The purpose of this research was to explore the impact of finfish bycatch on the ocean shrimp \textit{Pandalus jordani} fishery using two methods. One method looked at the breakage of the shrimp by finfish bycatch in the nets. The other looked at the impact of bycatch on fishing decisions.

At-sea research found that finfish bycatch contributes to the breakage of ocean shrimp. However, the impact is small relative to breakage caused by other handling procedures. Bycatch was measured from each net of a double-rigged shrimp vessel, where one side employed a Nordmore grate bycatch reduction device (BRD) and the other served as a control. Shrimp catch was controlled for BRD use and catch day, and sampled throughout processing to evaluate breakage. At greater than 50\% bycatch there was a significantly higher percentage of broken shrimp in the control side than in the BRD side for samples taken at the first and third sampling point (p<0.05). After this point the differences became non-significant. The percent
breakage increased from a mean 2.4% broken before placement in the hold to a mean 18.0% broken in the final product.

The impact of bycatch on fishing decisions was evaluated by distributing an expanded logbook to volunteer Oregon shrimp vessels in 1998. Logbook questions addressed the reasons and time involved for running to initial fishing grounds, relocating overnight, relocating between tows, dumping tows, and modifying gear. Completed logbooks were collected from 20 vessels representing 263 trips, 1043 fishing days, and 4727 tows. A soft mesh BRD was used at some point by 25% of vessels on 8.7% of trips and 3.3% of tows. Bycatch did not figure prominently in reasons given for choice of initial fishing grounds, relocating between fishing days, or relocating between tows. Bycatch was the main reason cited for dumping tows. In total, 430 (9%) tows were dumped. The estimated weight of fish and shrimp dumped equaled 11.3% and 0.3%, respectively, of the landed shrimp catch. Pacific whiting *Merluccius productus* caused 81.4% of the tows dumped due to bycatch. Opportunity costs attributed to bycatch alone were equivalent to net revenue resulting from 12.3 tows or $3,203 per study vessel. At the fleet level, opportunity costs due to dumped tows totaled 1,227 effort hours, 32.4 trips, or $155,070. This equates to a 4.6% loss in gross ex-vessel revenue.
Bycatch in the Ocean Shrimp *Pandalus jordani* Fishery

by

Vicki Hoover Krutzikowsky

A THESIS submitted to

Oregon State University

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APPROVED:

Redacted for Privacy
Major Professor, representing Fisheries Science

Redacted for Privacy
Head of Department of Fisheries and Wildlife

Redacted for Privacy
Dean of the Graduate School

I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Redacted for Privacy
Vicki Hoover Krutzikowsky, Author
Acknowledgment

This project was funded by Oregon Sea Grant with support from Oregon Department of Fish and Wildlife Marine Region. Many thanks to all those at Oregon Department of Fish and Wildlife, Astoria Seafood Laboratory, Fishhawk Fisheries and the shrimp boat crews that helped the project along. Thanks to my committee: Courtland Smith, Gil Sylvia, Bob Hannah and David Sampson, for their patience and feedback. A special thanks to my husband, Gregory Krutzikowsky, not only for support at home but also for being my front line editor.
Contribution of Authors

Robert Hannah and Dr. Gil Sylvia were involved in the funding, design, analysis and writing of each manuscript.
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Dedication

This thesis is dedicated to my family with all my love. Thank you so much for your support and motivation.
Bycatch in the Ocean Shrimp *Pandalus jordani* Fishery

Chapter 1

Introduction

Ocean shrimp, *Pandalus jordani*, locally known as pink shrimp, are the target of a commercial trawl fishery off the Pacific coast from California to British Columbia. The ocean shrimp fishery began in the 1950's and makes up approximately 20% of Oregon's commercial fishery revenues (OASS 1996). Oregon's landings represent 40% of West coast shrimp harvests (NMFS 1995), 20% of U.S. coldwater shrimp supplies, 4% of total coldwater shrimp landings worldwide (FAO 1995), and less than 2% of total U.S. shrimp supplies. Commercial concentrations are found in 40-150 fathoms during daylight hours while the shrimp are assembled on the bottom (Zirges and Robinson 1980). Single and double-rigged vessels make 4 to 5 day trips. A tri-state management plan through the Pacific Fisheries Management Council coordinates Washington, Oregon and California's management of the ocean shrimp fishery. The fishery is conducted from April to October in order to avoid gravid females. There is a count per pound maximum of 160 shrimp per pound to deter large catches of small shrimp. Most of the ocean shrimp catch is processed as individual quick frozen product sold as cocktail or salad shrimp. Ocean shrimp competes with other pandalid species for this market niche, primarily *Pandalus borealis*, from the
Alaska and the North Atlantic. Prices range form $.20 to $.85 per pound between years and are not stable within a season (Jones and Hannah 1992).

Bycatch discards in this fishery can range from relatively low to very high levels that can affect the efficiency and, possibly, the value of the fishery. Bycatch of Pacific whiting, *Merluccius productus*, in particular, can become high enough on the shrimp grounds to preclude efficient shrimping. Alverson (1997) estimated that 27 million mt of bycatch per year is discarded worldwide; discards in shrimp fisheries were estimated to make up approximately one-third of this amount or 9.5 million mt. He estimated the Northeast Pacific shrimp fishery discards 27,421 mt of bycatch or 0.3% of the global shrimp discards. In terms of fish to shrimp ratios, another study found that bycatch, both retained and discarded, ranged from 25-75% of the catch in this fishery (Hannah et al. 1996).

