{13 + 14}{2}} = 3.6742 \]

Rounding up yields 4 vessels that should be randomly selected from the list of longline vessels holding active CDQ permits for the Pacific Cod CDQ fishery for the year the survey is conducted.

5.4.2 Number of Hooks

To calculate the number of hooks needed in the survey, the coefficient of variation\(^{20}\), based on hook counts, is applied to the following formula

\[ v = \sqrt{\frac{13 + 14}{2}} = 3.6742 \]

\(^{20}\) The coefficient of variation is a useful measure of variance for data that is collected across different samples and over time, such as the case with set measurements (each defined as an individual sample of Pacific Cod). The coefficient of variation is calculated by dividing the standard deviation by the average. For more information on the coefficient of variation, see section 4.3.
\[ n_o = \frac{z_{.\alpha}^2 CV^2(y)}{\epsilon^2 \cdot \frac{z_{.\alpha}^2 CV^2(y)}{N}} \]

where, \( z_{.\alpha} \) is the \( z \) statistic from a normal distribution table at the predetermined \( \alpha \) level (section 5.3), \( CV(y) \) is the coefficient of variation for total hooks, \( \epsilon \) is the acceptable margin of error (section 5.3) for the survey, and \( N \) represents the total number of sets brought in for a given year.

Because this is a finite population (i.e., finite number of vessels fishing within the fishery each year), a finite population correction is applied to \( n_o \) to get the final sample size, \( n \).

\[ n = \frac{n_o}{1 - \frac{n_o}{N}} \]

A small \( n \) is calculated separately for 1999 and 2000 from the NPGOP data. Small \( n \) represents the number of sets needed for the survey, since \( N \) represented the total sets taken for the year. To get a total number of hooks for the survey, \( n \) is multiplied to the average number of hooks for the respective year (Figure 5.2).

**Figure 5.3 - Sample Sizes (Hooks)**

<table>
<thead>
<tr>
<th></th>
<th>1999</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>( n )</td>
<td>263 sets</td>
<td>251 sets</td>
</tr>
<tr>
<td>Total hooks</td>
<td>( 263 \times 11,832 = 3,111,816 )</td>
<td>( 251 \times 9,039 = 2,268,789 )</td>
</tr>
</tbody>
</table>

The average of the two sample sizes is calculated for the survey’s total hook count.

\[ \frac{3,111,816 + 2,268,789}{2} = 2,690,303 \]

---

For ease in calculating per vessel hook count, this number is rounded up to the nearest 100,000. Therefore, the total hook count for this survey is 2,700,000. The four PSU vessels will each bring in a total 675,000 hooks during their designated survey cruises.

5.4.3 Spatial and Temporal Considerations

The main objective of this study is to determine the accuracy of the observer OTC estimate. One question to be asked is does time and space have any effect on the OTC estimate? The answer is no. Regardless of where or when it is calculated, the OTC estimate is calculated in the same fashion and involves only the composition of the fish in the set at hand. Neither time nor space has any influence on the methods used to calculate the OTC estimate. What may potentially influence the accuracy of OTC estimate is the behavior of the observer. In other words, the care in which the observer takes in collecting the data for the OTC estimate will impact its accuracy more than any other factor.

Given the non-reliance on time and space, there is no need to randomize these factors in the survey. Another reason time and space should not be randomized for this survey is because the fishing vessels do not randomly select where they fish. The PSU’s that are randomly selected for this survey will fish where and when they are accustomed—where their efforts maximize their profits. Randomizing the time and space factors for the survey would only work to neutralize this very important behavioral aspect of the target population.

5.5 Survey Design Summary

A summary for the one-stage cluster sample of the Pacific Cod CDQ fishery is detailed in Figure 5.4. If the survey is conducted any later than 2002, the numbers for sample size and vessels to be included should be reconsidered based on the most current NPGOP data (i.e., 2001/2002).

