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MAR 2009
N.P.F.M.C.

March 13, 2009

Mr. Eric Olson, Chairman
North Pacific Fishery Management Council
P.O. Box 103136
Anchorage, Alaska 99511

Re: Salmon Bycatch

Dear Chairman Olson:

APICDA and NSEDC commissioned an analysis by Dr. James Wilen on the two salmon bycatch incentive programs. That report is attached. We asked Dr. Wilen to address the following questions:

- What is the magnitude of incentives created by each plan?
- Over what level of Chinook bycatch are the magnitude of those incentives greater than the incentives created by a mere hard cap of 47,591
- What are the behavioral changes you would expect from the pollock fleet as a result of the incentives generated by each plan?
- What is the reduction of Chinook bycatch that could be expected from each plan?
- Can either of these plans be "gamed," (especially by companies owning multiple vessels) such that the effectiveness of the plan can be diminished?
- Can the effectiveness of either of these plans be diminished by the fact that some companies hold large market shares of pollock quota? For the purpose of this issue, please assume that each plan will be used in both the inshore catcher vessel sector and the offshore catcher/processor sector.

Dr. Wilen will be attending the Council meeting and will be available for questions.

Sincerely,

Larry Cotter

Cc: NSEDC

Analysis of Alternative Incentive Plans for Reducing Salmon Bycatch in the Pollock Fishery

By
James E. Wilen
Dept. of Ag. and Resource Economics
University of California, Davis

Comments prepared for submission to the
North Pacific Fisheries Management Council
At request of APICDA and NSEDC
March 2009

Analysis of Alternative Incentive Plans for Reducing Salmon Bycatch in the Pollock Fishery

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Executive Summary

- Conventional bycatch management measures that prematurely close target fisheries when hard bycatch caps are met succeed in conserving bycatch species, at the expense of wasted returns from the target fishery. Measures applied at the fishery-wide level do little, if anything, to generate individual incentives to avoid bycatch.
- Both the Financial Incentive Plan (FIP) and Salmon Savings Incentive Plan (SSIP) are imaginative and thoughtful responses to the problem of generating individual incentives to avoid salmon bycatch. Both are capable of meeting the conservation objectives associated with the 47K salmon cap, at lower costs than conventional measures.
- Neither system is inherently superior to the other. Indeed it is possible, in principle, to design each to achieve identical outcomes.
- The FIP resembles "tournaments" that have been studied by economists. The main finding from economic research is that tournaments generate incentives to win "prizes" in proportion to the relative size of the prizes. Bycatch reduction incentives can thus be manipulated by adjusting the "ante" structure of the FIP to achieve any desirable degree of incentive provision.
- The SSIP is an individual bycatch quota program and we have experience with individual quota systems. The incentives to avoid bycatch provided by the SSIP depend importantly on the prices that emerge from the transfer market. Various design options can be selected to enhance SSIP incentives or dampen them, depending upon the manner in which design options influence the workings of the bycatch quota market.
- Because the FIP rewards participants in terms of their relative performance, it provides continual incentives to develop and adopt new methods and practices that avoid bycatch. FIP avoidance incentives do not necessarily vary with salmon abundance. The SSIP generates incentives proportional to bycatch transfer prices. Generally we would expect transfer prices to be high in high salmon abundance years and lower in low abundance years, and hence incentives would vary accordingly.
- Design features of each program can be chosen to strengthen or soften the bycatch reduction incentives, both on average and across periods of different salmon abundance.

- Each system pins down a particular important attribute with relative certainty and leaves another attribute uncertain. The FIP ensures that incentives to avoid bycatch are constantly in play, but the overall level of bycatch reduction will not be revealed until the plan is operative. The SSIP pins down the level of bycatch with relative certainty, but the bycatch avoidance incentives will not be certain until the plan is operative.
- The foundation of both policies is the devolution of bycatch allocations to individuals, groups, and sectors. This policy decision itself provides significant impetus to reduce bycatch by allocating to small groups rather than leaving it in a common pool. We would expect groups that no longer have to scamble for bycatch quota in a common pool to craft mechanisms that guarantee bycatch conservation objectives in ways that reduce costs and satisfy other internal objectives. This includes finding ways to eliminate undesirable features such as gaming that threaten meeting conservation objectives at low costs.
- The overall bycatch target is a critical policy choice. The degree to which these programs will reduce bycatch and do so without generating large costs depends upon important unknowns at this point. A significant unknown is the extent to which bycatch can actually be reduced by behavioral and technological means. If instead bycatch is rare and random, incentive systems will only punish fishermen for events beyond their control and do nothing to reduce bycatch.

Analysis of Alternative Incentive Plans
for Reducing Salmon Bycatch
in the Pollock Fishery[1]

Introduction

Fisheries bycatch problems share many features that are virtually identical with pollution problems. The inadvertent harvesting of salmon in pursuit of profits from pollock fishing is fundamentally no different from producing pollution as a byproduct of the pursuit of profits from electricity generation. There are thus insights that can be gleaned by examining what has been learned from addressing pollution problems over the past three decades. The main lessons from policy attempts to resolve pollution problems are three. The first is that it is generally not practical or desirable to reduce pollution to zero. Reducing pollution generates benefits but at a cost, namely reduced profits from power generation. Since we value both a clean environment and efficient power generation, the issue is how to find a balance between the benefits of reducing pollution and pollution reduction costs. Second, voluntary controls, industry-level standards, technology mandates and other arms length and top down methods have not worked well. They are gradually being abandoned for methods that create explicit incentives at the level of individual decision making to reduce pollution. In particular, increasing the cost of emitting pollution by making marginal units of emissions costly is necessary to change incentives at the plant level in order to induce decisions that reduce emissions. Third, there are many ways to "price" pollution, including individual quotas, taxes, or emissions reduction subsidies. Each of these puts continued pressure on participants to innovate and reduce pollution efficiently. Alternative policies may differ on their fiscal effects, but these can be influenced at the stage of initial design.