The United States ocean shrimp fishery is allowed to retain and market small allocations of groundfish bycatch such as sablefish *Anoplopoma fimbria*, yellowtail rockfish *Sebastes flavidus*, canary rockfish *Sebastes pinniger*, and lingcod *Ophiodon elongatus*. As this marketable bycatch contributes from 2-5.5% of the total ex-vessel value (Hannah and Jones 2001), the reduction of bycatch is not a simple issue. Pressure on certain groundfish species has reduced these limits and made bycatch, in general, an issue of concern (PFMC 2001). The majority of bycatch is discarded, such as the juveniles of the above species, Pacific whiting, slender sole *Lyopsetta exilis*, smelt Osmeridae sp., spiny dogfish *Squalus acantbias*, and spotted ratfish *Hydrolagus colliei* are not commonly retained for sale and are discarded at sea with presumed high mortality rates.
Presently, finfish bycatch reduction devices, BRDs, are being developed and are being used, voluntarily, by approximately 30% of the fleet on a part time basis (ODFW unpublished data). Recently, fishery management councils have considered making them mandatory (PFMC 2001). Many of these BRDs are mesh panels that block the entrance to the codend, allowing the shrimp to pass into the codend while the larger finfish are guided out an escape hatch above the panel. Oregon Department of Fish and Wildlife evaluated many models of BRDs and found them to exclude from 70-100% of the bycatch of large fish, with 7-35% shrimp loss (Hannah et al. 1996).

Costs of bycatch reduction in shrimp fisheries may include shrimp loss, purchase of new gear, gear modifications, and changes in fishing strategy. Costs arise from avoiding fish, as in the Gulf of Mexico where large concentrations of red snapper can be identified (NMFS 1996). BRDs are not costly, but do involve installation time a learning curve for efficient use, and some degree of lost production. When these costs get too high, shrimpers are at a competitive disadvantage to similar fisheries in other parts of the world. In the Gulf of Mexico fishery, the disadvantage was considered important enough to impose an embargo on other countries that do not require the use of turtle excluder devices (TEDs). In the ocean shrimp fishery, some bycatch is marketable and revenue may be decreased by the loss of this income.

Potential benefits of bycatch reduction in shrimp trawl fisheries include reduced time and equipment for sorting, reduced time avoiding bycatch, and better quality catch, all resulting in greater average returns (Pascoe 1997; Summers 1994). Improved relations with those concerned about catch of non-target species may be a benefit as well. Fishermen who use BRDs argue that soft panel BRDs have resulted in
little to no shrimp loss and have reduced the number of dumped tows. They find less need for sorting and expensive sorting equipment, and have the ability to get the nets back in the water sooner. Fewer crew may be needed. Also, it has been hypothesized that high finfish bycatch may result in damaged shrimp. Industry members hypothesize that finfish bycatch may affect the quality of trawl caught shrimp by causing breakage (Summers 1994).

The quality of the catch is important since *P. jordani* competes in the marketplace with other pandalid species, primarily *P. borealis*, from the U.S. and Canadian Atlantic, Alaska, Norway, Iceland, and Sweden. The purpose of the first part of this study was to measure the effect of finfish bycatch on the quality of ocean shrimp.

To understand the costs and benefits of implementing BRDs, we need to understand how unwanted bycatch, either anticipated or realized, influences normal fishing decisions and activities. If bycatch has little effect on fishing decisions, then bycatch reduction methods may not have a significant economic benefit for shrimpers. On the other hand, if bycatch has a significant impact on fishing decisions, then bycatch reduction may be more economically worthwhile. In the second part of this research we examined how bycatch influences fishing by examining data from an expanded logbook study.
Chapter 2

Finfish Bycatch Effects On Ocean Shrimp *Pandalus jordani*

Vicki Hoover Krutzikowsky, Robert W. Hannah and Gilbert Sylvia

Department of Fisheries and Wildlife
Abstract

Finfish bycatch contributes to the breakage of ocean shrimp *Pandalus jordani*. However, the impact is small relative to breakage caused by other handling procedures. Bycatch was measured from each net of a double-rigged shrimp vessel, where one side employed a Nordmore grate bycatch reduction device (BRD) and the other served as a control. Shrimp catch was separated according to side of gear and day of fishing and sampled throughout processing to evaluate breakage. At greater than 50% bycatch, there was a significantly higher percentage of broken shrimp in the control side than in the BRD side at the first and third sampling point (p<0.05). After the third sampling point the differences became non-significant. The percent breakage increased from a mean 2.4% broken before placement in the hold to a mean 18.0% broken in the final product. Other factors such as the molt condition, count per pound, carapace length, phosphate treatment, moisture, and bacterial culture did not influence breakage.
Introduction

Ocean shrimp *Pandalus jordani*, locally known as pink shrimp, are the target of a commercial trawl fishery in the Pacific Northwest United States and off of British Columbia, Canada. Bycatch discards in the ocean shrimp fishery can range from relatively low to very high levels that can affect the efficiency and, possibly, the value of the fishery. Bycatch of Pacific whiting, *Merluccius productus*, in particular, can become high enough on the shrimp grounds to preclude efficient shrimping. Industry members hypothesize that finfish bycatch may affect the quality of trawl caught shrimp by causing breakage (Summers 1994). The quality of the catch is important since *P. jordani* competes in the marketplace with other pandalid species, primarily *P. borealis*, from the U.S. and Canadian Atlantic, Alaska, Norway, Iceland, and Sweden. The purpose of this study was to measure the effect of finfish bycatch on the quality of ocean shrimp in this trawl fishery.

Processing of shrimp involves a series of steps. The catch is emptied from the nets into bins on deck, passed through sandpaper sorting belts called “smelt belts”, and then on to a conveyor belt where much of the bycatch is removed. The clean shrimp catch is then transferred to the hold where ice is mixed in with the catch by shoveling and raking. At the plant, the shrimp are shoveled from the hold into buckets that are lifted onto the dock. The buckets are then emptied into bins, more ice is added, and the bins are covered and left to “ripen” for an average of three days. After ripening, the catch may be de-iced and treated with phosphates, then emptied into the cooker. The catch then passes through machine peelers and a final sorting belt before being packaged for freezing. Pink shrimp are marketed and sold primarily as peeled,
cooked individual quick frozen (IQF) product, commonly called salad or popcorn shrimp in the retail stores.

Reduction of bycatch in this fishery is not a simple issue, as some bycatch species such as sablefish *Anoplopoma fimbria*, yellowtail rockfish *Sebastes flavidus*, and lingcod *Ophiodon elongatus* are marketable and make significant contributions to shrimper's income. The juveniles of these and other species including Pacific whiting, slender sole *Lyopsetta exilis*, smelt Osmeridae sp., spiny dogfish *Squalus acanthias*, and spotted ratfish *Hydrolagus colliei* are not commonly retained for sale and are discarded at sea with presumed high mortality rates. Presently, finfish bycatch reduction devices, BRDs, are being developed and are being used, voluntarily, by approximately 30% of the fleet on a part time basis (ODFW unpublished data). Many of these BRDs are mesh panels that block the entrance to the codend, allowing the shrimp to pass into the codend while the larger finfish are guided out an escape hatch above the panel. Oregon Department of Fish and Wildlife evaluated many models of BRDs and found them to exclude from 70-100% of the bycatch of large fish, with 7-35% shrimp loss (Hannah et al. 1996).

