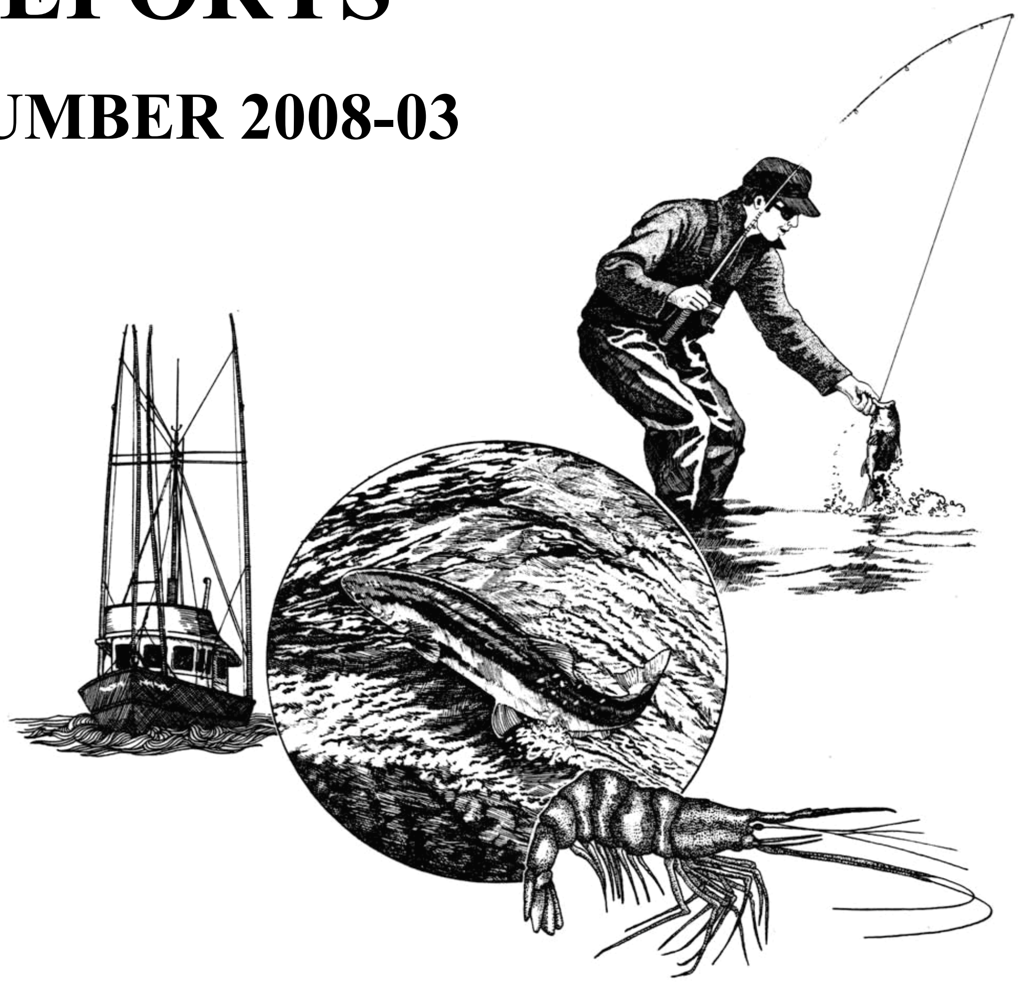
# INFORMATION REPORTS

## NUMBER 2008-03



# FISH DIVISION

## Oregon Department of Fish and Wildlife

Reducing Bycatch in Oregon's Recreational Groundfish Fishery: Experimental Results with Angling Gear Configured to Increase Bait Height Above Bottom

# Reducing bycatch in Oregon's recreational groundfish fishery: experimental results with angling gear configured to increase bait height above bottom

Robert W. Hannah

Troy V. Buell

Matthew T. O. Blume

Oregon Department of Fish and Wildlife

Marine Resources Program

2040 S.E. Marine Science Drive,

Newport, Oregon 97365

August 2008

## INTRODUCTION

Several long-lived, late-maturing rockfish (*Sebastes*) species found off the U.S. west coast have been seriously depleted by overfishing and are managed under long-term rebuilding plans that greatly restrict fishery impacts (PFMC 2006). Two of these species, canary rockfish (*Sebastes pinniger*) and yelloweye rockfish (*S. ruberrimus*), are caught in waters off Oregon and Washington as bycatch in recreational fisheries directed at black rockfish (*S. melanops*), yellowtail rockfish (*S. flavidus*), lingcod (*Ophiodon elongatus*) and Pacific halibut (*Hippoglossus stenolepis*). Recreational fishery impacts on the depleted species are constrained primarily via seasonal restrictions on the maximum depth of fishing, area closures and a ban on retention (PFMC 2006). However, needed future reductions in allowable impacts on either species could lead to more severe fishery restrictions, including bag limit reductions and seasonal or area closures (PFMC 2006). If angling gears can be developed that capture the target species effectively but are inefficient for these two bycatch species, then bag limit reductions or closures of the recreational groundfish fishery could be avoided.

The nearshore recreational fishery targeting black and blue rockfish (*Sebastes mystinus*) also captures several rockfish species which have not been the subject of formal stock assessments. A few of these rockfish species are long-lived and considered to be more vulnerable to overfishing than black rockfish. For example, china rockfish (*Sebastes nebulosus*) live to at least age 78 and tiger rockfish (*S. nigrocinctus*) to at least age 116 (Munk 2001). Harvest strategies that are acceptable for black and blue rockfish may result in overfishing of these sympatric rockfish species. Many of these unassessed, but vulnerable, rockfish species are also species that are most closely associated with the seafloor (Love et al. 2002). Conversely, many of the target species of the recreational fishery are more semi-pelagic in their vertical distribution, in that they are frequently found at some distance above the seafloor (Love et al. 2002). Gear-based methods that maintain catch rates for semi-pelagic rockfishes but reduce rates for more demersally-oriented rockfish could therefore also be helpful in successful mixed-stock management of nearshore fisheries. In this study, we tested the hypothesis that angling gear that keeps baits farther above the bottom would reduce the relative catch rates of yelloweye, canary and several demersal rockfishes, while maintaining acceptable catch rates for the semi-pelagic rockfish species most commonly caught off Oregon. In this report, we use the term "semi-pelagic" to specifically refer to black, blue, yellowtail, widow and redstripe rockfish (*S. proriger*). We use the term "demersal" to refer to rockfishes that are believed to live in close association with rocky substrate, specifically yelloweye, china (*S. nebulosus*), quillback (*S. maliger*), greenstriped (*S. elongatus*) and rosethorn (*S. helvomaculatus*) rockfishes.