The relevance of these findings for the pollock/salmon bycatch problem is straightforward. First, while it is desirable to reduce bycatch, there is an overarching policy choice that needs to be made about *how much* reduction should be achieved. While stakeholders from the salmon industry quite sensibly argue for stringent reductions, for Alaska as a whole, and for communities that depend upon both salmon

[1] This report was commissioned by APICDA and NSEDC. The main charge was to objectively assess the two existing FIP and SSIP bycatch reduction schemes in terms of their relative bycatch reduction effectiveness and costs. This has not been straightforward because each plan has been a moving target; both have morphed considerably from their forms in initial documents and both are undergoing fine-tuning as I finish this document. In addition, each plan is complicated, unlike anything in place elsewhere, and the time frame for this analysis has been exceptionally short. My strategy for preparing this document has been to view these two schemes as generic schemes, focusing on features that are likely to remain in place once the actual plans are chosen. I am new to the debate, not part of lead-up discussions, nor party to these plans as they have evolved, and I have no stake in the outcome. What I can offer is thus a fresh look and an arms-length assessment. This report should be viewed as talking points to be elaborated as each plan converges on its final design.

and pollock, the question is how to balance costs against benefits in a broader sense. Second, policies such as area closures and shortened seasons due to bycatch caps will not resolve the problem. Policies imposed at the level of the fishery as a whole do not by themselves transmit proper incentives to individual decision makers to avoid bycatch. There are essentially two routes that can be taken to devolve incentives to the level of individual decision makers. One is to directly implement policies such as quotas, or taxes or reduction subsidies at the level of the individual vessel. The other route is to implement sector level quotas to groups that are small enough to devise and self-manage their own bycatch reduction scheme. Evidence shows that groups with small numbers can successfully develop their own internal policies that incorporate individual vessel incentives that meet sector level allocations.[2]

Special features of the pollock/salmon problem

While fisheries bycatch problems are similar to pollution problems in the broad sense, fishing as an activity is not exactly like producing power or other industrial products that generate pollution. Moreover, each fishery has unique attributes regarding biology, fishing technology, markets, and regulatory history. These unique attributes mean that effective incentive-based fisheries policies may require tailoring to fishery-specific features. There are several features of the pollock/salmon fishery worth highlighting that are candidates for special attention. They are:

- The feasibility of bycatch reduction

Pollution reduction in industrial settings is generally achieved with process changes that reduce emissions per unit of output and/or with technological devices such as scrubbers. For the pollock fishery, an open question is: what are the ultimate limits of bycatch reduction possible by technological devices (such as excluders) and by process changes (changes in timing and spatial placement of gear)? Fisheries scientists tend to view the bycatch problem as exclusively a *technological* problem, but fisheries economists believe that the bycatch problem is to a large degree a *behavioral* problem caused by common property incentives. In particular, high bycatch rates may be a result of conventional bycatch regulation methods like industry-wide bycatch caps. These may induce a "race for bycatch" that is similar to the race to fish under industry-wide TACs.[3] If this view is correct, then creating incentives to avoid bycatch is necessary to induce individuals to make changes in the location and timing of fishing to avoid bycatch, just as has been done in targeted fisheries that have been rationalized. In the final analysis, the issue of how much reduction is feasible is more an issue of how much Alaska wants to pay for bycatch reduction. It is likely that it will be feasible to decrease bycatch by both

[2] The economics literature suggests that groups that are small enough for successful cooperation need to be on the order of a few decision makers (Bresnahan and Reiss, 1991). In fisheries, there are many examples of successful cooperation in groups with 10-20 decision makers, including important examples in Alaska. But Alaskan experiences such as the Chignkik case also show that effective cooperation can emerge even with relatively large groups.

[3] See Abbott and Wilen (2009).

technological and behavioral means, and it is also a certainty that more stringent reductions will be increasingly expensive.[4]

- salmon abundance and salmon vulnerability

When salmon abundance is low, there is the simultaneous coincidence of low encounter rates with high vulnerability for salmon populations. Low encounter rates make it easier to avoid salmon, but those that are caught may have a higher impact on population viability. An important question is whether intrinsically lower encounter rates are sufficient to protect salmon in high vulnerability years. If not, the problem could be addressed, in theory, by tightening bycatch caps when salmon abundance is low. But in practice, because salmon abundance is not easily predicted, it is difficult to determine a cap in advance of the season so that a bycatch quota program can be adapted to current conditions. In addition, determination of the appropriate cap is complicated when several year classes occupy the same space at the same time. These circumstances have induced the Council to direct stakeholders to develop plans that induce bycatch avoidance even when encounter rates are low. This feature is similar to pollution regulations that aim to avoid any health effects under any circumstances, rather than, for example policies that attempt to maintain conditions that are acceptable on average. Policies that demand regulation at all time in anticipation of "worst case" scenarios impose special design considerations, in addition to being more costly. It is important to acknowledge that this is partially a problem induced by lack of predictability, and that the potential costs could be reduced if prediction methods that were satisfactory could be developed.

- Incentives and compensation schemes

For individual incentives to be directed to behavioral decisions that matter, the system adopted must reach the principal decision maker. With polluting firms, making owners liable for pollution charges is sufficient to induce decisions that are responsive to policies. Owners that are liable for penalties ensure that appropriate investments are made and that managers adopt process procedures that reduce pollution. In fisheries, the principal decision maker responsible for avoiding bycatch is the skipper, who is generally compensated with a share. This suggests that bycatch reduction incentive systems will likely alter the share system in some way yet to be determined.

- Stability of existing cooperative arrangements

The Alaskan pollock fishery has taken significant and admirable steps to rationalize and become more profitable while remaining sustainable. The development and fine-tuning of harvester cooperatives has successfully resolved various issues associated with target fishing, often through hard fought negotiation and side agreements. Addressing the bycatch problem will potentially put pressure on those prior agreements.

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[4] There may be lessons to learn from pollution reduction experience. An economic/engineering rule of thumb when discussing pollution reduction costs is the "rule of 80". In particular, if it costs X dollars to reduce pollution 80%, it will cost 10X dollars to reduce it the next 80%---to 96% clean, and 100X to reduce it the next 80%, to 99.2% clean.