**Figure 5.4 - Survey Design Summary**

<table>
<thead>
<tr>
<th>Sample Size (total hooks)</th>
<th>2,700,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Vessels</td>
<td>4</td>
</tr>
<tr>
<td>Number of Hooks per Vessel</td>
<td>675,000</td>
</tr>
</tbody>
</table>

These numbers represent an *ideal* one-stage cluster sample of the Pacific Cod longline CDQ fishery. Logistically, these numbers and/or the assumptions for the survey may not be practical. Staff
members from NMFS and members of the Pacific Cod CDQ groups will need to work together to determine a feasible implementation of this design. If this design cannot be followed and needs to be altered, regular statistical inferences may be invalid for any data collected. Therefore, consultation with an expert in sampling design is recommended prior to the implementation of any change to this design.
6.0 SURVEY DESIGN ALTERNATIVE

6.1 Statement of Problem

After officials from NMFS reviewed the details of the one-stage cluster sample of the Pacific Cod longline CDQ fishery, they determined that it would be logistically impossible to implement. The major objective of the survey design was to provide accurate weight measurements of sets made by longline vessels fishing within the Pacific Cod CDQ fishery. These weight measurements would then be used to verify the accuracy of the observer official total catch (OTC) estimate and the round weight estimate (RWE).

In order to provide accurate weight measurements of sets, the actual weight of an entire set would need to be calculated. However, none of the longline vessels that usually fish in Pacific Cod longline CDQ fishery is equipped with scales large enough to handle weighing more than 50 kg of fish at one time. For an average 10,000 hook set, fish weight is typically several metric tons. Therefore, obtaining actual set weights on any of the survey vessels specified in the survey design of section 5.0 would be logistically impossible.

6.2 Proposed Survey Design Alternative

After consulting with an expert in sampling design and staff members from NMFS, it was decided that a research survey, sponsored by NMFS, would be a credible alternative. The research survey could provide actual set weights while incorporating most of the details from the one-stage cluster sample described in section 5.0. The data collected from the research survey should provide information credible enough to determine the accuracy of the observer OTC estimate and provide insight into the accuracy of the published PRRs and the RWE.

6.3 The Research Survey

Redesigning the factory area of a longline vessel to accommodate larger scales is extremely costly, therefore, the advantage of a research survey is the ability of NMFS to outfit one vessel, rather than four, with scales large enough to efficiently weigh several hundred kilograms of fish at one time. The vessel for the research survey will be selected by NMFS through a contracting process, which will help

22 Dr. D. Richard Cutler, Department of Mathematics and Statistics, Utah State University, Logan, Utah, (October 2001).
guarantee that critical components of the original survey design will be included in the vessel’s fishing and factory processes.

To make a research survey practical, it will need to consist of more than one cruise. The sample size of 2,700,000 hooks from the original survey design is an ideal number. Considering the average number of hooks brought in per set by a vessel from the target population (Figure 5.1, Section 5.1) and trying to maintain an equivalent level of activity on each research cruise as would happen under “normal” conditions on a CDQ longline vessel, a new sample size can be calculated that will be feasible for the research survey. If there were three separate twenty-one day cruises that retrieved 700,000 hooks each (approximately 33,333 hooks per day), a total of 2,100,000 hooks could be gathered during the research survey. This would be an adequate sample size to answer the questions of accuracy posed by this project.

The only aspect of the original cluster sample that cannot be mimicked by the research survey is the behavioral differences between vessels of the target population. If the original survey design could have been followed, this would have been accounted for by the random selection of four vessels from the target population. Because the calculation of the RWE is conducted by the vessel’s crew, this missing aspect will present problems for determining the accuracy of the RWE from the data collected by the research cruises.

RWEs will be calculated for all sets on the research cruises and can be verified for accuracy against the actual weights gathered for those same sets. However, because all of the RWE calculations during the research cruises will be done by only one crew (one vessel; one crew)—instead of by four randomly selected crews—statistical inferences may be invalid for the target population as a whole. In other words, averages, standard deviations, confidence intervals, and other statistical measures from analysis of the research survey data should not be used to represent the characteristics of the RWE for the entire target population.

On the other hand, analysis results and statistical measures regarding the observer OTC estimate should be valid for the Pacific Cod CDQ fishery as a whole, as long as each cruise of the research survey has a different, randomly selected set of CDQ observers (see section 6.5) included with its crew, and the tasks of the observers on the research cruises are not altered from the tasks required for a regular CDQ longline cruise.

