

Reducing Chinook Salmon Bycatch with Market-Based Incentives: Individual Tradable Encounter Credits

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Preface

Despite popular appeal, managing fishery bycatch with restrictive hardcaps is a strategy that can produce unexpected negative outcomes (such as the race for turtle bycatch seen in the Hawaiian swordfish fleet in 2006). This is particularly true when the prohibited species catch exhibits wide variation in numbers from year to year as with chinook salmon bycatch in the Bearing Sea pollock fishery. In this case, the fundamental weakness of a restrictive hard cap is that it protects Chinook populations exactly when they need it least (when they are most abundant) and offers no protection when chinook populations are most vulnerable (when they are least abundant, and encounters are low). Though intuitively appealing, such simple measures can actually harm Chinook salmon populations by encouraging more careless fishing exactly when encounter rates should be lowest (provoking a higher overall bycatch rate than would occur otherwise). Simple hardcaps and plans based on semi-fixed performance standards (eg. a bycatch target of 47,591 with a fixed hardcap of 68,392) punish the Pollock industry most severely when chinook need least protection and offer no penalty when salmon are rare¹. They create a mismatch between penalties and infractions.

Partly to address this problem and build a more rational solution, the Council process has arrived at the C-2 Motion PPA Incentive Requirements (see box).

Summary of the C-2 Motion PPA Incentive Requirements

- 1) Provide incentives to avoid bycatch that operate at the individual vessel level.
- 2) Reward vessels that successfully avoid Chinook and/or penalize vessels that fail to avoid Chinook.
- 3) Incentivize vessels to avoid Chinook bycatch at all levels of abundance in all years.
- 4) Incentives must influence fishing decisions at levels below the hard cap.

Box 0: C-2 Motion PPA

¹ The detrimental impacts of bycatch are largest when chinook are rare. A fixed hardcap or semi-fixed performance standard creates incentives to reduce bycatch independent of salmon abundance. Because incentives in these plans are unresponsive to underlying salmon abundance they do not protect Chinook when most needed. Indeed, incentives under these schemes can be zero (or worse) when Chinook are rare, producing bycatch rates much higher than expected. In addition, they may be extremely prejudicial to Industry who will leave a lot of Pollock on the table, without really addressing the needs of Chinook fisherman. Such plans are not reasonable management strategies.

Summary

A market based bycatch credits-trading plan, using individual (vessel-level) tradable encounter credits (ITEC), is examined that addresses the incentive requirements of the C-2 Motion PPA. This recommended approach for an Industry Market Incentive Plan is shown to provide robust vessel-level incentives to reduce Chinook salmon bycatch under all levels of Chinook and Pollock abundance² and can act cumulatively through time through consistent competition to further reduce overall fleet Chinook encounter rates. The plan is flexible, and with experimental implementation and monitoring can be tuned to meet any serious performance standards.

Sectors are given fixed annual allocations of salmon encounter (bycatch) credits (1 ITEC = 1 Chinook) in amounts as described in the C-2 motion document under the industry-wide hardcap of 68,392. These are then distributed to individual vessels via the coops according to a specifically designed uniform allocation rule (the Legacy Allocation Rule) that provides vessel-level incentives to avoid Chinook salmon encounters and explicitly addresses each of the C-2 motion requirements. Vessels can use or trade credits within and across sectors to offset salmon bycatch encounters and these transfers of ITEC are moderated by rules that further strengthen C-2 incentives and prevent potential abuses (eg. Dynamic Salmon Savings³).

In overview, the Recommended Industry Market Incentive Plan is designed to *reward* individual vessels with low (relative to other vessels) salmon bycatch levels, by: (1) providing higher credits allocations in the subsequent year (so called “bonus credits”), and (2) creating an additional source of revenue, through the selling of excess credits to vessels that need them. Conversely, it *penalizes* vessels with high encounter levels by: (1) decreasing credits allocations in the subsequent year (so called “credits penalty”), and (2) requiring vessels that have run out of credits to decide to either buy credits (cost) or lease their Pollock to cleaner vessels having extra ITEC.