A question worth raising is whether existing cooperative arrangements will provide a platform for quickly resolving bycatch problems with minimal turmoil, or whether the bycatch problem will destabilize existing agreements. This is likely to be determined by the feasibility and costs of meeting the targets imposed and by the ultimate fiscal effects of the designs of options chosen. Of importance also is whether bycatch policies might undermine coalitions and cooperation that have evolved in the target fishery. Vessels that fish together and share information about pollock availability may find their willingness to cooperate altered if they are at the same time competing over bycatch. It is not clear which scheme fares better along these dimensions, but it would be expected that once sector and group level allocations are distributed, there would be internal incentives to resolve features that threatened to destabilize existing arrangements.

Incentive effects versus fiscal effects of policies

The key to altering behavior is to impact decisions at the *margins* of choice. For example, if we want to induce consumers to buy more fuel efficient cars, one way is to increase the price of fuel by taxing it. This "makes it hurt" to buy each additional (marginal) gallon of gas, and that in turn causes people to give more attention to fuel efficiency attributes of car purchases. Of course, making it hurt is painful precisely because it is supposed to be if we wish to change behavior---indeed that is the point of such a policy. But while policies must be costly at the margin to affect behavior, they need not impose burdensome fiscal (out of pocket) costs. For example, it is entirely feasible to raise the tax on gasoline to induce buyers to purchase fuel efficient cars, and at the same time rebate to each person a lump sum that mitigates some of the fiscal effects. The analogous argument for bycatch is straightforward; to reduce bycatch, each marginal salmon landed must be made costly to the decision maker (skipper) to induce behavioral changes. But fiscal effects can be mitigated via adjustments in compensation that are lump sum. At the same time, care must be taken to avoid canceling incentive effects by making the lump sum dependent on the incentive penalty. For example, a policy that charges decision makers with a fee per salmon and then rebates the precise amount paid has different behavioral implications than a charge for undesirable outcomes and an independently and predetermined lump sum.

The Fishery Incentive Plan (FIP)

The Fishery Incentive Plan (FIP) is an ingenious and novel idea for resolving the bycatch problem. There is nothing remotely like it anywhere in other fisheries, and to my knowledge the discussion in background documents is the first to discuss the potential implications in a real world fisheries setting. This is not to say that the FIP isn't similar to other mechanisms that have been studied, or mechanisms in place in other settings. The FIP most closely resembles what economists have called "tournaments". Everyone is familiar with tournaments in sporting evens, such as golf and bowling tournaments, and NASCAR races. In general, tournaments are schemes that pay "prizes" to "winners" of contests that involve individual effort (and luck) and that result in measurable outcomes. Most sports tournaments are "rank order" tournaments that yield different prizes according to one's rank. Another type of tournament is a "relative performance" tournament that pays according to performance difference relative to one's competitors.[5]

Economists have studied tournaments in order to understand the incentive effects they have for compensating employees in firms. Tournaments turn out to have desirable incentive effects when it is difficult to monitor individual effort and/or an individual's contribution to output. In this situation, it has been shown that tournaments motivate individuals to put more effort into work activities than would be the case if they were paid by a wage per hour.[6] Much of the discussion of tournaments in the economic literature is about rank order tournaments where a prize is allocated to one or more people according to their relative rankings on some scale. For example, the high pay of CEOs is often cited as the outcome of a rank order tournament compensation scheme.[7] Under this view, high compensation is paid to CEOs not because it is a measure of the services that they contribute to the company, but because the promise of the high-pay CEO "prize" induces all the vice-CEOs to work harder and contribute at high levels to the firm. While this explanation to explain CEO pay might invite skepticism, research has shown that that tournament schemes in sporting events do indeed make contestants perform to higher levels.[8]

In fact, tournaments are more than conceptual notions debated in the ivory tower or schemes mostly applicable in sporting events. In broiler chicken production, for example, processors (or "integrators") use tournaments to compensate independent growers. Integrators supply chicks and feed to grower contractors who grow the chicks out to slaughter weight.[9] At the end of the grow-out period, contractors are ranked by their finished output weight/feed input ratios. Payment per pound is then made in some way related to relative performance among growers. For example, one common scheme compensates growers for the broilers produced at a base rate plus or minus X cents per pound times the difference between the individual's output/input ratio and the average for all contractors. A variant of the scheme divides contractors into four groups according to their rank order. Those in the quartile just above middle are paid a base price plus a

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[5] For example, rank order golf tournaments pay by compensating something like 500K for first place, 250K for second, 100K for third and so on, so that pay depends on rank. The alternative would be a relative performance tournament that offered prizes something like: the winner gets X thousand dollars times the difference in strokes between first and second place finisher; the second place finisher gets Y thousand dollars times the stroke differences between second and third place finishers, etc.

[6] Wage rate compensation pays people by the hour rather than by genuine productive effort. If people are simply paid by the hour, they have incentives to shirk and avoid productive effort. In contrast, piece rate compensation pays people by their contribution to output and they thus have incentives to maximize output. The share system in fisheries is a type of piece rate system that pays skippers and crew in a way that motivates productive effort. Tournaments are especially useful when it is difficult to measure absolute output, but possible to measure relative output, such as the "best" or "worst" performer.

[7] Lazear and Rosen (1981), Gibbons and Murphy (1990), Jensen and Murphy (1990).

[8] For example, Ehrenberg and Bognanno (1990a, 1990b) studied golf players to determine whether higher prize differentials between first and second place finishers motivated better performance. It did. Another study by Dole (2007) looked at similar effects in stock car races, finding that higher prize differentials did indeed motivate faster speeds (and higher risks).

[9] See Knoeber (1989) and Knoeber and Thurman (1994). Processors supply chicks and feed inputs in order to take advantage of economics of scale in buying, and to standardize the inputs that generate outputs. A chicken processor that left input choices to producers would find some chicks raised on corn and others on scraps or byproducts, compromising the standardization of the final product.

bonus per pound. Those in the top quartile are paid the base plus a bigger bonus per pound. Those in the quartile below the average are paid the base minus a penalty, and so on. Both of these kinds of tournaments are called "relative performance tournaments" because payment is made according to the difference between individual performance and some base performance.