When the analysis of the research survey data is complete and if it is shown that the observer OTC estimate is not accurate in estimating actual weight removals, it may be necessary at that point to scientifically verify the RWE through another survey of the target population. However, if analysis of the data shows that the observer OTC estimate is an accurate measure of weight removals, the point of verifying the accuracy of the RWE so it can be used instead of the observer OTC estimate may be moot.
6.4 Spatial and Temporal Considerations

Another consequence of not having a portion of the Pacific Cod CDQ vessels participating in the survey, is the loss of their intuitive selections of times and areas to fish. Although it was determined in section 5.4.3 that time and space would have no effect on the observer OTC estimate, it may have an effect on the actual PRR measurements. A secondary task of this project is to determine the accuracy of the published PRRs. As seen in section 4.2, there appears to be a positive bias associated with actual PRR measurements as compared to the published PRRs. Since data from the experimental cruises in Section 4 were gathered during one time of the year (August and September), this positive bias may be the result of temporal influences—and possibly spatial influences.

The federal reporting areas (Figure 6.1) were determined by NMFS for recording spatially the fishing activity of vessels fishing in the GOA and BSAI. They are also used for indicating critical spawning areas for various species of groundfish. During the spawning season for some of the threatened species of groundfish, selected federal reporting areas will be off-limits for fishing.

Figure 6.1 - Federal Reporting Areas

Each cruise of the research survey will occur at a different time of the year and in a different federal reporting area in order to account for possible seasonal fluctuations in species weight, which can directly affect PRRs. The selection of these times and areas is based on the behavior of the target population for 1999 and 2000. In other words, the cruises will happen during a popular spring,
summer, and fall month and in three federal reporting areas that represent popular choices of the target population. The tables in appendices C and D were used conjointly to determine three feasible combinations of time and area.

With spatial and temporal factors being incorporated into the research survey, it will be possible to assess whether or not there is any bias associated with the published PRRs. Actual PRR measurements will be conducted on all three cruises, which can then be compared to the published PRRs to determine the accuracy of the published PRRs. If analysis of the research survey data indicates a bias in the actual PRRs as compared to the published PRRs, it may be necessary for NMFS and the fishing industry to review the published PRRs, since use of them directly affects the accuracy of the RWE.

6.5 CDQ Observer Selection

To ensure all possible influences that could affect the observer OTC estimate are considered, different CDQ observers should be randomly selected for each cruise of the research survey. This random selection will effectively be accomplished by following the regular NPGOP process for selecting CDQ observers. The CDQ observers for the three cruises of the research survey should be selected as if they were going out to observe on regular CDQ vessels. Their duties on the research vessel should match those on a regular CDQ vessel. If time permits on the research cruises and the process of calculating the OTC estimate is not interfered with, they may be able to help with any additional tasks of the research cruise, like conducting actual PRR measurements. First and foremost, however, the CDQ observers on these research cruises must be able to calculate the observer OTC estimate in a manner similar to their regular duties on a CDQ vessel. Otherwise, statistical inferences made about the observer OTC estimate may be invalid.

6.6 Research Survey Summary

Figure 6.1 below summarizes the details of the research survey. All numbers represent what can reasonably be accomplished, while providing an adequate sample of the target population. Data collected from this research survey should be credible enough to assess the accuracy of the observer OTC estimate and provide insight into the accuracy of the published PRRs and the RWE.
Final decisions about when these cruises will take place (i.e., whether it’s June or July; October or November) will need to be negotiated by NMFS and the vessel selected to participate in the survey. Again, the times and areas selected for the cruises were three possible choices that represent popular choices by the target population. If these are not practical for NMFS or the vessel involved, the tables in appendices C and D could be used to determine other choices, as long as the choices are for three different times of the year and in different federal reporting areas of high fishing activity.
7.0 CONCLUSION

There are many fundamental questions that can be answered by the data collected during the research survey. The most critical question to be answered is the accuracy of the observer OTC estimate. The concerns of Pacific Cod CDQ groups stem primarily from not knowing its true accuracy. If it is shown, through the analysis of the research survey data, that the observer OTC estimate is accurate to within an acceptable level of error, the issue of the Pacific Cod CDQ groups using the RWE in lieu of the observer OTC estimate should be considered resolved. The observer OTC estimate was designed to estimate the mortality of all species brought in by a fishing vessel. Without these numbers, it would be difficult for NMFS to determine appropriate stock levels from year to year and to guarantee that sustainable fisheries will exist well into the future—a consequence that directly affects the Pacific Cod CDQ groups. Essentially, it would not be prudent—for all parties involved—to alter the current practice of estimating mortality removals with the OTC estimate if it is shown to be an accurate estimate of weight removals.