The main objective of the Recommended Industry Market Incentive Plan is to create cumulative financial incentives for a fleet-wide reduction of salmon encounters that satisfies the C-2 Motion requirements of vessel-level incentives in a way that provides incentives for continual behavioral improvements to reduce Chinook bycatch in order to minimize lost revenues due to unharvested Pollock if Chinook limits are hit. That is, *it minimizes industry losses due to unharvested Pollock under a hardcap while encouraging continual competitive evolution toward diminishing overall Chinook bycatch.*

The two main components of the plan are the Legacy Allocation component (rules to reallocate ITEC among vessels: address long-term financial incentives) and the Transfer

² Note that while the PPA wording uses *abundance*, bycatch rate or *encounter rate* is the defacto proxy for Chinook abundance (bycatch rate = [# Chinook caught] / [1 metric ton of Pollock]).

³ Dynamic Salmon Savings retires a variable fraction of the excess ITEC remaining after each vessel has completed its Pollock harvest, diminishing the supply of tradable credits in low to moderate encounter times.

component (rules to regulate ITEC trading between vessels: address both long and short term financial incentives).

The Legacy Allocation component reallocates ITEC away from vessels with higher encounter rates toward cleaner fishing vessels. It creates long term “insurance-like” incentives against catastrophic revenue losses that could occur under the PPA hardcap at times of moderate to high Chinook encounter levels. A particular strength of the Legacy Allocation scheme is that the incentives to avoid bycatch are strongest in years of low salmon abundance, when Chinook populations may be most fragile. These are times when the credits also have a higher intrinsic fishery value (not market value) due to the higher value of Pollock harvested per Chinook encounter, implying a higher theoretical upper bound on ITEC market value). Legacy-based reallocation depends on the past record of performance to determine current allocations (akin to a grade point average). This cumulative record creates inter-annual accountability, and dampens the effect of occasional chance events (bad luck) that are *not* due to individual vessel behavior. It emphasizes the *behavioral* component of vessel bycatch rates and minimizes the effect of *chance* encounters. Legacy Allocation creates a cumulative incentive for individual vessels (and hence, the fleet) to adopt consistent behaviors to reduce overall bycatch and its associated costs.

The Transfer component of the Recommended Industry Market Incentive Plan provides provisions for regulating trading of ITEC between individual vessels. These are designed specifically to: 1) discourage chronic bad players who place a drag on the fleet, 2) to reinforce the C-2 motion individual incentive requirements, and 3) to specifically keep the realized bycatch far below the hardcap whenever possible (i.e. through Dynamic Salmon Savings). The Transfer component limits the number of credits that a vessel can purchase and significantly reduces the excess supply of credits especially during low abundance years (per the C-2 motion). It reinforces the long-term incentives of the allocation scheme as well as the short-term incentives created by trading ITEC by promoting higher credits prices in times of low encounter rates.

Auxilliary Features of the plan:

- 1) An industry sponsored research component to monitor and evaluate the Legacy Market Incentive Plan performance in reducing bycatch as well as funding to obtain basic information on Chinook population dynamics (eg. runs counts and stock assessments) to better understand the impacts of the Pollock Industry on Chinook populations.
- 2) The implementation of a fixed fishing closure area (currently referred to as the Chinook Conservation Area).
- 3) Implementation of a 2-strikes rule to weed out chronic offenders.
- 4) A 3% emergency fund saved as a tax by the coop or sector to safeguard against genuine bad luck encounters

Auxilliary Benefits of the plan:

- 1) Perhaps the greatest long term benefit of the ITEC trading and allocation plan is the establishment of an independent (certified) organized market place for conducting fishery business. This infrastructural cornerstone would be likely find support from outside

sources. It would represent a significant step forward toward market efficiency and transparency and would be scalable to other bycatch issues and the trading of financial instruments to control risk.