Whether a tournament is a rank order or relative performance tournament, the attraction is that it motivates participants to shoot for the prizes. The main question addressed by investigation of these tournaments is: does a tournament induce more or less effort than some other scheme, say a piece rate system that pays a fixed amount per unit of output? The main finding from the literature on these kinds of systems is that (under certain assumptions) a properly structured tournament will induce the same effort as would be induced by a fixed payment per unit output.[10] This finding is important for this bycatch discussion, because it means that *the incentive effects of a properly designed tournament can mimic incentive effects of a scheme like a bycatch tax or a tradable bycatch quota scheme*. This in turn means that the two options under consideration can, in principle, provide identical bycatch avoidance incentives if properly designed.

With this background, we can now turn to the specific details of the FIP plan as outlined in Kochin et. al. (2009). Since this novel approach to the bycatch problem has not been analyzed before, my strategy for thinking this through utilizes the findings of the economics literature on related schemes, modified by consideration of features specific to the design of this FIP plan, and features of the pollock fishery.[11] To begin with, the FIP can be rightly considered a tournament because participants receive prizes. In particular, the FIP divides up participants into a "loser" group (the Dirty Harrys) and a "winner" group (the others). The economics literature on tournaments tells us that, *if everyone is similar in his avoidance abilities, the effort put into avoiding salmon will be proportional to the difference in the prize values*. Suppose we have N vessels that ante a total of A=aN dollars. Suppose further that we assign the M highest bycatch rate vessels to the Dirty Harry category and split the ante into *equal* prizes for each of the other N-M vessels. Then the payoff for being in the loser group is zero, and the payoff for being in the winner group is A/(N-M). The most important conclusion from the economics literature is that the effort that each (assumed identical) participant puts into avoiding bycatch will be proportional to the prize difference, in this case the winner's prize A/(N-M). Note several things. First, the higher the initial ante, the stronger the incentives will be to avoid bycatch. Second, the more participants are put into the Dirty Harry group, the larger the prize for being a winner, and the larger the incentive to avoid salmon. There are also some caveats to these conclusions from the literature on simple tournaments. First, if vessels are not alike, but differ intrinsically in their abilities to avoid salmon, then both perennially high bycatch vessels and low bycatch vessels may cut back on avoidance behavior relative to those close to the cutoff between the two prize groups. That may occur because intrinsically high bycatch vessels cannot take actions to move out of their low rank status and so it is not worth exerting effort. Similarly, low bycatch

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[10] Lazear and Rosen (1981).

[11] My analysis often assumes that the plans incorporate certain specific design attributes. Since the designs are still in progress as I compete this report, features that I have considered relevant may not be in play in the final designs, and I may not have addressed others that are.

vessels will still be likely to be in the winners group even with lower effort, and so they may withhold avoidance effort.[12]

Now, there is more to the analysis because the actual proposed FIP is more complicated than the above simple fixed prize game. Under the FIP, each member of the winners' group does not get a simple fixed payment, but rather a payment that depends upon his relative share of salmon avoided. So the FIP is basically a hybrid rank order/relative performance tournament in that the prizes received by "winners'" depend upon their relative performance level vis a vis all other participants. This feature of the FIP gives an even stronger incentive to avoid bycatch than the simple fixed prize game discussed above. The complete set of incentives from this hybrid game consist of the basic incentive that drives individuals to end up in the winners' group of the fixed prize game, augmented by additional marginal incentives associated with the change in the payoff associated with incremental salmon avoided.

The marginal avoidance incentives provided by the FIP can be influenced by altering various features of the design. The financial incentive provided to avoid salmon is, on a per salmon avoided basis, basically the ante divided by the total amount of salmon saved. Once the design is fixed, the incentive to avoid marginal salmon is the same for all vessels, although the actual payoff will differ because of different amount of salmon and pollock caught.[13] The *ante is a critical design choice* that can be increased or decreased depending upon how desirable it is to amplify or dampen incentives. The ante could also incorporate features that depend on vessels' performance with respect to an absolute standard, as well as their relative performance vis a vis each other. The ante may also be adjusted from season to season depending upon the expected pollock availability since the ante is computed as a contribution per unit pollock quota. In other words, low pollock quota years may require a higher contribution per unit pollock to maintain a large enough ante to influence salmon avoidance. The ante can also be adjusted and varied within the season as evidence points to either high or low salmon abundance years.

The total amount of salmon saved is a constructed or hypothetical quantity. In the FIP plan, it is the amount that would have been caught if everyone fished at the bycatch rate of the Dirty Harry group, minus the amount of salmon actually caught. If there is one Dirty Harry, the total (hypothetical) salmon saved will be its largest value and this largest value will be the divisor that determines how much ante is disbursed for each (hypothetical) salmon saved. What happens as the Dirty Harry group is made larger? My analysis suggests that the marginal incentive gets larger the more vessels are folded into the Dirty Harry category. So, again as in the fixed prize case, having more vessels assigned to the Dirty Harry group both splits the fixed pot among fewer winners, and also

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[12] These drawbacks can be fixed in the design of the game by "handicapping", which involves designing an unequal prize structure. Handicapping comes at the expense of complicating a scheme that is attractive precisely because it is relatively simple. A question that needs to be answered before great lengths are taken to complicate by handicapping is whether there is reason to believe that particular vessels are indeed intrinsically different in their bycatch reduction ability, or whether actual observed differences reflect behavioral choices made by skippers.

[13] It will be the same for vessels with similar bycatch rates. As discussed below, vessels with larger shares of bycatch may view incentives differently that those with relatively smaller shares.

increases the marginal incentive per salmon saved because the projected total salmon saved is smaller.

The Market Share Issue

Documents on the FIP discuss the potential need to adjust or handicap the FIP system when vessels have a significant share. This issue is somewhat confusing, and my interpretation is a bit different from that of Kochin and Barzel (2009). Here is the way I view this issue. As discussed above, the marginal avoidance incentive is essentially the ante divided by the projected salmon saved. Salmon saved is the difference between what the fleet would catch if they all had bycatch rates equivalent to the dirtiest vessel(s) in the Dirty Harry group and the actual fleet wide bycatch rate. If each vessel sees itself as a small part of the total bycatch, it will view this marginal avoidance value as a constant value—a ratio of the ante to projected salmon savings. But suppose that one vessel (or a company) is a big player with a large share of total salmon bycatch. A large player may realize that by increasing its salmon bycatch it will also have an affect on the denominator determining the marginal incentive effect. In particular, increases in bycatch by a large entity result in a financial penalty of the marginal value of salmon not saved. But a large entity will also have a non-marginal effect on the fleet-wide total salmon saved. In particular, by increasing bycatch, the large share vessel will reduce total salmon saved, thus reducing the marginal financial penalty. The overall effect is to reduce the actual financial penalty suffered by the large-share vessel for bycatch. This will reduce the incentive for large-share vessels to reduce bycatch, other things equal.[14]

The Salmon Savings Incentive Plan

The Salmon Savings Incentive Plan (SSIP) is an individual quota alternative to the tournament structure of the FIP. Many of the core ideas for this plan are outlined in the so-called Legacy Plan in Sugihara (2009). But the current SSIP contains numerous modifications of the original Legacy Plan, streamlining it by dropping some features, and adding modifications desirable by stakeholders as a general principle, and other modifications associated with specific features of the pollock fishery (Anonymous, 2009).