Other important issues can be addressed with the analysis results from the research survey data as well. The accuracy of the published PRRs used by NMFS and the fishing industry needs to be reviewed. If a bias exists in actual PRRs as compared to published PRRs, further research should be done to correct the bias, since PRRs directly affect the RWE. Although many NMFS monitored fisheries in the GOA and BSAI do not use the RWE to determine weight removals, other fisheries controlled by the state of Alaska do. Accurate accounting of fish removals by the entire fishing industry is critical to guaranteeing the continued existence of all groundfish fisheries in the GOA and BSAI.

In summary, what should come from this research project is an in-depth, scientific review of the accounting method used by NMFS and some general information on the accounting method used by the fishing industry. It should also provide a chance for both parties to discuss their concerns with each other. In the end, the ultimate goal is the same—guaranteeing the existence of a Pacific Cod fishing trade in the Bering Sea/Aleutian Islands region through a sustainable Pacific Cod fishery.
8.0 REFERENCES


Cutler, D. Richard. Department of Mathematics and Statistics, Utah State University, Logan, Utah.


Loomis, Todd M. “The Role of the North Pacific Groundfish Observer Program in the Community Development Quota Program.” NPGOP quarterly report, April/May/June 2000.


NOAA. *NOAA Fisheries: Conserving Our Nation’s Living Oceans*, promotional pamphlet, 1996.


APPENDICES
## APPENDIX A – Commonly Used Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFSC</td>
<td>Alaska Fishery Science Center</td>
</tr>
<tr>
<td>BSAI</td>
<td>Bering Sea/Aleutian Islands</td>
</tr>
<tr>
<td>CDQ</td>
<td>Community Development Quota</td>
</tr>
<tr>
<td>Council</td>
<td>The North Pacific Management Council</td>
</tr>
<tr>
<td>C/P</td>
<td>Catcher/processor</td>
</tr>
<tr>
<td>EEZ</td>
<td>Exclusive Economic Zone</td>
</tr>
<tr>
<td>GOA</td>
<td>Gulf of Alaska</td>
</tr>
<tr>
<td>NMFS</td>
<td>National Marine Fisheries Service</td>
</tr>
<tr>
<td>NOAA</td>
<td>National Oceanic and Atmospheric Administration</td>
</tr>
<tr>
<td>NPGOP</td>
<td>North Pacific Groundfish Observer Program</td>
</tr>
<tr>
<td>OTC</td>
<td>Official Total Catch</td>
</tr>
<tr>
<td>PRR</td>
<td>Product Recovery Rate</td>
</tr>
<tr>
<td>RWE</td>
<td>Round Weight Estimate</td>
</tr>
<tr>
<td>TAC</td>
<td>Total Allowable Catch</td>
</tr>
</tbody>
</table>
APPENDIX B – Definitions of Key Terms

**Bycatch:** Anything caught during the fishing process that is not the species being targeted for catch. This includes all non-targeted groundfish, marine mammals, seabirds, invertebrates, and inert objects.²³

**Cruise:** the period of time, from shore departure to return, that a vessel is at sea

**Finished Product:** a fish that has been prepared (headed, gutted, and frozen) for commercial use

**Official Total Catch (OTC):** is the best estimate, in [the observer’s] judgement, of total catch weight for each haul. The OTC should be a weight estimate, or verified scale weight, of *all species caught, whether retained or not*. There are four options for OTC’s in order of preference: a) flow scale weights b) proportioned plant delivery weight, c) observer volumetric estimates of catch weight, d) vessel operator’s haul weight²⁴

**Pelagic:** mid-water

**Product Recovery Rate (PRR):** represents the proportion of an organism that is used for finished product²⁵

**Round Weight Equivalent (or Estimate) (RWE):** The estimated fresh weight of a catch from the tonnage of finished product produced. RWE is found by dividing the finished product weight by the product recovery rate (PRR)²⁶

**Skate:** a length of longline gear, usually 100 fathoms or 600 feet long (also referred to as magazine)²⁷

**Total Allowable Catch (TAC):** based on number of fish or total weight of fish; depending on the fishery. TACs for each target species and “other species” categories are set for each calendar year by NMFS, after consultation with the Council²⁸


²⁵Ibid.