**Methods**

A double-rigged commercial shrimp vessel was chartered for two four-day trips in June 1998. Thirty-three paired tows were completed. One net was fished without a BRD as a control and the other was fished using a Nordmore grate BRD. Two different devices were used for on-deck sorting of the catch at different times; the standard smelt belt (Jones et al. 1996) and a customized grate for removing large hake.
The bycatch was sorted and weighed and each day's catch from each net was kept separate in the hold and throughout processing. Shrimp were offloaded in typical fashion and sampled throughout processing.

Shrimp samples were collected randomly, with a minimum amount of disturbance, at seven stages from the deck to finished product. One to two pound shrimp samples were collected from each of seven stages of handling and processing. Samples were taken at sea for each tow after sorting on deck, and after icing and raking in the hold. In the plant, three to four samples each day were taken before cooking, after the 1st peeler, 2nd peeler, blower, and before packaging. For simplicity, the samples are referred to as 1) deck, 2) hold, 3) raw, 4) stage 1, 5) stage 2, 6) stage 3, and 7) final. On the vessel, the count per pound and percentage of shrimp in soft-shell condition were evaluated for deck samples. In the plant, count per pound was measured again and the samples were labeled, placed in plastic bags (mesh bags for hold samples), and put on ice until stored in a freezer. Total shrimp weight for each net each day was calculated by deducting the weight of ice from the total landed weight, based on the percentage of ice in random subsamples. A de-icer was not utilized.

Breakage analysis

In the lab, samples were defrosted as needed in a water bath. Label information, including date of sample, sample type, BRD presence, tow, side, and/or tote was recorded. Up to 681 g of each sample was weighed on a triple beam scale
and sorted into categories. Procedures varied slightly for raw and final samples and are described separately.

For deck samples, the first 100 random shrimp carapace lengths were measured to establish size frequency distributions. For all raw samples, the heads were removed and the shrimp meats were sorted into five categories: tail pieces, body pieces, tail-less pieces, damaged whole meats, and undamaged whole meats. Tail and body pieces were obvious fragments of whole meats. Tail-less pieces were whole shrimp with the small 6\textsuperscript{th} tail segment missing. The length and number of segments of most pieces were recorded. Damaged shrimp were mostly whole meats with cuts into the meat that could feasibly cause separation into pieces further in the process. Whole meats were identified by a notch on one end where the carapace had been attached and at least a trace of the 6\textsuperscript{th} segment on the tail end. The weight and count of each category was recorded.

Final samples were divided similarly, but into four categories: small pieces, large pieces, damaged whole meats, and undamaged whole meats. Pieces were obvious fragments of whole meats. As in the raw samples, damaged pieces were mostly whole meats with cuts that could feasibly separate into pieces further in the process. Whole meats were identified by a notch on one end where the carapace had been attached and a nub of meat on the tail end from the 6\textsuperscript{th} segment. Percent breakage by weight was calculated by summing weights of all pieces and dividing by the total sample weight.

For breakage comparison to the fleet, 112 raw shrimp samples were collected from 5 plants and 27 vessels, from 1 to 15 trips per vessel. The samples were
collected by Astoria ODFW personnel from 1-4 days after offloading using the same methods detailed above for breakage analysis.

**Laboratory analysis**

Shrimp samples were taken in the plant for immediate microbial, pH, and moisture analysis at the Astoria Seafood Laboratory.

Microbial analysis consisted of duplicate total plate counts for concentrations from $10^{-6}$ to $10^{-1}$ from 50 g of the raw product. Ten g of shrimp were blended for 1 minute in sterilized jars with 90 mLs of sterilized peptone. One mL of puree was deposited onto each of two films and flattened with plastic for the $10^{-1}$ concentrate. After the test tube was sterilized over a Bunsen burner, 1 mL of puree, and 9 mL of 1% peptone was deposited and vortexed. One mL was deposited on each of two films for the $10^{-2}$ concentrate and so on. New pipettes were used with every dilution. Films were incubated for 2 days and colonies counted.

To measure pH, $30.00 \pm 0.1$ g of shrimp sample were mixed with 60 g deionized water and blended. A digital pH meter was calibrated and used to measure pH.

Moisture measurements were made using standard methods. Approximately 10 g of each shrimp sample were ground, homogenized, spread, weighed, dried, and re-weighed. Three repetitions were made for each side and day for raw and final samples.
Statistics

Single factor ANOVA was conducted for comparing percent breakage in the control and BRD samples with one-sided p-values of less than 0.05 considered significant. Standard deviations are reported after means. A Mann-Whitney U-test was conducted for comparisons of large differences in standard deviation.

Results

Similar to findings from previous studies (Hannah et al. 1996), the Nordmore BRD reduced bycatch significantly from a mean of 68% ± 14.2 (553 lb ± 425) bycatch by weight on the control side to 28.7% ± 17.2 (127 lb ± 167) on the BRD side (Mann-Whitney U-test, p-value < 0.0001, n=66). Percent bycatch is defined as weight of bycatch divided by total weight of all catch (Table 2.1.)

Table 2.1. Mean percent and mean total bycatch.