**METHODS**

To conduct angling experiments, we chartered the commercial passenger fishing vessels *Misty* (17 m) and *Miss Raven* (13 m), out of Newport and the *Endeavor* (15m) out of Depoe Bay, Oregon. The experiments were conducted across a broad depth range (7-196 m) in 2006-2008 and targeted black and blue rockfish at shallower depths and yellowtail rockfish, lingcod and Pacific halibut at deeper depths. All tests employed one of two sampling designs: "side-by-side" or "replicate drift" comparisons. These designs were selected to try and minimize added variance in catch rates that can result from different gears being fished in different locations.

***Side-by-side comparisons***

In side-by-side tests, we compared the catches from anglers fishing a “control” gear, with lures immediately above the terminal weight (Figure 1), with catches from anglers fishing gear with an additional 3.0 m or 4.6 m section of 22.7 kg test nylon monofilament line (Figure 1) inserted between the lowermost bait and the terminal weight (hereafter referred to as "long leader gear"). These two leader lengths were chosen based on a prior small scale experiment testing 1.8 m leader extensions that did not reduce the catch of demersal rockfishes. The two terminal leader lengths (3.0 and 4.6 m) were tested separately against the control configuration, but were ultimately combined for data analysis to provide larger sample sizes. We used VEMCO® temperature-depth mini-loggers attached to the lowermost bait and to the terminal weight on one deepwater drift to verify that the long leader gear resulted in the baits being elevated approximately 3.0 or 4.6 m above the bottom during fishing. Terminal weights ranged from 170 g to 900 g, depending on the depth and speed of the drift, and were always the same for control and treatment gear.

Test fishing was conducted by drift-fishing over areas known for producing catches of the target species and also in areas where the bycatch species of interest would be encountered. Rods, reels and line (material and test weight) were standardized for all anglers. Treatment and control configurations were fished concurrently, side-by-side,

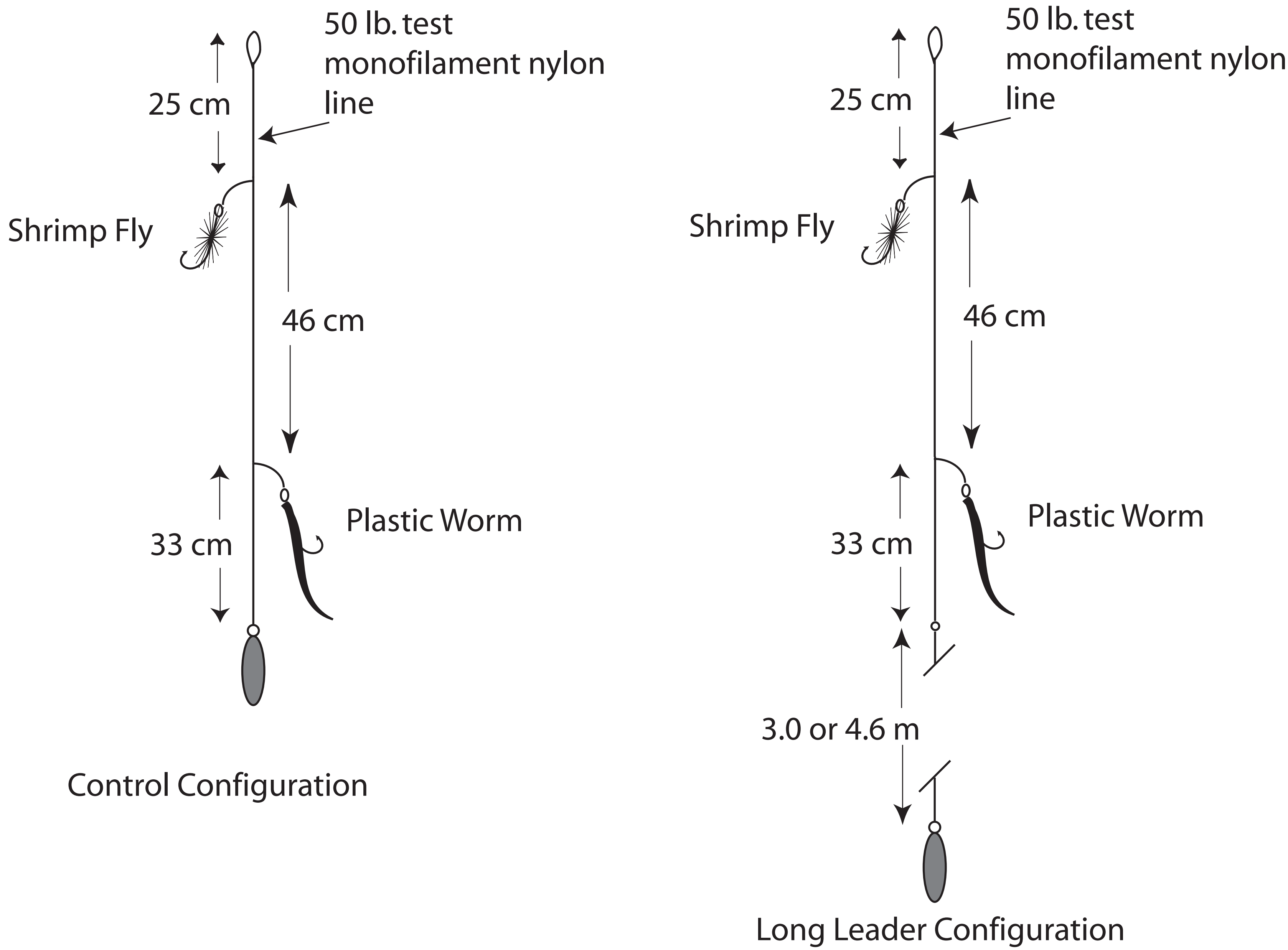



Figure 1. Schematic of the control and treatment angling gear used for targeting rockfish and lingcod.

with the gear configurations alternated down the side of the vessel. For each comparison, we used either 6 or 8 anglers, with half of the anglers fishing either the control or treatment gear. Fishing was organized in "drifts", with the length of each drift determined by the vessel operator. To control for differences in angling skill, anglers were randomized with respect to gear configuration prior to the start of each drift.