## APPENDIX C – Fishing Activity by Federal Reporting Area then Month

<table>
<thead>
<tr>
<th>1999</th>
<th>2000</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>area</td>
<td>month</td>
<td>area</td>
</tr>
<tr>
<td>509</td>
<td>April</td>
<td>524</td>
</tr>
<tr>
<td>April</td>
<td>August</td>
<td>524</td>
</tr>
<tr>
<td>August</td>
<td>December</td>
<td>524</td>
</tr>
<tr>
<td>December</td>
<td>November</td>
<td>524</td>
</tr>
<tr>
<td>January</td>
<td>May</td>
<td>513</td>
</tr>
<tr>
<td>June</td>
<td>April</td>
<td>513</td>
</tr>
<tr>
<td>May</td>
<td>November</td>
<td>513</td>
</tr>
<tr>
<td>November</td>
<td>March</td>
<td>513</td>
</tr>
<tr>
<td>October</td>
<td>May</td>
<td>513</td>
</tr>
<tr>
<td>September</td>
<td>May</td>
<td>513</td>
</tr>
<tr>
<td>512</td>
<td>June</td>
<td>531</td>
</tr>
<tr>
<td>June</td>
<td>October</td>
<td>531</td>
</tr>
<tr>
<td>May</td>
<td>May</td>
<td>517</td>
</tr>
<tr>
<td>November</td>
<td>May</td>
<td>517</td>
</tr>
<tr>
<td>October</td>
<td>May</td>
<td>517</td>
</tr>
<tr>
<td>September</td>
<td>May</td>
<td>517</td>
</tr>
<tr>
<td>514</td>
<td>September</td>
<td>534</td>
</tr>
<tr>
<td>August</td>
<td>May</td>
<td>518</td>
</tr>
<tr>
<td>June</td>
<td>May</td>
<td>518</td>
</tr>
<tr>
<td>May</td>
<td>May</td>
<td>518</td>
</tr>
<tr>
<td>October</td>
<td>May</td>
<td>518</td>
</tr>
<tr>
<td>516</td>
<td>August</td>
<td>531</td>
</tr>
<tr>
<td>August</td>
<td>April</td>
<td>521</td>
</tr>
<tr>
<td>June</td>
<td>April</td>
<td>521</td>
</tr>
<tr>
<td>May</td>
<td>April</td>
<td>521</td>
</tr>
<tr>
<td>October</td>
<td>April</td>
<td>521</td>
</tr>
<tr>
<td>September</td>
<td>April</td>
<td>521</td>
</tr>
<tr>
<td>517</td>
<td>April</td>
<td>524</td>
</tr>
<tr>
<td>August</td>
<td>April</td>
<td>524</td>
</tr>
<tr>
<td>December</td>
<td>April</td>
<td>524</td>
</tr>
<tr>
<td>May</td>
<td>April</td>
<td>524</td>
</tr>
<tr>
<td>November</td>
<td>April</td>
<td>524</td>
</tr>
<tr>
<td>October</td>
<td>April</td>
<td>524</td>
</tr>
<tr>
<td>September</td>
<td>April</td>
<td>524</td>
</tr>
<tr>
<td>518</td>
<td>April</td>
<td>531</td>
</tr>
<tr>
<td>May</td>
<td>August</td>
<td>521</td>
</tr>
<tr>
<td>September</td>
<td>August</td>
<td>521</td>
</tr>
<tr>
<td>519</td>
<td>May</td>
<td>521</td>
</tr>
<tr>
<td>November</td>
<td>May</td>
<td>521</td>
</tr>
<tr>
<td>521</td>
<td>April</td>
<td>521</td>
</tr>
<tr>
<td>August</td>
<td>May</td>
<td>521</td>
</tr>
<tr>
<td>June</td>
<td>May</td>
<td>521</td>
</tr>
<tr>
<td>November</td>
<td>May</td>
<td>521</td>
</tr>
<tr>
<td>October</td>
<td>May</td>
<td>521</td>
</tr>
<tr>
<td>521</td>
<td>April</td>
<td>521</td>
</tr>
<tr>
<td>August</td>
<td>May</td>
<td>521</td>
</tr>
<tr>
<td>June</td>
<td>May</td>
<td>521</td>
</tr>
<tr>
<td>November</td>
<td>May</td>
<td>521</td>
</tr>
<tr>
<td>October</td>
<td>May</td>
<td>521</td>
</tr>
</tbody>
</table>