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<th>Day</th>
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<td>Control</td>
<td>BRD</td>
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<tr>
<td>1</td>
<td>66.3</td>
<td>32.5</td>
</tr>
<tr>
<td>2</td>
<td>63.2</td>
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<tr>
<td>3</td>
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<td>42.5</td>
</tr>
<tr>
<td>4</td>
<td>76.5</td>
<td>18.7</td>
</tr>
<tr>
<td>5</td>
<td>51.0</td>
<td>12.7</td>
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<td>6</td>
<td>81.5</td>
<td>39.9</td>
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<td>7</td>
<td>76.7</td>
<td>36.3</td>
</tr>
<tr>
<td>8</td>
<td>70.1</td>
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<tr>
<td>Mean</td>
<td>68.0%</td>
<td>28.7%</td>
</tr>
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</table>
Breakage analysis

Table 2.2. shows the mean percent breakage and statistics for all sample stages. Deck samples had significantly less breakage in the BRD side than the control side. For tows with greater than 50% bycatch in the control net, the difference in breakage increased. Breakage increased significantly for all samples in the hold samples. Breakage for the BRD samples was not significantly lower than the control samples. For tows with greater than 50% bycatch in the control net, the BRD samples had significantly less breakage. The raw plant samples also showed increased

<table>
<thead>
<tr>
<th>Sample type</th>
<th>n</th>
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<td></td>
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<tr>
<td>Deck</td>
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<td>1.9</td>
<td>1.1</td>
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<tr>
<td>&gt;50% bycatch</td>
<td>58</td>
<td>*0.0031</td>
<td>1.8</td>
<td>1.0</td>
<td>3.2</td>
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<tr>
<td>Hold</td>
<td>54</td>
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<td>6.1</td>
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<td>&gt;50% bycatch</td>
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<td>6.3</td>
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<tr>
<td>Raw</td>
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<td>*0.0360 u</td>
<td>8.1</td>
<td>2.0</td>
<td>11.3</td>
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<tr>
<td>&gt;50% bycatch</td>
<td>14</td>
<td>*0.0313</td>
<td>8.5</td>
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<td>11.9</td>
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<td>Stage 1</td>
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<td>&gt;70% bycatch</td>
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<td>11.7</td>
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<td>18.7</td>
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<tr>
<td>&gt;70% bycatch</td>
<td>10</td>
<td>*0.0070</td>
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<td>&gt;70% bycatch</td>
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<td>0.3500</td>
<td>16.4</td>
<td>3.4</td>
<td>18.8</td>
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<td>17.5</td>
<td>6.5</td>
<td>18.4</td>
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<td>10</td>
<td>0.1778</td>
<td>17.3</td>
<td>7.1</td>
<td>18.4</td>
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</table>
breakage but the BRD samples had significantly less than the control samples. For
days with greater than 50% mean bycatch in the control net, the difference increased.
Stage 1 samples did not show a significant difference between BRD and control
samples. For days with greater than 50% mean bycatch in the control net, this
difference increases but was still not significant. Stage 2 samples showed a decrease
in breakage although there was no significant difference between BRD and control
samples. For days with greater than 50% mean bycatch in the control net, the BRD
side had significantly less breakage. The significance level increased even more for
days with greater than 70% mean bycatch in the control net. Stage 3 samples
increased in breakage but again were not significantly different, regardless of bycatch
level. Breakage increased again in the final samples, but BRD and control samples
were not significantly different regardless of bycatch level. For every sample type,
with the exception of stage 3, the BRD side had less breakage than the control side.
The mean percent breakage increased 15.5% for both nets from boat deck to final
product. The percent product recovery was not significantly different between the
BRD and control side (21% ± 7.3 vs. 20.5% ± 9.0; Mann-Whitney U-test, p-value =
0.9200, n=16).

The mean percent breakage from raw fleet samples was 3.9% ± 2.4 with a
range from 0.2% to 16.0%. Means, by vessel, ranged from 0.89% to 7.2%. The mean
of raw samples for the chartered vessel was 9.5% (range 3.2% to 22.7%), which was
higher than the level observed in the fleet.
Other measured factors

The shrimp collected in BRD and control nets were similar. There was no significant difference in mean percentage of molting shrimp in the control and BRD nets (9.2% ± 4.3% vs. 7.9% ± 3.9%; p-value = 0.1503). The mean count per pound was not significantly different for control and BRD nets (126 ct/lb ± 28 vs. 127 ct/lb ± 29; p-value = 0.5588). The mean carapace length ranged from approximately 14 mm to 18 mm. There was no significant difference in mean carapace length between control and BRD samples (16.1mm ± 1.2 vs. 16.0mm ± 1.4, p-value = 0.45, n=16). There was no significant difference between the percent breakage in phosphated and non-phosphated raw samples (8.6% ± 2.8 vs. 11.4% ± 3.4, p-value = 0.0518, n=16).

There was no significant difference in moisture levels between BRD and control sides for raw or final samples (raw: 69.4% ± 2 vs. 69.9% ± 2, p-value = 0.34; final: 68.7% ± 1 vs. 69.0% ± 1, p-value = 0.32, n=16). In trip 1, day 1 and 2 there was a significant difference between the raw BRD and control samples percent moisture (day 1: 67.2% vs. 71.1%, p-value = 0.0001; day2: 69.4% vs. 67.1%, p-value = .0031).

The raw samples showed a consistently higher pH than the corresponding final samples. There was no significant difference in pH between BRD and control sides for either raw or final samples (raw: 8.2% ± .26 vs. 8.1% ± .26; final: 7.7% ± .2 vs. 7.7% ± .3, p-value = 0.38 for both, n=16).

The microcultures ranged from approximately 700 to 22,000 CPU per mL. There was no significant difference between the BRD and control samples (6418 CPU/mL ± 8686 vs. 6739 CPU/mL ± 6184, p-value = 0.46, n=16).
Discussion

The main finding of this study was that the effect of finfish bycatch on shrimp breakage was most apparent when the shrimp were first emptied from the net. At each handling stage, overall breakage increased due to handling and processing and the effect of bycatch on breakage became proportionally less important. During the cooking process, the difference between breakage in the BRD and control catch was insignificant. The mean percent breakage increased from 2.4% on deck to 18.0% in the final product. Higher bycatch levels may have illustrated the finfish damage effect more strongly, however higher bycatch was not encountered during sampling despite efforts to find it.

Some anomalies in the results occurred. The hold samples showed no significant difference at any bycatch level yet the raw samples that followed did show a significant difference. The hold samples were handled differently than other samples. A shovel was necessary to collect these samples and mesh bags were used as containers in order to allow the ice to drain off. These differences could have affected the breakage of the samples. Also, after stages 1 and 2, the percent breakage decreased. One explanation is that some small pieces fell to the floor between these sampling locations.