2) Finally, along with transparency this system will provide natural price signals for the value of bycatch, in terms of the risk and costs of forgone Pollock when ITEC become limiting. A major strength of this system is that the penalties and rewards are tied naturally to the actual market value of bycatch to the Pollock industry.

I. Introduction:

Regional pollution credits trading schemes have been shown to provide effective financial incentives to allow industries over time to evolve new behaviors to minimize emissions, and do so with minimal financial stress. A hallmark example is the New England sulfide emissions market, created in 1990 to regulate atmospheric SO₂ released by the smoke stack power industry (namely coal-burning power plants that contributed to acid rain). Here polluters are able to buy credits from non-polluters to offset their excess emissions allowing the industry to retool gradually without dismantling or taxing the industry externally to drain revenues. Regulators set a cap on emissions and the individual entities are allowed to trade offsets to keep below the cap. Non-polluters are rewarded by collecting revenues from sales of credits while emitters are penalized by buying credits to offset their sulfide emissions. This market-based system provides individual firm incentives for the industry to dramatically reduce sulfide emissions. It is estimated that in the first decade the emissions trading system resulted in SO₂ reductions, totaling a 40% reduction nationally from 1980 levels (a 10 million ton reduction annually), the largest and most successful program of its kind designed to date. This market-based incentive system has shown the potential to save up to half of the compliance costs associated with more traditional source-by-source emission limit programs⁴. In general open market-incentive systems can be relatively inexpensive to implement and enforce, in part because as a many player game, they are not easily manipulated.

Here we will examine a new market-incentive system to reduce Chinook salmon bycatch that is analogous to the sulfide offsets trading scheme, but only in its use of credits trading to create *short-term* individual vessel incentives to reduce Chinook encounter rates⁵. More significant individual incentives of this Recommended Industry Market-Incentive Plan come from an annual allocation scheme for credits (individual tradable encounter credits or ITEC) that creates *long-term accountability* for current behavior or “insurance-like” incentives to reduce bycatch. These allocation incentives promote responsible behavior, are cumulative, and as required by the C-2 Motion they operate at all levels of salmon encounter. Most significantly, the incentives for bycatch avoidance created are strongest at low levels of salmon encounter: times when Chinook populations may be most vulnerable.

In effect, avoiding bycatch in low encounter years enhances a vessel’s subsequent ITEC allocations and creates “insurance” for moderate-to-high-encounter years when credits may otherwise be unavailable; times when many vessels would otherwise deplete their encounter credits before they can fully harvest their Pollock quota. With this allocation scheme, the financial benefits of having additional encounter credits can be considerable. Similarly the costs of having a reduced ITEC allocation can be high.

⁴ Rico 1995, The U.S. allowance trading system for sulfur dioxide: An update on market experience, Environmental and Resource Economics Volume 5, Number 2 / March, 1995

⁵ Chinook encounter rate = bycatch rate = [#Chinook caught] / [1 metric ton of Pollock]

One of the more interesting things we find is that even without any incentives operating in the historical data, the ITEC reallocation scheme alone actually results in lower bycatch and higher industry revenues (Figure 6). This occurs because vessels already show some consistency in bycatch behavior (in the historical non-incentivized data), and the allocation scheme tends to move credits away from poor performing vessels toward cleaner vessels. Not surprisingly, more dramatic cumulative benefits accrue when the incentives are explicitly acknowledged (Figure 9). Moreover, the magnitudes of these incentives and of the consequent bycatch reduction can be adjusted with monitoring and experimentation to fit most reasonable standards. Because of the complexities of human behavior, we believe that the magnitudes of bycatch reduction in any plan cannot be determined *ex ante*, but will require monitoring and evaluation. An advantage (and political liability) of this plan is its flexibility with regard to parameterization to accommodate adjustments if necessary.