A-3
### APPENDIX D – Fishing Activity by Month and Federal Reporting Area

(sorted by # of vessels)

<table>
<thead>
<tr>
<th>Area</th>
<th>Number of Vessels</th>
<th>Number of Sets</th>
<th>Total OTC</th>
<th>OTC/Sets</th>
</tr>
</thead>
<tbody>
<tr>
<td>531</td>
<td>16</td>
<td>1442</td>
<td>11531.30</td>
<td>8.00</td>
</tr>
<tr>
<td>509</td>
<td>12</td>
<td>529</td>
<td>3607.34</td>
<td>6.82</td>
</tr>
<tr>
<td>517</td>
<td>11</td>
<td>504</td>
<td>3236.34</td>
<td>6.42</td>
</tr>
<tr>
<td>521</td>
<td>11</td>
<td>39</td>
<td>215.87</td>
<td>5.54</td>
</tr>
<tr>
<td>513</td>
<td>10</td>
<td>374</td>
<td>3417.37</td>
<td>9.14</td>
</tr>
<tr>
<td>542</td>
<td>9</td>
<td>168</td>
<td>691.04</td>
<td>4.11</td>
</tr>
<tr>
<td>541</td>
<td>8</td>
<td>179</td>
<td>1547.42</td>
<td>8.64</td>
</tr>
<tr>
<td>524</td>
<td>7</td>
<td>128</td>
<td>732.50</td>
<td>5.72</td>
</tr>
<tr>
<td>533</td>
<td>7</td>
<td>32</td>
<td>138.98</td>
<td>5.87</td>
</tr>
<tr>
<td>543</td>
<td>6</td>
<td>379</td>
<td>4012.71</td>
<td>10.59</td>
</tr>
<tr>
<td>518</td>
<td>4</td>
<td>125</td>
<td>530.56</td>
<td>4.24</td>
</tr>
<tr>
<td>516</td>
<td>4</td>
<td>46</td>
<td>427.92</td>
<td>9.30</td>
</tr>
<tr>
<td>519</td>
<td>2</td>
<td>14</td>
<td>87.93</td>
<td>4.85</td>
</tr>
<tr>
<td>512</td>
<td>1</td>
<td>2</td>
<td>16.79</td>
<td>8.40</td>
</tr>
<tr>
<td>523</td>
<td>1</td>
<td>1</td>
<td>8.87</td>
<td>4.44</td>
</tr>
<tr>
<td>514</td>
<td>1</td>
<td>11</td>
<td>6.07</td>
<td>0.55</td>
</tr>
<tr>
<td>534</td>
<td>1</td>
<td>1</td>
<td>0.38</td>
<td>0.38</td>
</tr>
</tbody>
</table>

Total: 111 | 3975 | 30238.39 | 7.61

(sorted by OTC/sets)