The fleet had a lower average and range of breakage than the charter vessel. This probably resulted because the charter vessel sought out high bycatch levels in order to insure a comparison between the BRD and control net. Under normal fishing conditions, the charter vessel should have a have a smaller degree of breakage due to lower bycatch levels.
Three main implications of this study can be identified. First, finfish can cause some reduction in the quality of ocean shrimp and BRDs can help reduce bycatch of finfish. The reduction in quality is small in comparison to other handling procedures, so the conservation of finfish resources, rather than product quality, provides the strongest rationale for BRD use in the ocean shrimp fishery during conditions similar to those experienced in this study. Secondly, shrimp product quality improvement may be achieved most readily by altering handling procedures at sea and in the plant. Thirdly, the effect of bycatch on product quality may be of greater concern in other shrimp fisheries where processing is more delicate and preventing breakage is of greater concern. Researching possible benefits of BRDs will hopefully aid fishermen and industry in managing bycatch and maximizing the economic value of the shrimp resource.
Acknowledgments

Many thanks to Oregon Sea Grant and Oregon Department of Fisheries and Wildlife, Marine Region for their support of this research. The experiment would not have been possible without the cooperation of Steve Fick, Jeff and crew at Fishhawk Fisheries of Astoria, Oregon. The efforts of the F/V Lady Kaye crew were greatly appreciated. Thanks to many people at ODFW, including Steve Jones, Terry Link, Dick Durbin, Bill Miller, Cathy Nist, Marcia Macomber, Jennifer Menkle, and Cormac Craven for assistance with planning, sampling and lab work. Laboratory assistance was invaluable from Michael Morrissey and his staff and students, Elizabeth Greene, Michelle, Lew, Benny and Angie at the Astoria Seafood Lab.
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Chapter 3

The Influence of Bycatch on Fishing Decisions in the Ocean Shrimp *Pandalus jordani* Fishery: A Logbook Analysis

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Department of Fisheries and Wildlife
Abstract

In 1998 an expanded logbook was distributed to volunteer shrimp vessels participating in the Oregon ocean shrimp *Pandalus jordani* fishery. Besides the customary catch and effort data, information was also collected on fishing decisions and activities. In particular, the study sought to understand how problems associated with discarded bycatch may influence fishing behavior. Specific questions addressed the reasons and time involved for running to initial fishing grounds, relocating between fishing days and between tows, dumping tows, and modifying gear.

Completed logbooks were collected from 20 vessels representing 263 trips, 1043 fishing days, and 4727 tows. A soft panel bycatch reduction device (BRD) was used at some point by 25% of vessels on 8.7% of trips and 3.3% of tows. Bycatch was not a prominent factor for explaining choice of initial fishing grounds, relocating between fishing days, or relocating between tows. Bycatch was the main reason cited for dumping tows. In total, 430 (9%) tows were dumped. The estimated weight of fish and shrimp dumped equaled 11.3% and 0.3%, respectively, of the landed shrimp catch. Catches of Pacific whiting *Merluccius productus* were the cause for 81.4% of the tows dumped due to bycatch. Flatfish were a distant second, causing 7.7% of dumped tows. Dumped tows also resulted in relocations and gear modifications. Opportunity costs attributed to bycatch alone were equivalent to net revenue resulting from 12.3 tows or $3,203 per study vessel. At the fleet level, opportunity costs due to dumped tows totaled 1,227 effort hours, 32.4 trips, or $155,070. This equates to a 4.6% loss in gross ex-vessel revenue.
Introduction

Bycatch discards in the ocean shrimp *Pandalus jordani* fishery can range from relatively low to very high levels that can affect the efficiency and, possibly, the value of the fishery. Alverson (1997) estimated that 27 million mt of bycatch per year is discarded worldwide; discards in shrimp fisheries were estimated to make up approximately one-third of this amount or 9.5 million mt. He estimated the Northeast Pacific shrimp fishery discards 27,421 mt of bycatch or 0.3% of the global shrimp discards. In terms of fish to shrimp ratios, another study found that bycatch, both retained and discarded, ranged from 25-75% of the catch in this fishery (Hannah 1996).

The United States ocean shrimp fishery is allowed to retain and market small allocations of groundfish bycatch such as sablefish *Anoplopoma fimbria*, yellowtail rockfish *Sebastes flavidus*, canary rockfish *Sebastes pinniger*, and lingcod *Ophiodon elongatus*. Stock declines in certain groundfish species have reduced these limits and bycatch is becoming an issue of significant concern (PFMC 2001). As this marketable bycatch contributes from 2-5.5% of the total ex-vessel value (Hannah 2001), the reduction of bycatch is not a simple issue. The majority of finfish bycatch is not marketable and must be discarded at sea with high mortality rates. Bycatch of Pacific whiting, in particular, can become high enough on the shrimp grounds to preclude efficient shrimping.

Finfish bycatch reduction devices, BRDs, are being developed and carried voluntarily by up to 30% of the Northwest U.S. fleet (ODFW unpublished data). Most BRDs are mesh panels that block the entrance to the codend, allowing the shrimp to
pass into the codend while larger finfish pass out an escape hatch. Oregon Department of Fish and Wildlife evaluated many models of BRDs and found them to exclude from 70-100% of the large fish bycatch, with 7-35% shrimp loss (Hannah et al. 1996). The Pacific Fisheries Management Council is now evaluating the relative merits of BRDs and debating whether they should become mandatory (PFMC 2001).

Costs of bycatch reduction in shrimp fisheries may include shrimp loss, purchase of new gear, gear modifications, and changes in fishing strategy. Costs can result from avoiding fish, as in the Gulf of Mexico shrimp fisheries where large concentrations of red snapper occur (NMFS 1996). BRDs are not expensive to purchase but costs associated with installation, education, and lost production may be significant. When these costs become substantial, shrimpers are at a competitive disadvantage relative to similar fisheries in other parts of the world. In the Gulf of Mexico fishery, the disadvantage was considered significant enough to impose an embargo on countries that do not require the use of turtle excluder devices (TEDs). In the ocean shrimp fishery, some bycatch is marketable and BRDs may result in lost income.