For targeting rockfish and lingcod, the specific control gear we selected (Figure 1) was a combination of a "shrimp fly" and a 10 cm long purple plastic worm, each on Mustad size 7 Duratin® hooks (#2330DT), on leaders of 22.7 kg test nylon monofilament line with "dropper" loops. The shrimp flies were simply made, consisting of about 8 strands of red and yellow 95 mm long, 1 mm wide, stiff polyethylene "whiskers", doubled through the hook eye and secured along the hook shank via a 5 mm wrapping of red pipe cleaner. A recreational terminal gear that is truly standard probably cannot be defined for U.S. west coast recreational rockfish fisheries, however, we chose this configuration as our control because it has been widely used by many charter vessels fishing the Oregon coast for many years. The fishing rods used were 2.1 m long boat rods with medium-heavy action. In shallower depths (<46 m) the rods were equipped with Penn 3/0 conventional casting reels and 22.7 kg test nylon monofilament line (2006) or 22.7 kg test braided synthetic line incorporating Spectra® fiber for reduced drag (2007 and 2008). At deeper depths, larger Penn 4/0 reels were used, spooled with the 22.7 kg test braided synthetic line. These same rods and reels, with different terminal tackle, were used for targeting Pacific halibut. We angled for Pacific halibut using 18-20 cm TL frozen whole Pacific herring (*Clupea pallasii*) as bait, threaded onto either of two terminal gear configurations. In 2006, single 9/0 Faultless Octopus hooks (model # 9299), tied on 31 cm leaders constructed from 90 kg test monofilament nylon line were used. In 2007 and 2008, a double-hook bait rig was used incorporating one 7/0 and one 9/0 Faultless Octopus hook on Steelon® nylon-coated 54 kg test stainless steel leader. For both hook configurations, leaders similar in construction to those shown in Figure 1, but with only a single dropper loop, were constructed out of 90 kg test nylon monofilament and secured to the main fishing line with a snap swivel.

***Replicate drift experiments***

Foraging theory suggests that direct side-by-side comparisons of angled baits may be influenced by gear interactions that can distort results. For example, it has been shown that many fishes select food items in proportion to their perceived size in the visual field, in part due to the apparently larger bait being detected more readily (Werner and Hall 1974, Howick and O'Brien 1983). Fish presented with identical food items at different distances should similarly be more likely to detect and strike at the closer (apparently larger) bait. Therefore, for demersal rockfishes, differences in catch rates with baits at different distances off of the bottom could simply reflect a prey "choice" based on perceived size. Alternatively, such differences could result from the fish failing to detect the distant bait, or from the distance exceeding the fish's maximum reaction distance, or from the species having a very strong affinity for the bottom.

Which of these models of fish behavior is influencing catch rates in gear comparisons could be very important when results from side-by-side experiments are applied to an actual fishery. If the distance to the baits exceeds the maximum reaction distance of a bycatch species or the species is hesitant to leave the bottom, then using the modified gear in a fishery should result in roughly the degree of bycatch reduction seen in side-by-side comparisons. If catch rate differences stem from a bait "choice" based on perceived size, then bycatch reduction in a fishery could be much less than predicted from side-by-side comparisons. This problem should be most acute when the bycatch species of concern is relatively uncommon in the catch, like yelloweye rockfish. If the few fish at any particular site are hooked and removed with closer (larger appearing) baits, leaving few if any to strike at the more distant (smaller appearing) baits, then an appearance of bycatch reduction will be created by this “gear interaction”. However, in a subsequent fishery, in the absence of the control gear, the few available fish at any site may still strike at the more distant baits. In such a situation, bycatch reduction would be much less than predicted from side-by-side comparisons.

We conducted additional tests of long leader gear with a “replicate drift” sampling design to determine if reductions we observed in catch rates of specific rockfishes in side-by-side tests may have been due to bait choice based on perceived size. In the replicate drift tests, we targeted areas expected to yield catches of yelloweye and other demersal rockfish and made replicate drifts over the same habitat. On the first drift, only the long leader configuration was used. On the second drift, half of the rods were switched to the control gear configuration. Much lower catches for the bycatch species in the first drift were interpreted as evidence that gear interaction was not the principal cause of catch reductions seen in side-by-side tests. Conversely, equal or higher catches of bycatch species in the first drifts were interpreted as evidence that reductions in catch rates seen in side-by-side comparisons were likely a result of bait choice and might not be realized in an actual fishery.

***Data and Analysis***

Each fish caught was identified to species (Table 1), measured (cm, FL) and released. Rockfish with significant barotrauma, as determined by having a gas-filled everted esophagus, were released at depth using a remotely-triggered, stainless-steel release cage. The angler's name, rod number, and terminal gear configuration were recorded in association with each fish caught. When weights or baits became snagged on the bottom and were broken off, the terminal gear was replaced from a supply of pre-tied tackle kept on board for that purpose.