This analysis will focus on the Inshore Catcher-Vessel sector using annual data on Pollock harvests and Chinook encounters from 2003-2007, and in part from daily data from 2000-2007. These data show that without behavioral changes, vessels will run out of credits under the PPA hard cap even in low abundance years (Figure 1). If ITEC are expensive or unavailable for sale, the cost of unfished Pollock due to a shortage of credits can be considerable (see ppt slides 21 & 22 and figure 5 & 8). *Therefore, in the Recommended Industry Market-Incentive Plan the best position for a vessel owner to be in is to have sufficient ITEC in reserve so as to never have to buy credits, and have the option of gaining extra revenue by selling unused credits.* These aims can be accomplished with bycatch avoidance.

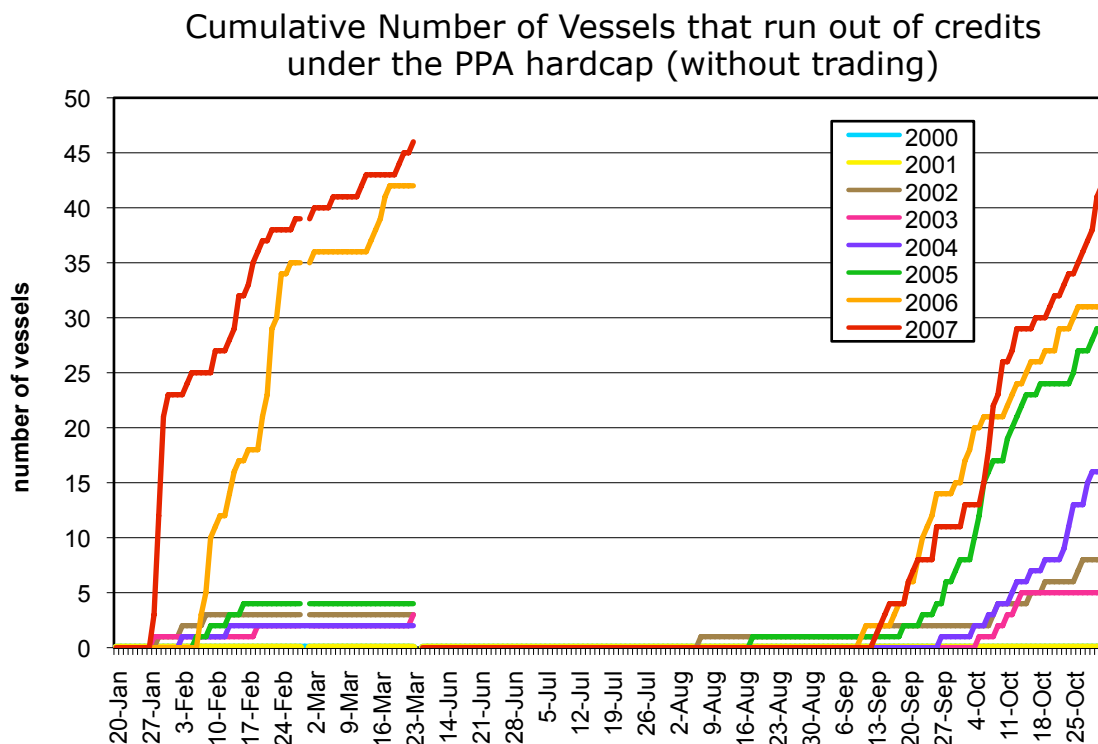


Figure 1. Timing and cumulative numbers of vessels in each season that would have run out of encounter credits under the PPA hardcap with no trading and without behavior changes. (from Inshore sector daily data). Note that vessels can run out of credits even in low encounter years (e.g. 2002, 2003).

This is clearly only an indication as it is hard to predict how people would behave with a hard cap in place. The 2006 experience with Hawaiian Swordfish and turtles produced a race for bycatch. Still the graph is instructive as it gives an indication of what might happen in the neutral case, “with all things being equal.”