Potential benefits of bycatch reduction in shrimp trawl fisheries may include reduced time and equipment for sorting, reduced time avoiding bycatch, and better quality catch (Pascoe 1997; Summers 1994). Improved relations with those concerned about catch of non-target species may also be a benefit. Non-target species that would have otherwise been discarded may add value to other fisheries. Some fishermen using BRDs contend that soft panel BRDs have resulted in little shrimp loss and have reduced the number of dumped tows. They find less need for sorting, a decrease in
the amount of time that the net needs to be on the deck, and potentially fewer crew. Additionally, reduced levels of finfish bycatch may result in less damaged shrimp (Summers 1994).

To understand the costs and benefits of implementing BRDs, we need to understand how unwanted bycatch, either anticipated or realized, influences normal fishing decisions and activities. If bycatch has little effect on fishing decisions, bycatch reduction methods may not have significant economic benefits for shrimpers. Conversely, if bycatch avoidance significantly impacts fishing behavior, bycatch reduction may be economically viable.

In this research we examine how bycatch influenced fishing behavior, and resulting opportunity costs, using data from expanded logbooks. Specifically, the reasons and the time involved were summarized for multiple fishing decisions including choice of initial fishing location, relocating between fishing days and between tows, dumping tows, and modifying gear. How BRDs affected these decisions was also analyzed.

**Methods**

In 1998 an expanded logbook (Figure 3.1) was distributed to volunteer Oregon shrimp vessels before the April 1st season start. Shrimp logo hats and entries for a gift certificate drawing were offered as incentives to the volunteers for carrying the expanded logbooks. The logbook collected data on trip-by-trip, day-by-day, and tow-by-tow basis. Trip-by trip data included the type of BRD used, the amount of time spent to reach the initial fishing grounds, and the reason for selecting the location.
### Special Oregon Shrimp/Scallop Trawler Log - Economics Study - Complete One Page Per Day of Fishing

**Complete this section on the first day of the trip.**

**How many hours run to where you started fishing?**

- Why did you select this location (check all that apply)?
  - Catch was good here previously
  - Grade was good here previously
  - Fishing was clean
  - Prospecting a new area
  - Closer to port or short run time
  - Avoid Weather
  - Other

**Completed on subsequent days of the trip.**

**Did you run to a new fishing location last night?**

- Y N Hrs. Running

**Reason for relocating to a new fishing area (check all that apply):**

- Find Higher Catch Rate
- Look for Better Grade
- Avoid Fish bycatch
- Other

**Excluder Use Information:**

- Type of Excluder Used?
- Mesh size or bar spacing:
- Was an excluder used this trip? Yes No

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>CH</th>
<th>Loran/Lat-Lon</th>
<th>Est. Weight of Shrimp (pounds)</th>
<th>Dumped Tow Information</th>
<th>Change in Fishing Location Between Tows</th>
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**Tow Dumped?**

- Y N Wt. of Shrimp Dumped

**Reason:**

- Grade
- Fishy
- Other

**Looking for:**

- Better shrimp catch
- Better Grade
- Cleaner fishing
- Other

**Change in Fishing Location Between Tows:**

- Did you make a significant change to your trawl gear today? Y N Modification

**Time of day/ tow #**

**Time spent on modification:_____ hours.**

**Did you relocate prior to this tow?**

- Y N Time Running

**Reason for altering gear:**

- Fishing too dirty
- Not catching enough shrimp
- Gear broke down
- Other

**Date**

**Receiving Ticket #**

**Gear**

**Port**

**Vessel Name**

**Landing Date**

**Port**

**Rig Type:** Single Double Signed:

**No. XXXXX**

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Figure 3.1. Example page of 1998 Oregon expanded shrimp logbook.
Day-by-day data included the time, type, duration and reason for modifications to trawl gear, the time spent relocating between fishing days, and reason for the relocation. Besides the customary tow-by-tow data already gathered by normal logbooks (depth, time, location, estimated weight of shrimp, and BRD use), we asked whether the tow was dumped, what were the estimated weights of dumped shrimp and fish, and the reason the tow was dumped. Tow data were also collected to determine whether the boat was relocated prior to the tow, and the amount of time and reasons for relocating. Categorical choice-responses were provided along with an option for “other reasons.” If multiple reasons were given, the primary reason was not always indicated.

The data were entered into Foxbase® and the database was queried to measure the frequency of reasons and time for each decision. Though it reduced the sample size, instances in which only one reason was cited were considered separately from those in which multiple reasons were indicated. Chi-squared statistical analysis was conducted to assess the difference between results. Significance was determined with p-values less than 0.05.

Results

Twenty vessels volunteered to carry the expanded logbook, 18% of all shrimp vessels landing in Oregon in 1998. They recorded data from 4727 tows on 1043 fishing days on 263 trips. Each vessel completed an average of 6.9 (1 to 16) trips, 128 (11 to 374) tows, and 282.7 (16.1 to 726.4) towing hours. There was an average of 18 (1 to 44) tows per trip and 5 (1 to 9) tows per day. Vessels averaged 9.4 hours of
towing per day with tows averaging 2.1 (6 minutes to 8 hours) hours. The time between tows was measured for tows that were relocated only.

A 3 to 5 inch soft mesh BRD was used on 157 (3.3%) tows and at some point on 23 (8.7%) trips. Five (25.0%) vessels used a BRD, but no vessel used the device for all tows. These five vessels made an average of 15.4 (5 to 21) trips and used a BRD on 30% of trips, an average of 4.6 (1 to 7) trips per vessel.

Choice of Initial Fishing Location

Vessels traveled an average of 5.7 hours to their initial fishing location. Anticipated problems with bycatch were a minor influence on choice of initial fishing location. Fishermen cited prospecting and good previous catch as the main reasons for choosing their initial fishing location. Bycatch was never the only reason for choice of initial fishing location (Figure 3.2). The reason for choosing initial fishing

![Figure 3.2. Proportion of time spent running to initial fishing grounds by BRD use and reason, when only one reason was cited (130 out of 263 trips, 736 total hours).]
location did not differ significantly between vessels using a BRD and those that did not ($\chi^2 = 2.0$, df = 4). Bycatch was one of the reasons on 9.9% trips. None of the vessels citing bycatch as a reason for initial fishing location utilized BRDs.