The SSIP is essentially an individual bycatch quota scheme. I am purposefully refraining from calling this an individual *tradable* bycatch quota scheme because the degree to which actual trades occur is a design issue currently under development. At this point in the evolution of fisheries policy, there is significant understanding of how quota systems work, and how various design options can be used to tailor a system to the features stakeholders and regulators desire. Tradable quotas for targeted fisheries have been shown to have dramatic effects on incentives of decision makers, as intended (Casey

[14] My modeling of this issue suggests that marginal incentive felt by a vessel is the base level marginal incentive determined by the ante, multiplied by one minus the vessel's share of bycatch quota. If vessels see themselves as small, their perceived shares are close to zero and they experience a marginal incentive equal to the ante divided by projected salmon saved. But if vessels perceive themselves as being able to influence overall salmon bycatch, their marginal avoidance incentive is reduced. This can be fixed by altering the share of the ante returned to large share vessels.

et. al. 1995). In the directed component of fisheries, quotas remove race to fish incentives and replace them with race to generate value incentives (Wilen, 2006). These fundamental incentive changes have been shown to increase profits in all fisheries in which they have been implemented, both through added market value and reduced costs and waste from the race to fish.

As Alaskans are well aware, individual tradable quota schemes have not been without controversy. Contentious battles are always waged over initial allocations, and additional issues always arise over structural changes that are induced as fisheries transform from race to fish incentives. The SSIP is, like the FIP, a novel and exceptionally imaginative solution to the bycatch problem. By relying on individual quotas, it forces vessels to stay within limits defined by bycatch caps. And by making quota trading possible, the system may take advantage of the flexibility that market-based schemes provide by allowing transfers from those with surplus quota to those with shortages. In addition, numerous specialized features have been built into the system to account for particular features of the pollock fishery and the mandates of the Council to provide continued incentives to avoid salmon when abundance is low.

As with the FIP and literature on and experience with tournaments, the SSIP is similar to other real world programs and analogous systems from which we can glean evidence. British Columbia and New Zealand have both converted mixed species trawl groundfish fisheries regulated by closures and trip limits into individual tradable quota systems. These effectively replace systems of complex and increasingly burdensome top down regulations with decentralized systems in which all important species harvested are accounted for with quota. Hence what was once bycatch in targeted fisheries is now simply a part of a portfolio of quotas that fishermen must hold in order to harvest mixed species trawls. The experience in BC has been positive. As seasons progress, growing scarcity of both targeted and incidentally caught fish induces behavioral changes away from species with impending quota limits, ensuring that bycatch TACs are met. Quota prices for fish that serve as bycatch can rise to reflect their implicit value associated with being able to avoid closing the target fishery. New Zealand similarly has an even longer experience with tradable quotas used in mixed species fisheries.

The SSIP contains elements that serve to constrain each vessel and the fleet landings to levels that fall within the overall 47K salmon bycatch cap on average. Each vessel may save quota in low encounter years in order to use in high encounter years. In addition, the SSIP allows trade among vessels in order to cover shortfalls and dissipate surplus holdings. Transfers and trading generate incentives to avoid salmon bycatch in a manner that depends upon the workings of the quota market. In particular, as with the FIP system, catching salmon as bycatch can be made to "hurt" in order to cause behavioral changes that avoid bycatch. The pain in a tradable quota system is generated by the price for bycatch that emerges in a quota market. When a vessel must pay to buy quota from someone who has it in order to cover an accidental overage of bycatch, the pain of the price paid is most tangible. But the attractive feature of a market is that even someone who does not actually need to purchase quota feels its shadow continuously, if it is always possible to sell quota to others rather than use it. Every unit of quota that a person holds and uses himself thus generates an implicit cost, namely what he could have gotten by selling it to someone else, and this implicit cost (or opportunity cost) also generates avoidance behavior.

The SSIP will guarantee convergence to the 47K salmon cap on average. But the key question bearing on whether the SSIP will generate continual incentives to innovate and avoid bycatch is: what prices will emerge? How high will they be, and what patterns will emerge over and between various seasons? The higher the tradable salmon quota prices, the more incentives there are to avoid salmon. Unfortunately, forecasting bycatch quota prices before such a system is put into place is virtually impossible. We can make educated guesses, however, about how various factors might play a role and think through some of the features of program design. The first important determinant of quota prices is the degree to which the bycatch TAC is binding. For example, consider a situation where a bycatch TAC is set above or close to the highest levels of bycatch that have prevailed under business-as-usual conditions. Suppose, in addition, that each vessel gets an allocation that is close to its historically high bycatch levels. Then the price of bycatch quota would be zero because everyone's supply of bycatch quota would be sufficient to cover his demand.[15] Now consider the situation where the overall TAC is less than business-as-usual initial conditions so that the total allocation is binding. Then each vessel will have allocations below status quo needs, and each will need to adjust bycatch rates by saving quota, trading quota, changing behavior, or some combination. In the final analysis, quota prices in a well-functioning market should rise to reflect the marginal costs of salmon avoidance necessary to meet the overall binding quota. In a well-designed tradable quota system, each vessel will hold quota after trades equal to its needs, and each vessel will face the same marginal cost of avoiding the last salmon. That marginal cost will be its actual avoidance costs, equal to the quota price, which is the alternative way to cover a marginal salmon.