II. Basic Elements of the Plan

1) Initial Sector Allocation:

Sectors are given fixed annual allocations of salmon encounter (bycatch) credits (1 ITEC = 1 Chinook) in amounts as described in the C-2 motion document under the industry-wide hardcap of 68,392. For this analysis, the Inshore Catcher-Vessel sector receives 38,059 credits, of which 23,841 are reserved for the A-season and an additional 14,218 credits are allotted at the start of the B-season.

2) Legacy Vessel Allocation: (a key element)

Individual vessel allocations of ITEC are made separately for each season (A and B-season computed separately)⁶ and it is assumed that 100% of any remaining A-season credits are carried forward to the B-season. A 100% carry-forward rule creates incentive to avoid bycatch in the A-season and keeps ITEC prices high at the end of A-season because of the uncertainty in bycatch levels that will occur in the B season. It builds additional incentive for careful fishing (conservation of salmon credits) in the A-season, by providing additional insurance for completing the B-season pollock harvest. As we discuss below, careful fishing in the B-season is incentivized mainly by the Legacy Allocation scheme as well as by the rewards and penalties associated with trading ITEC.

A key provision is a formula to reward vessels with low Chinook encounter rates by reallocating extra encounter credits the following year, and conversely penalize vessels with high encounter rates. This creates several different incentives to lower bycatch, including having extra credits as insurance against costly moderate to high salmon abundance years (times when additional ITEC are needed to finish one’s Pollock allocation, but may not be widely available for sale). The cost of unfished Pollock due to a shortage of credits can be considerable. *The allocation scheme uses these potential costs as incentive for individual vessels to maintain a maximal reserve of credits.*

At the start of each season credits are distributed to the individual vessels via the coops according to an allocation formula that takes three factors into account for that vessel:

⁶ Note: for analyses based on the annual data, allocations with P are based on annual averaged bycatch rates.

- (i) Pollock quota for the season
- (ii) Previous year's proportional allocation factor for the season (season specific legacy)
- (iii) Previous year's relative bycatch rate for the season (season specific bycatch)

This is summarized in the following general formula:

$$P_{s,y,i} = \alpha + \beta P_{s,y-1,i} + \gamma Q_{s,y-1,i} \quad (1)$$

where $P_{s,y,i}$ is the proportional allocation factor for vessel i for season s (i.e., A-season or B-season) of year y . The constants α , β and γ are proportional weights that sum to 1 (see Appendix A for complete formula)⁷. For simplicity, the analyses based on annual data shown here use yearly averages (dropping i), and the results have the same qualitative behavior as those based on daily/seasonal data. The first term α acts as a fixed constant, the second term β is the weight given to the previous year's proportional allocation factor $P_{s,y-1,i}$ (the so-called "legacy" term), and γ is the weight given to the bycatch function $Q_{s,y-1,i}$, which can take any sensible monotonic form that penalizes high bycatch rates. A particularly nice property of (1) is that (for most parameterizations) it is possible to derive asymptotic upper and lower limits for P that place bounds on how far the proportional allocations for any vessel can ultimately deviate.

The proportional allocation factor reflects a vessel's allocation relative to its initial allocation. During the first year of implementation, all vessels would receive an ITEC allocation pro rata to their Pollock allocations and the proportional allocation factor for each vessel would be 1. In subsequent years, this proportional allocation factor will fluctuate (between some asymptotic bounds) and vessels will receive differing ITEC allocations. For vessels with the same Pollock allocation, the relative values of their proportional allocation factors will reflect their relative ITEC allocations: if one vessel's proportional allocation factor is 20% larger than the other vessel, it will receive 20% more credits than the other vessel. (again, assuming that the vessels receive the same Pollock allocation).