Relocating between fishing days

There were 211 relocations between fishing days. They averaged 4.1 hours per relocation with a range from 0.5 to 17 hours. Bycatch was rarely the only reason for relocating between fishing days (Figure 3.3). These relocations totaled 5 hours or 0.6% of all hours spent relocating. The reason for relocating between days did not differ significantly between vessels using a BRD and those that did not ($\chi^2 = 0.67$, df = 3). Bycatch was one of several reasons cited for relocating on 2.8% of trips. None of the vessels citing bycatch as a reason for relocating between fishing days utilized BRDs.

![Figure 3.3. Proportion of time spent relocating between fishing days by BRD use and reason, when only one reason was cited (157 out of 211 nights, 621 total hours).](image-url)
Relocating between tows

There were 1010 relocation between tows. Time between relocated tows averaged 18 minutes and ranged from 6 minutes to 5 hours. Again, bycatch was rarely the only reason cited for relocating between tows (Figure 3.4). This totaled 7 hours or 1.2% of all hours spent relocating between tows. There was a significant difference in the reason to relocate between BRD use, but it was almost entirely attributable to instances when “other” was given as a reason for relocating ($\chi^2 = 15.2$, df = 3).

Bycatch was one of the reasons for relocating between tows in 4.1% of tows. Only one vessel that cited bycatch as a reason for relocating between tows utilized a BRD.

![Graph showing proportion of time spent relocating between tows by BRD use and reason](image)

Figure 3.4. Proportion of time spent relocating between tows by BRD use and reason, when only one reason was cited (825 out of 1010 tows, 448 total hours).

Dumping of tows

A total of 430 (9.1%) tows were dumped. Bycatch was usually the only reason cited for dumping tows (Figure 3.5). The reasons for dumping tows did not significantly differ between BRD and non-BRD vessels ($\chi^2 = 0.11$, df = 2). Dumped
tows also had some ramifications on relocating and modifying gear. After tows were dumped, 50.5% of vessels relocated their next tow accounting for 16.9% of all relocated tows. Fishing gear was modified after 1.6% of dumped tows, accounting for 11.7% of all gear modifications.

Figure 3.5. Percent tows dumped by BRD use and reason, when only one reason was cited (379 out of 430 tows).

A BRD was utilized on 10 (0.2%) of these tows. In contrast to other studies demonstrating the effectiveness of BRDs, the number of tows dumped did not significantly differ with BRD use ($\chi^2 = 1.3$, $df = 1$). BRDs did help avoid dumping tows some of the time. A BRD was used 11 times after a tow was dumped or after 2.6% of dumped tows. Four of these times a BRD was already installed and three times the next tow was dumped as well. That leaves four tows when a BRD might have helped avoid a dumped tow.
Landed shrimp for the study vessels totaled 2,286,838 pounds. An estimated 260,365 lb. of fish and 5,988 lb. of shrimp were dumped. Compared to the shrimp landed by these vessels, this was equivalent to 11.3% and 0.3% of the finfish and shrimp dumped. Ninety-one percent of the fish and 79.9% of the shrimp that were dumped were due to bycatch reasons alone. Pacific whiting was the largest contributor to bycatch with 306 (81.4%) tows dumped due primarily to their presence. Flatfish, with slender sole *Lyopsetta exilis* being the only identified species, came in a distant second with 29 (7.7%) tows dumped due primarily to their presence. Unidentified red rockfish and yellowtail rockfish *Sebastes flavidus* were the only marketable species identified as reasons for dumping tows and that occurred only twice (.05%). Other species cited as reasons for dumping tows included spiny dogfish *Squalus acanthias*, northern anchovy *Engraulis mordax*, Pacific hagfish *Eptatretus stouti*, heart urchins *Brisaster latifrons*, and spotted ratfish *Hydrolagus colliei* (Figure 3.6).

**Modification of gear**

Modifications were made to the trawl gear between tows on 55 (1.4%) days. None of these vessels were using BRDs. Bycatch was the most common reason for modifications. When only one reason was cited, bycatch was the primary cause, but resulted in less time lost than when gear repairs were the reason cited (Figure 3.7). When multiple reasons were cited, a similar pattern was observed.
Figure 3.6. Percent estimated weight of species in dumped tows by BRD use.

Figure 3.7. Percent instances and time spent modifying gear by reason, when only one reason was cited.

Opportunity costs

Opportunity costs are estimates of the benefits that would result from an alternative use of a resource. In this case, opportunity costs were estimated for the time resource spent on bycatch. The time spent on bycatch was considered as time
that could have been spent fishing and the value of the possible catch was estimated. On a study level, the time that was involved in avoiding bycatch through relocations, modifications and dumping tows was combined and divided between participating vessels. On a fleet level, the time involved in dumping tows due to bycatch was extrapolated by using effort hours in 1998.

Adding up all events that were attributed to bycatch alone totals 514.5 hours or 4.1% of “lost opportunity time” for the participating vessels. Most of this came from dumped tows. With an average of 2.1 hours per tow, this totals 245 tows. Trips averaged 18.3 tows which equates to 13.4 trips. An average of 8,692 pounds of shrimp were caught per trip equaling 116,473 pounds of shrimp. At an average of $0.55 per pound (ODFW 1999), revenue totals $64,060 for all participating vessels. With 20 vessels participating in this study, this equates to 12.3 tows or $3,203 in lost net revenue per participating vessel.

Events that were attributed in part to bycatch totaled 839.4 hours or 6.7% of lost time for the participating vessels. Using the same averages as above, this totals 400 tows, 21.8 trips, 189,486 pounds or $104,217 for all participating vessels or 20 tows, 1.1 trips or $5,211 per vessel per year.

Shrimping effort for the 1998 shrimp season totaled 24,067 hours (ODFW unpublished report). Tows dumped due to bycatch alone cost 493 (5.1%) of the 9,762 effort hours logged in this study. Extrapolating to the entire 1998 season for all vessels, this totals 1,227 effort hours, 584 tows, 31.9 trips, 272,275 pounds or $152,501 lost revenue due to bycatch by the entire fleet. Per each vessel landing in Oregon (109) totals 11.3 effort hours, 5.4 tows, 2,543 pounds, or $1,399 revenues.
The total seasons catch was 6,070,842 lbs, which at $0.55 per pound would equal $3,338,963. This equates to a 4.6% loss in ex-vessel gross revenue.