<table>
<thead>
<tr>
<th>Area</th>
<th>Number of Vessels</th>
<th>Number of Sets</th>
<th>Total OTC</th>
<th>OTC/Sets</th>
</tr>
</thead>
<tbody>
<tr>
<td>543</td>
<td>6</td>
<td>379</td>
<td>4012.71</td>
<td>10.59</td>
</tr>
<tr>
<td>516</td>
<td>4</td>
<td>46</td>
<td>427.92</td>
<td>9.30</td>
</tr>
<tr>
<td>513</td>
<td>10</td>
<td>374</td>
<td>3417.37</td>
<td>9.14</td>
</tr>
<tr>
<td>541</td>
<td>8</td>
<td>179</td>
<td>1547.42</td>
<td>8.64</td>
</tr>
<tr>
<td>512</td>
<td>1</td>
<td>2</td>
<td>16.79</td>
<td>8.40</td>
</tr>
<tr>
<td>531</td>
<td>16</td>
<td>1442</td>
<td>11531.30</td>
<td>8.00</td>
</tr>
<tr>
<td>509</td>
<td>12</td>
<td>529</td>
<td>3607.34</td>
<td>6.82</td>
</tr>
<tr>
<td>517</td>
<td>11</td>
<td>504</td>
<td>3236.34</td>
<td>6.42</td>
</tr>
<tr>
<td>521</td>
<td>11</td>
<td>39</td>
<td>215.87</td>
<td>5.54</td>
</tr>
<tr>
<td>513</td>
<td>10</td>
<td>374</td>
<td>3417.37</td>
<td>9.14</td>
</tr>
<tr>
<td>542</td>
<td>9</td>
<td>168</td>
<td>691.04</td>
<td>4.11</td>
</tr>
<tr>
<td>541</td>
<td>8</td>
<td>179</td>
<td>1547.42</td>
<td>8.64</td>
</tr>
<tr>
<td>524</td>
<td>7</td>
<td>128</td>
<td>732.50</td>
<td>5.72</td>
</tr>
<tr>
<td>521</td>
<td>11</td>
<td>39</td>
<td>215.87</td>
<td>5.54</td>
</tr>
<tr>
<td>519</td>
<td>2</td>
<td>14</td>
<td>67.93</td>
<td>4.85</td>
</tr>
<tr>
<td>523</td>
<td>1</td>
<td>2</td>
<td>8.87</td>
<td>4.44</td>
</tr>
<tr>
<td>518</td>
<td>4</td>
<td>125</td>
<td>530.56</td>
<td>4.24</td>
</tr>
<tr>
<td>542</td>
<td>9</td>
<td>168</td>
<td>691.04</td>
<td>4.11</td>
</tr>
<tr>
<td>514</td>
<td>1</td>
<td>11</td>
<td>6.07</td>
<td>0.55</td>
</tr>
<tr>
<td>534</td>
<td>1</td>
<td>1</td>
<td>0.38</td>
<td>0.38</td>
</tr>
</tbody>
</table>

Total: 111 | 3975 | 30238.39 | 7.61

<table>
<thead>
<tr>
<th>Month</th>
<th>Number of Vessels</th>
<th>Number of Sets</th>
<th>Total OTC</th>
<th>OTC/Sets</th>
</tr>
</thead>
<tbody>
<tr>
<td>August</td>
<td>12</td>
<td>650</td>
<td>4191.12</td>
<td>6.45</td>
</tr>
<tr>
<td>December</td>
<td>12</td>
<td>365</td>
<td>2572.38</td>
<td>7.05</td>
</tr>
<tr>
<td>September</td>
<td>12</td>
<td>247</td>
<td>1922.64</td>
<td>7.78</td>
</tr>
<tr>
<td>April</td>
<td>11</td>
<td>11</td>
<td>707</td>
<td>53530.02</td>
</tr>
<tr>
<td>March</td>
<td>10</td>
<td>536</td>
<td>5143.25</td>
<td>9.60</td>
</tr>
<tr>
<td>May</td>
<td>10</td>
<td>571</td>
<td>4373.31</td>
<td>7.66</td>
</tr>
<tr>
<td>October</td>
<td>8</td>
<td>172</td>
<td>1183.15</td>
<td>6.88</td>
</tr>
<tr>
<td>November</td>
<td>7</td>
<td>479</td>
<td>3705.13</td>
<td>7.74</td>
</tr>
<tr>
<td>June</td>
<td>6</td>
<td>137</td>
<td>1062.51</td>
<td>7.76</td>
</tr>
<tr>
<td>July</td>
<td>4</td>
<td>110</td>
<td>742.97</td>
<td>6.75</td>
</tr>
<tr>
<td>January</td>
<td>1</td>
<td>1</td>
<td>6.91</td>
<td>6.91</td>
</tr>
</tbody>
</table>

Total: 93 | 3975 | 30238.39 | 7.61