II.2.1 Note on Potential Flexibility:

The formula is presented in its most generic and flexible form to emphasize the fact that with monitoring and feedback on performance, it can be adjusted to effect different magnitudes of bycatch reduction and performance standards. We note, however that the actual magnitude of bycatch reduction produced by any plan involving complex human behavior cannot be known *ex ante*, except by experimental implementation. We will return to this issue in the section on "Hypothetical Modeling of Incentives," where we

⁷ Note that the proportional allocation factor (P) is multiplied by the original ITEC allocation for each individual vessel to determine the number of credits that a vessel receives. In the first year of the program, ITEC allocations are pro rata to Pollock allocations and $P = 1$. In subsequent years, P increases or decreases depending on bycatch performance, but will remain within the $2/3$ and $4/3$ bounds if the parameters are as described in Appendix A2.

present a heuristic simulation and crude estimate based on what can realistically be known without experimental manipulation.

II.2.2 Specific Parameterization Used Here:

Here we will consider the specific case where the bycatch function is linear of the form $Q_{s,y-1,i} = \delta + \varepsilon p_i$ where δ and ε are constants and p_i is the penalty value for vessel i computed via a penalty function dependent upon the relative bycatch rate of vessel i . (See Appendix A for a detailed description of calculations). In addition, for heuristics two different weighting schemes will be considered that alter the importance of the legacy component: when $\alpha=\beta=\gamma=1/3$ (equal weighting) and $\alpha=\gamma=1/4$, $\beta=1/2$ (augmented legacy weighting), and where $\delta=1/3$ and $\varepsilon=4/3$. That is, we will consider

$$P_{s,y,i} = 1/3 + 1/3 P_{s,y-1,i} + 1/3 Q_{s,y-1,i} \quad (2)$$

or the (1/3, 1/3, 1/3) “equal” weighting.

And,

$$P_{s,y,i} = 1/4 + 1/2 P_{s,y-1,i} + 1/4 Q_{s,y-1,i} \quad (3)$$

or the (1/4, 1/2, 1/4) “augmented legacy” weighting.

Both of these weighting schemes have a lower bound of 2/3 relative to the initial allocation (based on Pollock) and an upper bound of 4/3.⁸ This means that in both formulas (2) and (3) no vessel can lose more than 1/3 of its initial allocation or gain more than 1/3 as insurance against running out of credits in moderate to high salmon abundance years. A swing of 2/3's in the allocation scheme is reckoned to provide sufficient motivation for the incentives to be effective, however this can be adjusted as necessary (See Appendix A for a discussion of bounds and weighting formulas). These specific bounds [2/3, 4/3] are the lower and upper bounds recommended to industry, along with augmented legacy weighting.

Most of the analyses here are based on the augmented legacy model (3). Except for the speed of convergence (speed at which it is possible to recover from a low ranking) the results here do not differ qualitatively from (2) (see Appendix A-5 for a discussion of convergence). Indeed, eqn (3) may be preferable in some cases as discussed below. In particular, a higher weight given to the legacy component is a way to minimize the random effects of sampling error in bycatch rates (bad luck encounters) and emphasize the consistent intentional behavioral component of variation in ITEC allocations among vessels. Because the year-to-year changes are smaller, vessels must do consistently well (i.e. lower bycatch) in order to obtain the maximum possible increase in ITEC allocation. Similarly, vessels which initially have high bycatch are given more opportunities to improve over time. That is, a larger β in eqn (1) helps to sort out the behavioral

⁸ Note: that when $\alpha=\gamma$ the upper and lower bounds on P do not change with different weightings. The bounds [2/3, 4/3] are the lower and upper bounds recommended here, but these can be adjusted if it is determined by monitoring outcomes that wider/narrower bounds would be more effective.

component from the chance component in determining relative seasonal ITEC allocations (penalties and rewards). However, the smaller value for γ creates less yearly incentive to reduce bycatch, as the changes in proportional allocation factor will be smaller. One must balance these two factors in arriving at a final model. As a starting point we suggest the augmented legacy weighting $[1/4, 1/2, 1/4]$, and unless otherwise stated, this weighting will be used in our analysis.