Catch and length data were separated by fish size prior to analysis of the effects of gear modifications. This was done to separately analyze how long leader gear influenced catch rates and mean size for fish that would likely be retained by anglers (rockfish ≥ 30 cm, lingcod ≥ 59 cm) as well as catch rates for discard-sized fishes (rockfish< 30 cm, lingcod < 59 cm). A length of 30 cm was determined to be the approximate minimum retention size for rockfish captured by the CPFV fleet based on questions posed to operators and deckhands of the charted vessels and on a review of Oregon recreational fishery length frequency data (ODFW unpublished data). The minimum retention size for lingcod was based on the 22 inch legal minimum size for retention. Throughout this report, fish that were large enough to be retained by anglers are referred to as "large",

Table 1. Common and scientific names of species captured in this study.

| Common name | Scientific name |
|---|---|
| Black rockfish | *Sebastes melanops* |
| Blue rockfish | *Sebastes mystinus* |
| Bocaccio | *Sebastes paucispinis* |
| Brown rockfish | *Sebastes auriculatus* |
| Canary rockfish | *Sebastes pinniger* |
| China rockfish | *Sebastes nebulosus* |
| Copper rockfish | *Sebastes caurinus* |
| Greenstriped rockfish | *Sebastes elongatus* |
| Quillback rockfish | *Sebastes maliger* |
| Redstripe rockfish | *Sebastes proriger* |
| Rosethorn rockfish | *Sebastes helvomaculatus* |
| Tiger rockfish | *Sebastes nigrocinctus* |
| Vermilion rockfish | *Sebastes miniatus* |
| Widow rockfish | *Sebastes entomelas* |
| Yelloweye rockfish | *Sebastes ruberrimus* |
| Yellowtail rockfish | *Sebastes flavidus* |
| Arrowtooth flounder | *Atherestes stomias* |
| Blue shark | *Prionace glauca* |
| Cabezon | *Scorpaenichthys marmoratus* |
| Chinook salmon | *Oncorhyncus tshawytscha* |
| Kelp greenling | *Hexagrammos decagrammus* |
| Lingcod | *Ophiodon elongatus* |
| Petrale sole | *Eopsetta jordani* |
| Pacific halibut | *Hippoglossus stenolepis* |
| Sablefish | *Anoplopoma fimbria* |
| Spiny dogfish | *Squalus acanthias* |

while fish below these minimum sizes are referred to as "discard-sized". Since there is no minimum retention size for Pacific halibut, all halibut were considered to be large fish. Catch rates were calculated as the number of fish per drift for side-by-side comparisons and as the number of fish per 10 angler-drifts for replicate drift experiments to account for the different number of anglers fishing each gear on the first and second drifts. Catch rates for the treatment and control configurations were analyzed, by species, using a Wilcoxon signed rank test for paired data applied to species for which at least 10 specimens were captured with the control gear. This non-parametric test procedure was chosen because the catch data we collected were highly skewed and were not normalized by log transformation. The length data for the treatment and control configurations were compared for large fish only, by species, using the Mann-Whitney nonparametric test, again applied to species in which at least 10 specimens were captured with the control gear. This test was chosen over parametric alternatives because of the truncation of the length distribution caused by separating large and discard-sized fishes.

**RESULTS**

We completed a total of 191 experimental drifts comparing catches with long leader and control gear in side-by-side comparisons, 130 targeting rockfish and lingcod with artificial lures and 61 targeting Pacific halibut with large whole bait (Table 2). An additional 44 pairs of replicate drifts were completed, 34 targeting rockfish and lingcod and 10 targeting Pacific halibut. In the experiments targeting rockfish and lingcod, 2,130 fish of 23 different species were captured, measured and released at 8 different sites

Table 2. Summary of experiments testing the effect of long leader extensions (3.0 and 4.6 m) between the lowermost bait and the terminal weight in recreational angling gear on the species and size composition of the catch, by fishery. Tests were conducted in ocean waters between Cape Perpetua and Lincoln City, Oregon, 2006-08.

| Experiment | Primary target species | Baits tested | Days fished | Drifts completed | Depth range (m) |
|---|---|---|---|---|---|
| *Side-by-side comparisons* | | | | | |
| Rockfish fishery | Lingcod/rockfish | Shrimp flies, plastic worms | 9 | 130 | 7-152 |
| Halibut fishery | Pacific halibut | Whole Pacific herring | 7 | 61 | 62-196 |
| Total | | | 16 | 191 | |
| | | | | | |
| *Replicate drift experiments* | | | | | |
| Rockfish fishery | Lingcod/rockfish | Shrimp flies, plastic worms | 4 | 34 pairs | 21-142 |
| Halibut fishery | Pacific halibut | Whole Pacific herring | 2 | 10 pairs | 60-183 |
| Total | | | 6 | 44 | |

between Cape Perpetua and Lincoln City, Oregon. In the Pacific halibut experiments, 269 fish of 15 different species were captured.

From a practical standpoint, the study design we used for testing recreational angling gear was very successful. The anglers fishing long leader gear had little difficulty in handling the long lines. When retrieving long leader gear, they simply wrapped the extra line around one side of the conventional casting reels they were using. Comments by vessel operators indicated that there were many different options for handling the extra line. The side-by-side comparisons went smoothly and randomization of anglers between drifts proved simple and reliable. Precisely duplicating replicate drifts was more difficult than expected. At times, due to changing wind and currents, the vessel would be unable to replicate the drift. When this happened, replicate drift work was suspended until conditions improved.

***Side-by-side comparisons***

In side-by-side comparisons targeting rockfish and lingcod, long leader gear did not significantly reduce catch rates for large semi-pelagic rockfishes like black, blue and yellowtail and significantly increased catch rates for widow rockfish (Tables 3 and 4, $P<0.05$). Catch rates for yelloweye and canary rockfish were reduced 84% and 41%, respectively (Tables 3 and 4, $P<0.05$). Quillback rockfish catch rates were also reduced 100% (Tables 3 and 4, $P<0.05$). Although only a few specimens of other rockfish species were encountered, long leader gear showed a tendency towards reduced catch rates for some of these species as well. In all, 4 copper rockfish, 3 brown rockfish and 1 china

Table 3. Total catch and mean catch rate (fish/drift), by species and gear type, in 130 drifts testing the effect of long leader angling gear (see text) on catches in Oregon's recreational rockfish fishery. Rates are shown separately for fish of a size that would normally be retained by anglers (rockfish ≥ 30 cm, FL, lingcod ≥ 59 cm) and that would normally be discarded. Standard error is shown in parentheses.