As this discussion suggests, the combination of avoidance costs and the degree to which the bycatch TAC binds determines market quota prices when quota is freely traded. If it is relatively costless to avoid salmon, market quota prices will be low. But costs are related to how stringent the constraint is, because fishermen will use methods to avoid bycatch that array from lowest cost to highest cost. For example, suppose that excluder devices can reduce bycatch by 10% at a cost of (for example) $100 per salmon avoided per year. Then a TAC reduction of 10% from the business as usual non-binding bycatch TAC will result in everyone installing excluders and bycatch quota trading at $100 per salmon. But a more stringent quota reduction would cause fishermen to seek out the next most costly alternative way to reduce salmon. Suppose that fishermen can steam to distant grounds to reduce bycatch by 15% total, at a cost per salmon reduced of $1000. Then the 10% TAC cut will generate a $100 quota price but a 15% TAC cut will generate a $1000 price. The more stringent the quota, the higher bycatch trading prices will be if markets are functioning well.

An important feature of a bycatch quota market is that high prices in the short run generate stronger incentives to innovate in the long run. In the above example with quota prices at $1000 per salmon for the 15% TAC cut, there will be strong incentives for someone to design means to avoid paying such high prices. Suppose that someone develops a new excluder that can achieve 15% rather than 10% reductions from the original base. Then that person will be able to sell excess quota at $1000 per salmon for

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[15] The current SSIP allocates initial bycatch quota in proportion to historical pollock quota so that bycatch allocations will be unequal. Still, if the initial overall TAC is not binding, each vessel will find itself with enough bycatch to satisfy needs and price will be zero.

every additional salmon avoided by the new device. Ultimately, as everyone adopts the new technology, quota prices will fall again to new levels reflecting marginal costs of adopting the new technology.

What happens as salmon abundance rises and falls? In the SSIP system as currently designed, the effective long run bycatch will converge to the stringent 47,000 fish equivalent target on average. In high salmon abundance years, the encounter rates will be high and the TAC will be more binding. In a system that allocates all bycatch quota on a strictly year to year basis, prices would vary from year to year, directly reflecting relative abundance. But a unique feature of the SSIP is its "banking" provisions that smooth some of the potential swings in quota prices. Banking allows vessels to carry forward unused quota from low bycatch abundance and low encounter years into high abundance and high encounter years. Banking means that relative quota scarcity resulting from abundance changing from low to high will be attenuated somewhat, compared with what might emerge without banking. High abundance years deplete bycatch savings and hence when a low abundance year follows a high abundance year, fishermen are likely to want to replenish their saving. This puts upward pressure on prices in low abundance years that would, without the banking provision, be relatively lower.

The most recent incarnation of the SSIP (Anonymous 2009) embodies several design features that influence the degree to which trades are made and the prices that develop for bycatch quota. Over the long run, banking moderates the swings in quota prices from year to year relative to more restrictive carryover designs, meaning that high abundance years will experience lower quota prices and low abundance years will experience higher prices other things equal. But an important feature that influences how much moderation occurs is the carryover discount rate that discounts the amount of salmon that are placed in the salmon savings account. The discount rate is significant, over 43%. Discounting the savings banked generates incentives to carry fewer salmon forward than would be done without discounting. This means that in low abundance years when salmon savings are most likely to be generated, there will be relatively more salmon bycatch savings offered up for lease rather than banking in that year, moderating the prices that will emerge in low abundance years. Another design feature embodied in the current plan is that salmon savings are accumulated in a "rolling 3 year sum." My understanding of this feature is that savings accumulated more than 3 years prior are simply erased from the account. This has the effect of reducing the incentive to save, compared with a plan that does not wipe out more distant salmon saved.

The SSIP incorporates transfer rules and buy side and sell side rules that also have potential to affect the levels of the quota market prices that develop and that generate incentives to avoid bycatch. The current plan calls for liberal allowance of trading within cooperatives, between cooperatives, and between sectors, and between entities in non-SSIP schemes. Flexibility to trade is an efficiency-enhancing feature and will serve to enhance the degree to which vigorous and well-functioning quota markets develop. Sell side rules in the current SSIP are such that "bycatch allotments above the Base Allotment are the result of previous savings by that particular vessel and are only available for direct use by that vessel." The prohibition on trading accumulated savings discourages bycatch savings in low abundance years, which by itself reduces low abundance year prices. On the other hand, the feature that allows bycatch savings to be credited over all savings under the Base Allotment, even when transferring part of those savings, enhances the incentives to save in low abundance years. Similarly, buy side rules allow the flexibility of buying to cover potential overages but bycatch transferred in must be subtracted from next year's base allotment. This inhibits buying bycatch to transfer in, which reduces market transactions.

This discussion of various features of the current SSIP reveals a reasonably complex program that satisfies a broad spectrum of goals and that balances and makes tradeoffs between various objectives. The overall design of the SSIP ensures that the conservation objectives of a binding 47K cap will be met. The remaining issues addressed by various choices influence the costs that meeting the cap imposes on the industry, and the degree to which incentives can be generated to impose persistent pressure to continue to find ways to reduce bycatch. There are multiple levers that can be adjusted to influence objectives other than the pure conservation objective, and multiple ways to fine-tune the system if it is adopted.

Comparing the Two Plans

What are the mechanisms by which incentives are created in each program? What are the magnitudes of the incentives created by each program?

The two programs differ in the mechanisms by which marginal bycatch avoidance incentives are created. The FIP sets "*prices*" (the prize structure) and then bycatch quantities emerge as a result of individual behavioral choices aimed at winning the contest. The SSIP sets bycatch *quantities*, and then prices emerge in the byproduct quota market as individuals scramble to stay within the quantities of quota available. The SSIP program thus pins down bycatch quantities with relative certainty—but the bycatch trading prices and incentives those impose on the fleet are uncertain and difficult to predict. In contrast, the FIP pins down prices with certainty (and hence the magnitude of the incentives that will be created)---but bycatch quantities are hard to predict.