Again, it is assumed that these allocation factors are computed separately for each season and that there is 100% carry forward of remainder credits from the A-season to the B-season. In practice, a running tab will be kept to let each vessel know in real-time where it stands with respect to the "expectation" of next year's relative allocation. This way there are no surprises, and people will be informed and better motivated. Each vessel can know where it stands "on the fly" relative to the sector (presumably only the data on fleet-wide bycatch will be available to each vessel, with individual vessel performance remaining private information). It is worth noting that privacy is not essential here. In contrast to UIP/FIP there is no advantage to knowing the rank of others, thus the advantage that larger companies might possess in those systems is moot in the Legacy Plan.

The incentives created by the asymptotic behavior of the Legacy Allocation model provide continual incentive to reduce bycatch and promote consistent good behavior. Thus, *if a vessel is near the top of the pack, then it will remain near the top of the pack only if it consistently continues to perform well relative to the fleet.* If a vessel at the top of the pack has an average year (middle of the pack), it will lose some credits in the subsequent reallocation. It is not possible for vessels to slack off and maintain an augmented ITEC allocation. *Incentives are always present (from year 1 onwards).* This also means that there is consistent vessel-level incentive for improvement. As credits are transferred away from vessels with high bycatch rates to cleaner vessels, the bycatch rates for the fleet as a whole will continue to evolve toward lower rates.

Conversely, if a vessel is at the bottom of the heap in terms of bycatch avoidance, it will remain there only if it stays at the bottom relative to other vessels in each year. It can dig out of this hole by consistently moving its behavior closer to the mean. The constant competition and a cumulative record of how competitive you are will keep industry motivated toward evolving ever-lower bycatch rates.

Because of the large variability in Chinook salmon abundance, even vessels at the asymptotic lower limit of ITEC allocation may not be forced to forego Pollock harvest every year. However, this should *not* be viewed as a flaw in the legacy plan. These vessels will likely lose a large amount of potential revenue in mid- and high-encounter years. During these times, trading of credits will be scarce, so these vessels will be unable to simply purchase more credits to continue fishing Pollock. The only reasonable plan for these vessels (to avoid revenue losses) is to improve its allocation by reducing bycatch rates. Due to the nature of the plan, this can be accomplished even with small changes in bycatch rates: such a vessel would not need to reduce bycatch dramatically to see improvements in ITEC allocation (but larger reductions in bycatch would result in

larger increases in ITEC allocation). Thus, these vessels are incentivized to reduce bycatch in all years, even when their allocations may not be binding.

Another option to deal with the worst offenders is to consider some sort of special rule (see Appendix D-2), which might prohibit vessels that are the worst offenders in consecutive years from purchasing any credits. These rules may provide additional incentives for vessels that may be initially unresponsive to the incentives laid out in the legacy plan.

II.2.3 A “False Legacy” Model:

To further clarify how Legacy allocation works it is interesting to consider a degenerate case of the general Legacy Allocation formula (1), $P_{s,y,i} = \alpha + \beta P_{s,y-1,i} + \gamma Q_{s,y-1,i}$, when $\alpha = 0$ and $\beta = \gamma = 1$, which no longer has the desired legacy behavior:

$$P_{s,y,i} = P_{s,y-1,i} + Q_{s,y-1,i} \quad (4)$$

Here the relative legacy-term weight is adjusted via the bycatch function, Q , which will have a different form than discussed above. Case (4) describes a simple random walk where the proportional allocation factor P_y , depends only on the last value P_{y-1} , and the bycatch term, Q . The specific form of Q can be anything sensible that transforms a penalty function to a proportional-factor reflecting the fractional gain or loss in ITEC the following year (see Appendix A for further details). Q is a transformed bycatch rate that is ultimately a random variable. Unfortunately, this simple random walk formula for credits allocations no longer has the desirable property of asymptotic bounds, and it can increase or decrease indefinitely (or go negative). However one can implement an *ad-hoc* patch to this problem by setting arbitrary limits on P (e.g hard limits of $[2/3, 4/3]$ as effective absorbing bounds to the random walk).