| Species | Large fish | | | | Discard-sized fish | | | |
|---|---|---|---|---|---|---|---|---|
| | Standard gear | Long leader | Standard gear | Long leader | Standard gear | Long leader | Standard gear | Long leader |
| | Number Caught | Number Caught | Catch/drift | Catch/drift | Number Caught | Number Caught | Catch/drift | Catch/drift |
| Black rockfish | 194 | 159 | 1.49 (0.28) | 1.22 (0.25) | 23 | 6 | 0.18 (0.06) | 0.05 (0.03) |
| Blue rockfish | 57 | 64 | 0.44 (0.13) | 0.49 (0.13) | 45 | 55 | 0.35 (0.15) | 0.42 (0.13) |
| Blue shark | 1 | 0 | 0.01 (0.01) | 0.00 (0.00) | 0 | 0 | 0.00 (0.00) | 0.00 (0.00) |
| Bocaccio | 2 | 2 | 0.02 (0.02) | 0.02 (0.01) | 1 | 0 | 0.01 (0.01) | 0.00 (0.00) |
| Brown rockfish | 3 | 0 | 0.02 (0.01) | 0.00 (0.00) | 0 | 0 | 0.00 (0.00) | 0.00 (0.00) |
| Cabezon | 1 | 0 | 0.01 (0.01) | 0.00 (0.00) | 0 | 0 | 0.00 (0.00) | 0.00 (0.00) |
| Canary rockfish | 125 | 74 | 0.96 (0.17) | 0.57 (0.14) | 38 | 6 | 0.29 (0.07) | 0.05 (0.03) |
| China rockfish | 1 | 0 | 0.01 (0.01) | 0.00 (0.00) | 0 | 0 | 0.00 (0.00) | 0.00 (0.00) |
| Copper rockfish | 4 | 0 | 0.03 (0.02) | 0.00 (0.00) | 1 | 0 | 0.01 (0.01) | 0.00 (0.00) |
| Greenstriped rockfish | 2 | 0 | 0.02 (0.01) | 0.00 (0.00) | 11 | 0 | 0.09 (0.04) | 0.00 (0.00) |
| Kelp greenling | 5 | 0 | 0.04 (0.02) | 0.00 (0.00) | 0 | 0 | 0.00 (0.00) | 0.00 (0.00) |
| Lingcod | 19 | 6 | 0.15 (0.04) | 0.05 (0.02) | 12 | 0 | 0.09 (0.03) | 0.00 (0.00) |
| Pacific halibut | 0 | 1 | 0.00 (0.00) | 0.01 (0.01) | 0 | 0 | 0.00 (0.00) | 0.00 (0.00) |
| Quillback rockfish | 22 | 0 | 0.17 (0.05) | 0.00 (0.00) | 0 | 0 | 0.00 (0.00) | 0.00 (0.00) |
| Redstripe rockfish | 0 | 1 | 0.00 (0.00) | 0.01 (0.01) | 11 | 11 | 0.09 (0.03) | 0.09 (0.03) |
| Rosethorn rockfish | 1 | 0 | 0.01 (0.01) | 0.00 (0.00) | 21 | 0 | 0.16 (0.04) | 0.00 (0.00) |
| Vermilion rockfish | 1 | 1 | 0.01 (0.01) | 0.01 (0.01) | 0 | 0 | 0.00 (0.00) | 0.00 (0.00) |
| Widow rockfish | 16 | 33 | 0.12 (0.05) | 0.25 (0.09) | 3 | 2 | 0.02 (0.02) | 0.02 (0.01) |
| Yelloweye rockfish | 19 | 3 | 0.15 (0.04) | 0.02 (0.01) | 1 | 0 | 0.01 (0.01) | 0.00 (0.00) |
| Yellowtail rockfish | 219 | 226 | 1.69 (0.32) | 1.74 (0.31) | 33 | 40 | 0.25 (0.06) | 0.31 (0.06) |

Table 4. Percent change in catch rates, by species and gear type, in 130 drifts testing the effect of long leader angling gear (see text) on catches in Oregon's recreational fishery targeting rockfish and lingcod (side-by-side tests). Data are shown separately for fish of a size that would normally be retained (rockfish ≥ 30 cm FL, lingcod ≥ 59 cm FL) and that would normally be discarded. P-values reference results of Wilcoxon signed rank tests comparing control and long leader catches.

| Species | Large fish | | Discard-sized fish | |
| --- | --- | --- | --- | --- |
| | Percent change | P-value | Percent change | P-value |
| Black rockfish | -18.0 | 0.4341 | -74.0 | 0.0051 |
| Blue rockfish | +12.3 | 0.2452 | +22.3 | 0.0340 |
| Canary rockfish | -40.9 | 0.0003 | -84.2 | 0.0001 |
| Greenstriped rockfish | -100.0 | nm | -100.0 | 0.0422 |
| Lingcod | -68.5 | 0.0068 | -100.0 | 0.0030 |
| Quillback rockfish | -100.0 | 0.0007 | -- | -- |
| Redstripe rockfish | nm | nm | 0.0 | 0.9999 |
| Rosethorn rockfish | -100.0 | nm | -100.0 | 0.0002 |
| Widow rockfish | +106.5 | 0.0051 | +34.8 | nm |
| Yelloweye rockfish | -84.2 | 0.0011 | -100.0 | nm |
| Yellowtail rockfish | +3.1 | 0.5340 | +21.3 | 0.5689 |

nm - not meaningful, -- no data

rockfish were captured on the control angling gear and none of these species were captured on long leader gear. For discard-sized fish, catch rates were reduced most for rosethorn rockfish (-100%, $P<0.05$, Tables 3 and 4), greenstriped rockfish (-100%, $P<0.05$) and canary rockfish (-84%, $P<0.05$), while catch rates for discard-sized blue rockfish were increased 22% ($P<0.05$). Long leader gear also greatly reduced catch rates for large and discard-sized lingcod, 69% and 100%, respectively (Tables 3 and 4, $P<0.05$). In drifts targeting Pacific halibut with whole bait, long leader gear reduced the catch of yelloweye rockfish 73% in side-by-side comparisons, but did not significantly reduce catch rates for Pacific halibut (Tables 5 and 6).