The magnitudes of incentives created by each program ultimately depend upon design features of each program. In principle, it is possible to choose design features and design parameters that can make the incentives in each program virtually *identical*. In practice, however, each plan will have to be launched with considerable uncertainty about the outcomes that will emerge from the specific design features chosen. Bycatch outcomes from the SSIP plan will be relatively certain, but it will not be known until the program has been in operation for some time what magnitude incentives will be generated for further bycatch reduction; these will depend upon the ultimate functioning of the bycatch quota market. The incentives generated by the FIP plan will be quite certain and dependent upon the design of the prize structure, but the manner in which these incentives translate into specific bycatch outcomes will not be predictable without some experience with the program.

Given the uncertainty that exists about the exact outcomes from these two programs, it is likely that there will be adjustments needed, regardless of which program is adopted. The FIP allows adjustments in the incentives (prizes) in a very direct way by altering the ante structure. Altering the ante changes incentives immediately and directly, but the effect of these incentive changes on bycatch outcomes will be indirect and will be revealed as the season unfolds. Fine tuning the SSIP will impact incentives only indirectly and in a manner that will also be revealed as the season unfolds. A critical component of the SSIP is a well-functioning bycatch market. Bycatch must actually be traded in order to generate incentives and the market must have enough participants for the prices to converge to actual marginal bycatch reduction costs. If participants don't trade, the market will be too "thin" and hence there will be insufficient intrinsic incentives to innovate created. This suggets that fine tuning may have to focus on features that open up and make the bycatch market more viable.

Over what levels of Chinook bycatch are the magnitude of program incentives greater than the incentives created by a hard cap of 47,591?

To begin with, a binding hard cap that is applied to the entire fishery or a sector without allocation to individual vessels will, with proper enforcement mechanisms, ensure that the bycatch cap is met. But hard caps will create virtually no individual *incentives* to avoid bycatch. While each vessel will experience, after the fact, the cost and pain of premature pollock closures, no individual vessel will have sufficient incentives, before the fact, to avoid bycatch and the subsequent premature closures. *Individual-level bycatch avoidance incentives are only generated when either: 1) hard caps are converted into individual quotas and made tradable; or 2) when hard caps are allocated to small groups who then implement mechanisms that provide vessel-level incentives within the group.* So—an easy answer to this question is that both the FIP and SSIP will create incentives that simply will not exist under an unallocated hard cap—and these incentives should be operative over all Chinook bycatch levels.

On the more specific question of how incentives are generated under high and low salmon abundance conditions, each system acts somewhat differently. The FIP system (as initially designed) is a relative performance based system for which incentives per se depend upon relative rather than absolute levels of bycatch and encounter rates. As a result, the FIP prize structure generates a marginal value of bycatch avoidance that is constant (once the ante structure is determined) over all different abundance conditions. Thus there is always a consistent inducement to avoid bycatch under both high and low abundance conditions with FIP. The amount of actual bycatch that emerges as a result depends upon the interaction between prize structure, abundance and the costs of avoidance. In general, other things equal, increasing the ante will increase the incentive to avoid bycatch. The SSIP provides variable marginal incentives that are likely to vary depending upon abundance. When abundance is high, encounters are high and with a fixed and binding TAC, quota demand will be high relative to quota availability. With low abundance, encounter rates are lower and hence the need for quota is lower. Prices ought to reflect the relative differences between demand and supply and so we expect prices and incentives to be positive and stronger during high abundance years. Prices ought to be lower during low abundance years and hence incentives during that period would be attenuated relative to high abundance years. But the carryover feature links years by allowing individuals to bank quota during low abundance years to use in high abundance years. This has the effect of smoothing out some of what otherwise would be quota price variability from year to year. If one can borrow during high need years, low abundance year prices will be propped up while high abundance year peaks will be moderated. High discounting disrupts this smoothing, amplifying the price swings so that high abundance years will have higher peak prices and low abundance years lower prices compared with less restrictive borrowing and banking rules.

What can we say about which program provides more incentives during low abundance periods? This is difficult to answer without knowing the specific features of system design for each case. The FIP system can maintain incentives under high and low abundance years and these incentives can be amplified by raising the ante and increasing the Dirty Harry group size. The SSIP incentives cannot be tweaked as directly, and the incentives it provides in low abundance years depend upon how fully and efficiently the market for bycatch develops and how the prices are for bycatch in low abundance years. If it is desirable to influence low abundance year incentives, it is possible to tweak the design to enhance the market and boost prices. Reducing the discounting of carryover, for example, would enhance incentives to hold quota to carry over into high abundance years---thus increasing incentives in low years.

What are the behavioral changes expected from the pollock fleet as a result of the incentives generated by each program?

The behavioral changes anticipated depend (again) upon design features. We do expect that fishermen will array options from low cost to high cost and adopt those in order from low to high cost. It seems that the main options are technological (excluders) and process changes. Of process changes, the most important are changes in location of fishing over time and space. This can be done almost at will, but at a cost that includes the movement costs and lost opportunities for pollock catch. In the final analysis, predicting actual changes is impossible to any degree of accuracy, for several reasons. First, the design features have not been chosen yet and hence it is uncertain how high the marginal avoidance incentives will be. For the FIP, these incentives depend upon the prize structure and for the SSIP, incentives depend upon bycatch market prices, which will be unknown until the program develops. Second, even if we knew exactly how each system was going to unfold, understanding behavioral changes would require some in-depth and quantitative understanding of bycatch avoidance costs. There has been virtually no scientific investigation of these issues, particularly in settings that are likely to be as complex as in the Bering Sea pollock fishery. The difficulty relates mainly to understanding how skippers choose where to fish and when, and whether that translates into any stable relationships between effort and costs that can be statistically estimated and simulated. The state of the art in the science of this kind of prediction is not sufficient to answer this question at the moment.

What is the reduction of Chinook bycatch that could be expected from each program?

Both programs will (ultimately) bring bycatch down to 47,000 on average. The SSIP program is designed to achieve that target, by decentralizing the overall TAC constraint to the vessel level via the quota trading program. The degree to which there will be continued incentives under the SSIP that drive bycatch below 47,000 depends upon how the market develops. As long as a viable and vigorous market develops, then we would expect positive bycatch prices that would provide incentives in proportion to their magnitudes. In the long run, an important question is how feasible it is to reduce bycatch by technological or behavioral means. If technologies or practices exist to avoid bycatch, they will be adopted in order of cost effectiveness, and as a result the bycatch prices could fall. One can foresee situations whereby low cost and efficient technological innovations and behavioral practices are adopted, and the price of bycatch quota ultimately falls as a result of it becoming less necessary.