The fishing effort associated with tows dumped at least in part because of bycatch totaled 557.5 hours. This represented 5.7% of the total fishing effort recorded by the vessels participating in the study. Extrapolated to the total 1998 season effort, this equates to 1,372 effort hours, 653 tows, 35.7 trips, 310,304 pounds or $170,667 (5.1% of total ex-vessel value) lost net revenue due to bycatch by the entire fleet. This equates to a loss of 12.6 hours, 6.0 tows, 2,847 pounds or $1,566 per vessel landing into Oregon in 1998.

**Discussion**

Discarded bycatch had a significant effect on the decision to dump tows, but did not have a major influence on other fishing decisions. The estimated losses in net revenue associated with dumped tows could make the economic benefits of bycatch reduction significant, particularly during years when there is a large biomass of Pacific whiting. Bycatch as a contributing factor figured into the choice of initial fishing grounds on 9.9% of trips. It contributed to relocating between fishing days on 0.2% to 2.8% of trips. It affected relocating between tows on 0.3% to 4.1% of tows.

The effect of bycatch on the dumping of tows was significant. Close to one-tenth of all tows were dumped and 77% to 87% were due to bycatch, depending on whether bycatch was the only reason or a contributing reason for dumping the tow. This amounted to the greatest number of bycatch related events and amount of time and effort lost. Dumped tows also had an effect on relocations and gear
modifications. After dumped tows, vessels relocated over half of the time and resulted in one-tenth of all gear modifications. Time was lost not only to towing, but also to relocating and modifying gear.

The calculations of opportunity cost help to put these data into clearer perspective. Based on lost fishing opportunities, costs of bycatch were estimated to result in a reduction of 9.5 tows, 2.1 fishing days, or $2,488 in net revenues per study vessel. When extrapolated to the entire fleet, dumped tows result in a reduction of 1,227 effort hours, 32.4 trips or $155,070 in net revenue for the entire fleet or $1,399 per 1998 vessel. This equates to a 4.6% loss in ex-vessel gross revenue from fishing decisions due to bycatch. This is comparable to the 2-5.5% of total ex-vessel value contributed by marketable bycatch (Hannah and Jones 2001).

This is a simple estimation that does not take into account other costs and benefits. Fishing behavior could change if bycatch problems were not anticipated or experienced. Tows could be of longer duration, catch rates may be altered and trips might be shorter. Further, the savings to other fisheries is not considered here. Discards that occur in any fishery represent potential lost landings to other fisheries. Currently, Pacific whiting makes up a large proportion of these discards.

In the early 1990's, voluntary BRD use was as high as 25% on vessels that carried them (Jones et al. 1996). Fleet wide during the 1998 season BRD use was practically nonexistent (ODFW unpublished data). This may have been due to decreased Pacific whiting on the shrimp grounds, shortcomings with BRDs, or alternative methods of bycatch handling and reduction methods (Hannah and Jones 2001). Low BRD use was reflected in data from the expanded logbook. BRDs were
used at some point on 25% of study vessels, but on only 5.7% of trips and 3.3% of
tows. This results in a relatively small sample size for evaluating shrimping behavior
while using one. Though not demonstrated in this study, the use of BRDs or other
bycatch reduction methods when bycatch is interfering with normal fishing operations
may be of economic benefit to shrimpers and/or the region. Particularly, if marketable
bycatch limits are reduced with the current groundfish status concerns, the savings
could be considerable.

This is the first study to examine the effects of bycatch through the use of
expanded logbook data. The results suggest some ideas to improve logbooks. For
example, in the event of multiple reasons for a fishing decision, a “primary” reason
should be required. In addition, actual tow times should be entered into the database
in order to determine time between tows and diel effects. Also, the logbook should
indicate whether a BRD was available on the vessel, even if it wasn’t employed. A
focus on vessels using BRDs or other bycatch reduction methods might address
specific questions more thoroughly.
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References


Chapter 4

Summary

Bycatch was found to have some effect on the ocean shrimp fishery in both studies. The shrimp quality study's main finding was that the effect of finfish bycatch on shrimp breakage was most apparent when the shrimp were first emptied from the net. At each handling stage overall breakage increased due to handling and processing and the effect of bycatch on breakage became more difficult to discern. During the cooking process the difference between breakage in the BRD and control catch became insignificant. The mean percent breakage increased from 2.4% on deck to 18.0% in the final product. Higher bycatch levels may have illustrated the finfish damage effect more strongly, however higher bycatch was not encountered during sampling despite efforts by the fishing vessel to increase bycatch.

Three main implications of this study have been identified. First of all, finfish can cause some reduction in the quality of ocean shrimp and BRDs can help reduce bycatch of finfish. The reduction in quality is small in comparison to other handling procedures, so the conservation of finfish resources, rather than product quality, provides the strongest rationale for BRD use in the ocean shrimp fishery. Secondly, shrimp product quality improvement may be achieved most readily by altering handling procedures at sea and in the plant. Thirdly, the effect of bycatch on product quality may be of greater concern in other shrimp fisheries where processing is more delicate and lack of breakage is of greater concern.
In the logbook study, discarded bycatch greatly affected the dumping of tows, but did not have a major effect on the other fishing decisions that were examined. Close to one-tenth of all tows were dumped, 77% to 87% due to bycatch. The estimated cost of dumped tows could make bycatch reduction methods worthy of economic consideration. Opportunity costs, based on this study, were estimated using time lost due to all fishing decisions based on bycatch. Opportunity costs came to 9.5 tows, 2.1 fishing days or $2,488 per study vessel. Fuel costs add $220 per vessel. For the fleet as a whole, by using effort hours only, the opportunity costs would be conservatively estimated to be 1,227 effort hours, 32.4 trips or $155,070. The use of BRDs or other bycatch reduction methods when bycatch is interfering with normal fishing operations may be of economic benefit to shrimpers. Particularly, if marketable bycatch limits are reduced with the current groundfish status concerns, the savings could be considerable.


http://www.pcouncil.org/Newsletters/spring01.html#bycatch