***Replicate drift experiments***

The replicate drift experiments, though small in scope, were very informative as to what might happen if the results from the side-by-side comparisons were implemented in a fishery. In replicate drifts targeting rockfish and lingcod with small artificial lures, catches confirmed the findings of the side-by-side experiments with regard to yelloweye rockfish. No yelloweye rockfish were captured with long leader gear on either the first drift (fishing all long leader gear) or with the 3 or 4 rods fishing long leader gear during the second replicate drift (Table 7). The capture of a total of 20 yelloweye rockfish on the control gear during the second drifts confirmed that the areas being fished held yelloweye rockfish that simply weren't efficiently captured with long leader gear and small lures. Conversely, the catches of quillback rockfish indicated that the results from side-by-side comparisons might be misleading for that species, with this type of terminal gear. Side-by-side comparisons suggested that long leader gear with small artificial lures

Table 5. Total catch and mean catch rate (fish/drift), by species and gear type, in 61 drifts testing the effect of long leader angling gear (see text) on catches while angling with whole bait for Pacific halibut. Rates are shown separately for fish of a size that would normally be retained by anglers (rockfish ≥ 30 cm, FL, lingcod ≥ 59 cm) and that would normally be discarded. Standard error is shown in parentheses.

| Species | Large fish | | | | Discard-sized fish | | | |
|---|---|---|---|---|---|---|---|---|
| | Standard gear | Long leader | Standard gear | Long leader | Standard gear | Long leader | Standard gear | Long leader |
| | Number Caught | Number Caught | Catch/drift | Catch/drift | Number Caught | Number Caught | Catch/drift | Catch/drift |
| Arrowtooth flounder | 1 | 0 | 0.02 (0.02) | 0.00 (0.00) | 0 | 0 | 0.00 (0.00) | 0.00 (0.00) |
| Bocaccio | 1 | 3 | 0.02 (0.02) | 0.05 (0.04) | 0 | 0 | 0.00 (0.00) | 0.00 (0.00) |
| Canary rockfish | 7 | 13 | 0.12 (0.05) | 0.21 (0.07) | 0 | 0 | 0.00 (0.00) | 0.00 (0.00) |
| Greenstriped rockfish | 1 | 0 | 0.02 (0.02) | 0.00 (0.00) | 0 | 0 | 0.00 (0.00) | 0.00 (0.00) |
| Lingcod | 35 | 44 | 0.57 (0.13) | 0.72 (0.14) | 5 | 1 | 0.08 (0.04) | 0.02 (0.02) |
| Pacific halibut | 35 | 33 | 0.57 (0.14) | 0.54 (0.13) | 0 | 0 | 0.00 (0.00) | 0.00 (0.00) |
| Petrale sole | 1 | 0 | 0.02 (0.02) | 0.00 (0.00) | 0 | 0 | 0.00 (0.00) | 0.00 (0.00) |
| Quillback rockfish | 0 | 1 | 0.00 (0.00) | 0.02 (0.02) | 0 | 0 | 0.00 (0.00) | 0.00 (0.00) |
| Rosethorn rockfish | 0 | 0 | 0.00 (0.00) | 0.00 (0.00) | 3 | 0 | 0.05 (0.04) | 0.00 (0.00) |
| Sablefish | 3 | 5 | 0.05 (0.04) | 0.08 (0.04) | 0 | 0 | 0.00 (0.00) | 0.00 (0.00) |
| Spiny dogfish | 1 | 0 | 0.02 (0.02) | 0.00 (0.00) | 0 | 0 | 0.00 (0.00) | 0.00 (0.00) |
| Widow rockfish | 1 | 0 | 0.02 (0.02) | 0.02 (0.02) | 0 | 0 | 0.00 (0.00) | 0.00 (0.00) |
| Yelloweye rockfish | 22 | 6 | 0.37 (0.11) | 0.10 (0.04) | 0 | 0 | 0.00 (0.00) | 0.00 (0.00) |
| Yellowtail rockfish | 6 | 8 | 0.10 (0.05) | 0.13 (0.05) | 0 | 0 | 0.00 (0.00) | 0.00 (0.00) |

Table 6. Percent change in catch rates, by species and gear type, in 61 drifts testing the effect of long leader angling gear (see text) on catches taken angling with whole bait for Pacific halibut. Data are shown only for fish of a size that would normally be retained by anglers (rockfish ≥ 30 cm, FL, lingcod ≥ 59 cm). P-values reference results of Wilcoxon signed rank tests comparing control and long leader catches (species with 10 or more observations on the control gear).

| Species | Large fish | |
|---|---|---|
| | Percent change | P-value |
| Lingcod | 25.7 | 0.0843 |
| Pacific halibut | -5.7 | 0.7686 |
| Yelloweye rockfish | -72.7 | 0.0099 |

Table 7. Catch rates (fish/10 angler-drifts) from an experiment comparing replicate drifts over the same habitat (N = 34 pairs) in Oregon's recreational rockfish fishery using small artificial lures for bait. All rods (6 or 8 total) in the first drift employed 4.6 m leaders between the lowermost bait and the terminal weight. For the second drift, half of the rods were switched to the control configuration. Number of fish captured is shown in parentheses.