The FIP program will generate consistent incentives to avoid bycatch in ways dependent upon the specific features of the design. Moreover, those incentives will persist regardless of abundance levels and the adoption of technology and fishing practices. But it is difficult to predict exactly what level bycatch will emerge. For coops or sectors that adopt the FIP, we would anticipate that the basic relative performance incentive plan will be augmented with some auxiliary mechanisms that enforce adherence to a sector-level quota. There are many options for these auxiliary mechanisms. For example, a coop might overlay the tournament structure with vessel-specific allocations that act either as hard caps, or as initial allocations for an internal quota trading scheme. This kind of backup internal quota scheme would guarantee that the group remains within the overall group-level quota while the tournament would promote continual innovations to avoid bycatch. In their present incarnations, the SSIP program is destined to converge to a quota associated with 47K fish. The level of bycatch that will emerge out of the FIP program is less certain until its design features are chosen, but it could conceivably go below the 47K equivalent cap.

Can either of these programs be "gamed" (especially by companies owning multiple vessels) such that the effectiveness of the program can be diminished?

For the SSIP, the ultimate level of bycatch will be constrained by the sector level bycatch TAC allocation, and hence conservation objectives will be met. So the relevant issue is whether gaming increases the overall sector-level costs of attaining the bycatch target relative to the least cost methods. If the quota market is working effectively and legitimate arms-length marginal quota prices are generated, then each vessel will trade and/or make changes in behavior until its marginal avoidance costs are equal to the quota price. This *is* the least cost way for the sector to attain the overall bycatch target. Any actions that disrupt the functioning of the market, or that prevent a market from developing, would increase costs of avoidance. The potentially relevant gaming that seems important in the SSIP is if companies withhold the trading of quota. There are several ways this can happen. One is if companies fail to trade in arms-length market transactions and instead barter or otherwise trade quota in ways that are not transparent. There is potential for this in companies that own several vessels and that cooperate to maximize company profits. These internal trades may still reflect implicit trading prices, and hence generate proper incentives within the firm, but they will not be transparent prices seen by the rest of the industry as a whole. While this possibility is not "gaming" per se, it would still hinder market formation and transparency. A more serious and explicit gaming possibility is if companies withhold quota that is marketable in order to attain some strategic advantage in pollock fishing or marketing. A company with a fleet of clean vessels might purposefully withhold trading excess quota to individual dirty vessels in order to truncate their season and reduce profitability. These potential problems are fixable by altering the rules of quota use and quota trading and hence are not fatal flaws of the SSIP. For example, rules that allow a wide market in which trade can occur within and between SSIP groups, and between SSIP groups and non-SSIP groups will militate against exercise of large share power by any one vessel or firm.

With respect to the FIP, it is a bit more difficult to predict gaming opportunities without understanding the specific nature of the design. As discussed above, the incentives provided by the tournament can be weakened if particular vessel/skipper/crew combinations are inherently less or more efficient in avoiding bycatch than others. A vessel that finds it impossible to change practices to avoid being in the Dirty Harry group will not have incentives to avoid bycatch because it can't win. A vessel that cannot avoid fishing relatively clean will similarly have diminished incentives to avoid bycatch. Vessels at the ends of the spectrum could potentially unravel the contest if there were no auxiliary mechanisms disentangling the individuals' actions from the group quota.[16] But this can be fixed by altering the design of the system, particularly by handicapping or altering the ante design structure.

Can the effectiveness of either program be diminished by the fact that some companies hold large market shares of pollock quota?

The SSIP allocates bycatch quota in proportion to pollock quota and hence vessels or companies with high market shares of pollock will have high shares of salmon bycatch quota. As discussed above, the possibility that vessels or firms with large shares might withhold bycatch quota in order to exert power in the pollock fishery is one possible design problem that might need addressing. There is some evidence of this in New Zealand, where market caps are loosely applied and where some firms hold significant (30-40%) of the quota market. These large companies tend to trade within the firms and withhold surplus species quota from the competitive fringe. The power that can be exerted is relative to the market as a whole however, and expanding the market scope to allow between-coop trades, and even intersectoral trades is one mechanism that dilutes any one entity's power. The issue in the SSIP may be less related to large market shares and more of simply inducing everyone (small and large firms alike) to engage in the market with transparent arms-length transactions. In the British Columbia experience, there is competition in the quota trade market, but it is not always arms-length. For example, there are a few species that act as bycatch species in mixed groundfish trawl complexes, and prices don't seem to rise above market prices when the bycatch quota constraint begins to bind. The reason appears to be because much of the trading is barter between long term colleagues, and fishermen don't want to be seen as "gouging" each other. While this is admirable for maintaining friendships, it has the side effect that real

[16] For example, suppose a coop had a group quota allocation that, once met, would close the fishery to the group's participants. As long as each individual vessel internalizes the incentive effects of winning the potential contest, each vessel will attempt to win and thus avoid salmon. But if a vessel believes that it is inherently unlikely to avoid being the Dirty Harry vessel, it might give up avoiding bycatch and induce others to follow. This is mitigated when each vessel has a pollock quota, and it could be avoided altogether by allocating bycatch quota to vessels in the first place as an augmentation of the contest, or by handicapping the contest to account for differential inherent abilities.

prices reflecting the true cost of impending scarcity of bycatch don't develop, and hence incentives may be weakened.

As discussed above, there may be an additional design issue that needs addressing with the FIP in order to ensure that small and large firms face the same bycatch reduction incentives. This has been satisfactorily addressed in some of the documents on the FIP (Kochin and Barzel 2009). My interpretation of the problem is a bit different, but the essence of the problem is that firms with large shares of pollock will also have large shares of salmon bycatch. As a result, they may not see the marginal incentive provided by the contest as constant to them. Instead large firms may see their own impact on total projected salmon saved and, incorporating that into their computation of the value of avoidance, have reduced marginal incentives. If they catch that extra fish, they lose the marginal value on salmon saved, but they also reduce the industry's total salmon saved. So the marginal value increases a bit to compensate—and the net loss that they see is smaller. This is not a fatal flaw but something that can be fixed with system design if it is deemed significant.

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