| Species | Large fish | | | Discard-sized fish | | |
|---|---|---|---|---|---|---|
| | First drift (all 6 or 8 anglers with long leader gear) | Second drift – long leader (3 or 4 anglers) | Second drift – control gear (3 or 4 anglers) | First drift (all 6 or 8 anglers with long leader gear) | Second drift – long leader (3 or 4 anglers) | Second drift – control gear (3 or 4 anglers) |
| Black rockfish | 1.33 (34) | 1.88 (24) | 2.66 (34) | 0.04 (1) | 0.08 (1) | 0.31 (4) |
| Blue rockfish | 0.74 (19) | 0.47 (6) | 0.23 (3) | 0.74 (19) | 0.39 (5) | 0.08 (1) |
| Cabezon | 0.00 (0) | 0.00 (0) | 0.08 (1) | 0.00 (0) | 0.00 (0) | 0.00 (0) |
| Canary rockfish | 1.48 (38) | 2.11 (27) | 3.28 (42) | 0.23 (6) | 0.00 (0) | 1.02 (13) |
| China rockfish | 0.00 (0) | 0.00 (0) | 0.16 (2) | 0.00 (0) | 0.00 (0) | 0.16 (2) |
| Greenstriped rockfish | 0.00 (0) | 0.00 (0) | 0.16 (2) | 0.00 (0) | 0.00 (0) | 0.08(1) |
| Kelp greenling | 0.00 (0) | 0.08 (1) | 0.23 (3) | 0.00 (0) | 0.00 (0) | 0.00 (0) |
| Lingcod | 0.04 (1) | 0.00 (0) | 0.08 (1) | 0.04 (1) | 0.08 (1) | 0.39 (5) |
| Petrale sole | 0.00 (0) | 0.00 (0) | 0.16 (2) | 0.00 (0) | 0.00 (0) | 0.00 (0) |
| Quillback rockfish | 0.12 (3) | 0.08 (1) | 0.23 (3) | 0.00 (0) | 0.00 (0) | 0.00 (0) |
| Tiger rockfish | 0.00 (0) | 0.00 (0) | 0.08 (1) | 0.00 (0) | 0.00 (0) | 0.00 (0) |
| Widow rockfish | 0.31 (8) | 0.31 (4) | 0.00 (0) | 0.16 (4) | 0.00 (0) | 0.00 (0) |
| Yelloweye rockfish | 0.00 (0) | 0.00 (0) | 1.56 (20) | 0.00 (0) | 0.00 (0) | 0.39 (5) |
| Yellowtail rockfish | 3.44 (88) | 3.36 (43) | 2.19 (28) | 1.02 (26) | 0.78 (10) | 0.23 (3) |

would completely eliminate the catch of quillback rockfish (Tables 3 and 4). However, when long leader gear was presented alone, 4 quillback rockfish were captured, more than were caught on the control gear during the second replicate drifts (Table 7).

For canary rockfish targeted with small artificial lures, the replicate drift experiments were a little more difficult to interpret, but generally support a substantial reduction in canary rockfish catch rates with long leader gear. The side-by-side comparisons shown in Tables 3 and 4 suggest that long leader gear will reduce canary rockfish catch rates by about 40%. Comparing catch rates from the first replicate drifts with catch rates for just the anglers fishing the control angling gear on the second drifts (Table 7) indicates a reduction of about 55% with long leader gear and small artificial lures, but this is complicated by the fact that the first drift has already removed some fish from the area, as did the anglers fishing long leader gear on the second drift. For discard-sized fish, the replicate drift experiments confirmed reductions in black and canary rockfish and lingcod and an increase in catch rates for blue rockfish (Table 7). For other species that showed reductions in catch rates in the side-by-side experiments, such as lingcod and rosethorn and greenstriped rockfish, too few were encountered in the replicate drift experiments to evaluate changes in catch rates.

Results from the replicate drift experiments using whole bait for Pacific halibut were very different. In six pairs of drifts (Table 8), four yelloweye rockfish were captured on long leader gear on the first drifts. An additional three yelloweye rockfish were caught on the second drifts, two on the control gear and one on long leader gear. Similarly, three

Table 8. Catch rates (fish/10 angler-drifts) from an experiment comparing replicate drifts over the same habitat (N = 10 pairs) in Oregon's Pacific halibut fishery using whole Pacific herring for bait. All rods (6) in the first drift employed 4.6 m leaders between the lowermost bait and the terminal weight. For the second drift, 3 rods were switched back to the control gear. Number of fish captured is shown in parentheses.

| Species | Large fish | | | Discard-sized fish | | |
|---|---|---|---|---|---|---|
| | First drift (all rods with long leader gear) | Second drift – long leader | Second drift – control gear | First drift (all rods with long leader gear) | Second drift –long leader | Second drift – control gear |
| Canary rockfish | 0.50 (3) | 1.67 (5) | 0.67 (2) | 0.00 (0) | 0.00 (0) | 0.00 (0) |
| Chinook salmon | 0.17 (1) | 0.00 (0) | 0.00 (0) | 0.00 (0) | 0.00 (0) | 0.00 (0) |
| Lingcod | 0.67 (4) | 0.00 (0) | 0.33 (1) | 0.00 (0) | 0.00 (0) | 0.00 (0) |
| Pacific halibut | 0.33 (2) | 0.67 (2) | 0.67 (2) | 0.00 (0) | 0.00 (0) | 0.00 (0) |
| Quillback rockfish | 0.17 (1) | 0.00 (0) | 0.33 (1) | 0.00 (0) | 0.00 (0) | 0.00 (0) |
| Yelloweye rockfish | 0.67 (4) | 0.33 (1) | 0.33 (1) | 0.00 (0) | 0.00 (0) | 0.33 (1) |
| Yellowtail rockfish | 0.17(1) | 0.33 (1) | 0.00 (0) | 0.00 (0) | 0.00 (0) | 0.00 (0) |

canary and one quillback rockfish were captured on the first drifts using just long leader gear. Although this is a very small sample, it contrasts with the results of the similar comparison employing small artificial lures. The capture of several yelloweye rockfish on long leader gear with whole bait suggests that the results from side-by-side experiments reported above may be misleading in regard to how long leader gear would perform in an actual fishery using large whole baits.

***Size composition of large fish***

In experiments targeting rockfish and lingcod, the use of long leader gear did not substantially alter the size composition of large fish captured, for most species (Table 9). The mean FL of canary rockfish taken with long leader gear was 2.6 cm larger than with the control configuration and the mean length of yellowtail rockfish was 1.6 cm smaller with long leader gear ($P<0.05$, Table 9). Similarly, in drifts targeting Pacific halibut with bait, the mean lengths of large fish were not strongly influenced by the use of long leader gear (Table 9).

## DISCUSSION

The data from this study suggest that angling with small artificial lures, elevated at least 3.0 m above the bottom, can be an effective tool for separating semi-pelagic rockfishes from lingcod and some demersal rockfishes, particularly yelloweye rockfish. Our results also suggest that a recreational fishery employing long leader gear and small artificial lures to target semi-pelagic rockfishes such as yellowtail, widow, black or blue rockfish would probably have much lower bycatch rates for yelloweye and canary rockfish in

Table 9. Mean fish length (FL ± 1 standard error), by species and gear type in experiments testing the effect of long leader angling gear on catches while targeting rockfish and lingcod with artificial lures or Pacific halibut with whole bait. Data shown are for fish of a size that would normally be retained by anglers (rockfish ≥ 30 cm, FL, lingcod ≥ 59 cm) and are from side-by-side and replicate drift experiments combined. Sample size is shown in parentheses. Species included if 10 or more length observations were collected with the control angling gear. Asterisks denote a significant difference in mean fish FL between standard and long leader gear (Mann-Whitney U test, P<0.05).

| Species | Target species | | | |
|---|---|---|---|---|
| | Rockfish and lingcod (lures) | | Pacific halibut (bait) | |
| | Control angling gear | Long leader gear | Control angling gear | Long leader gear |
| Black rockfish | 38.67 ± 0.29<br>(228) | 38.89 ± 0.29<br>(217) | -- | -- |
| Blue rockfish | 35.53 ± 0.43<br>(60) | 34.43 ± 0.36<br>(89) | -- | -- |
| Canary rockfish | 37.06 ± 0.42*<br>(167) | 39.67 ± 0.58<br>(139) | -- | -- |
| Lingcod | 74.10 ± 3.34<br>(20) | 82.80 ± 9.26<br>(5) | 75.71 ± 1.61<br>(35) | 75.98 ± 1.37<br>(44) |
| Pacific halibut | -- | -- | 88.13 ± 1.71<br>(35) | 85.50 ± 1.67<br>(33) |
| Quillback rockfish | 37.00 ± 0.71<br>(25) | 37.00 ± 0.91<br>(4) | -- | -- |
| Widow rockfish | 35.81 ± 1.03<br>(16) | 35.71 ± 0.65<br>(45) | -- | -- |
| Yelloweye rockfish | 45.66 ± 1.68<br>(38) | 53.00 ± 1.00<br>(3) | 54.86 ± 1.00<br>(22) | 55.50 ± 2.23<br>(6) |
| Yellowtail rockfish | 36.83 ± 0.30*<br>(247) | 35.22 ± 0.22<br>(357) | -- | -- |

-- No data or less than 10 specimens for the control angling gear.

comparison to current west coast recreational fishing practices. Such a fishery would very likely also have reduced catch rates for lingcod. Although Pacific halibut were caught effectively with long leader gear and large whole bait, long leader gear was not effective at reducing catch rates for yelloweye or canary rockfish when large whole bait was used.

The most probable explanation for the divergent results seen in side-by-side and replicate drift experiments for quillback rockfish with artificial lures and for yelloweye rockfish with whole bait is that when long leader and control gear are presented together, the baits on the control gear are taken first by the available fish, because they are closer and appear larger to the fish, or are detected sooner. For reefs without a large abundance of quillback or yelloweye rockfish, most of the available fish may become hooked on the control gear, leaving fewer to detect and strike at the more distant long leader gear. If this hypothesis is correct, then a fishery using long leader gear with small artificial lures will not attain the bycatch reduction for quillback rockfish implied by the side-by-side results shown in Table 3, but should still perform well with regard to yelloweye rockfish. However, in a fishery using whole bait to target Pacific halibut, yelloweye rockfish bycatch would probably not be reduced very much by requiring the use of long leader angling gear.

The differing results we obtained for some species and gears with our two sampling designs show that neither of the sampling designs we used in this study are optimal for evaluating gear-based bycatch reduction strategies in recreational fisheries. The flaw in side-by-side comparisons is that gear interactions can produce misleading results: catch rates may differ when one gear is presented alone. The replicate drift approach has two problems: drifts are difficult to truly replicate in the variable marine environment and catch rate estimates from replicate drifts are not fully independent, so catch rates cannot be estimated without bias. The best sampling design for these kind of experiments is probably paired drifts that are laid out over similar habitat, in fairly close proximity, with gear assigned randomly to each drift.

The small scale of our study argues for caution in applying these results to immediate fishery management problems without additional larger-scale tests and perhaps tests of even longer leaders that may perform better for canary and quillback rockfish. Our study did not measure the effects of season, time of day, water clarity, fish density, temperature or the physical structure of individual reefs, any of which could influence the performance of long leader gear at catching yelloweye or canary rockfish, various demersal rockfish or lingcod.

**Acknowledgements**

The charter vessels *Misty* and *Miss Raven*, operating out of Newport, and *Endeavor*, operating out of Depoe Bay, Oregon assisted with this study, as did numerous volunteer anglers. Polly Rankin and J. Scott Malvitch assisted with field data collection. This study was funded, in part by Sport Fish Restoration grant number F-186-R, entitled "Population Status of Black Rockfish in Oregon Coastal Waters" and also by the National Marine Fisheries Service through contract #NA16FM2915.

**References**

Howick, G. L. and W. J. O'Brien. 1983. Piscivorous feeding behavior of largemouth bass: an experimental analysis. Trans. Amer. Fish. Soc. 112:508-516.

Love, M.S., Yoklavich, M. and L. Thorsteinson. 2002. The rockfishes of the northeast Pacific. University of California Press, Berkeley, California.

Munk, K. M. 2001. Maximum ages of groundfish in waters off Alaska and British Columbia and considerations of age determination. Alaska Fishery Research Bulletin 8(1):12-21.

PFMC (Pacific Fishery Management Council) and NMFS (National Marine Fisheries Service). 2006. Proposed acceptable biological catch and optimum yield specifications and management measures for the 2007-2008 Pacific coast groundfish fishery, and Amendment 16-4: rebuilding plans for seven depleted Pacific coast groundfish species; final environmental impact statement including regulatory impact review and initial regulatory flexibility analysis. Pacific Fishery Management Council, Portland, OR. October 2006.

Werner, E. E. and D. J. Hall. 1974. Optimal foraging theory and the size selection of prey by the bluegill sunfish (*Lepomis macrochirus*). Ecology 55:1042-1052.

OREGON
Fish & Wildlife

3406 Cherry Ave. NE
Salem, Oregon 97303