The cost associated with the lack of this property (convergence to natural limits) is that (4) is not really a legacy system in terms of the way incentives work, nor in terms of separating out the behavioral component from the chance component. It lacks all of the interesting strengths that make a true Legacy system work.

For example, if you are at the top of the heap, you will remain there if you have an average year. There is no incentive to be good going forward... just average. Similarly, if you are at the bottom of the heap, you will stay there, even if your bycatch rate is average (middle of the pack) the next year. The realistic incentive is to stay bad. In other words, once you become an A student you remain an A student even if you perform like a C student from then on, and once an F student, you remain there even if you consistently perform like a C student. A consistent C student can get rewarded in perpetuity as an A student or and F student. There is a discontinuous mismatch between current actions and consequences. It is a degenerate case that will produce a distribution of allocations that is flat with spikes at either end.

Asymptotic (gradual) convergence to intrinsic upper and lower bounds (eg. $4/3$, $2/3$) is essential to have sensible incentives. (eg. consistent good behavior etc).

Although case (4) is a bit “homegrown” and does not have the sensible cumulative incentive dynamics that accompany the nice mathematical properties of the other more general cases, it does have some merit. Namely, it is easy to explain and adjust in ad-hoc ways, and is therefore likely to be useful in non-technically guided discussions about specific parameter implementations. For example, it is possible to specify a rapid linear (non-asymptotic) approach to a boundary. Thus, the limits on Q could be set so that a lower-bound can be hit in 3 years, giving rise to a “3-strikes rule” so that the consistent worst case performer hits the lower limit (eg. $P = 2/3$) in 3 years starting from the initial allocation. Here, the penalty for being the worst performing vessel is equal for all 3 years (e.g., - 11.1%) rather than in progressively smaller increments (see Figures A-5 and A-6) as the vessel approaches the lower-bound in the more general case (e.g. eqn. 2). Yet as seen in the Appendix (section A, Figures A-5 and A-6) the differences in convergence behavior between this alternative and the true Legacy alternatives can be small; so although it is not a viable incentive system, it may be useful in sharpening discussion.

11.2.4 The Importance of Scaling for Vessel Size to Place Large Vessels/Firms and Small Independent Vessels on Level Ground

The variance in bycatch rates between vessels can be attributed in part to *chance encounters* with patchy pockets of Chinook salmon, which is related in part to sample size effects or sampling variation. This, in turn, is directly related to vessel size. Consequently, as shown in Figure 2 and Appendix A-4, we found that the variance in bycatch rates of smaller vessels in the inshore sector was systematically higher than that expected for larger vessels. That is, small vessels suffer greater risk of being assigned an errant bycatch rate due to sampling variation⁹ than larger vessels or companies that manage groups of vessels. Because small vessels are subject to more sampling error of this kind (Figure 2), we used a corrected standard deviation in the allocation calculation to adjust for the effects of random noise due to vessel size (Appendix A-4), effectively treating vessels belonging to a single company as a single large vessel. This random noise varies with the inverse square root of $1 + \text{pollock allocation \%}$ and is applied to put small independent vessels on the same level playing ground with respect to legacy allocations as larger vessels and companies that employ many vessels (see Appendix A-4 for details). It is a minor but measureable correction on reallocation that removes the disadvantage of increased risk experienced by smaller vessels.

⁹ By sampling variation, we mean the variation in bycatch rates in a hypothetical experiment where two vessels are fishing in the same region at the same time in the same way. These vessels would be expected to have the same bycatch rate. However, a larger vessel is more likely to have a smaller variation in bycatch rate for multiple hauls than a smaller vessel. We do NOT refer to observer coverage of boats: we expect any plan with a hardcap on Chinook bycatch will require 100% observer coverage for all vessels.

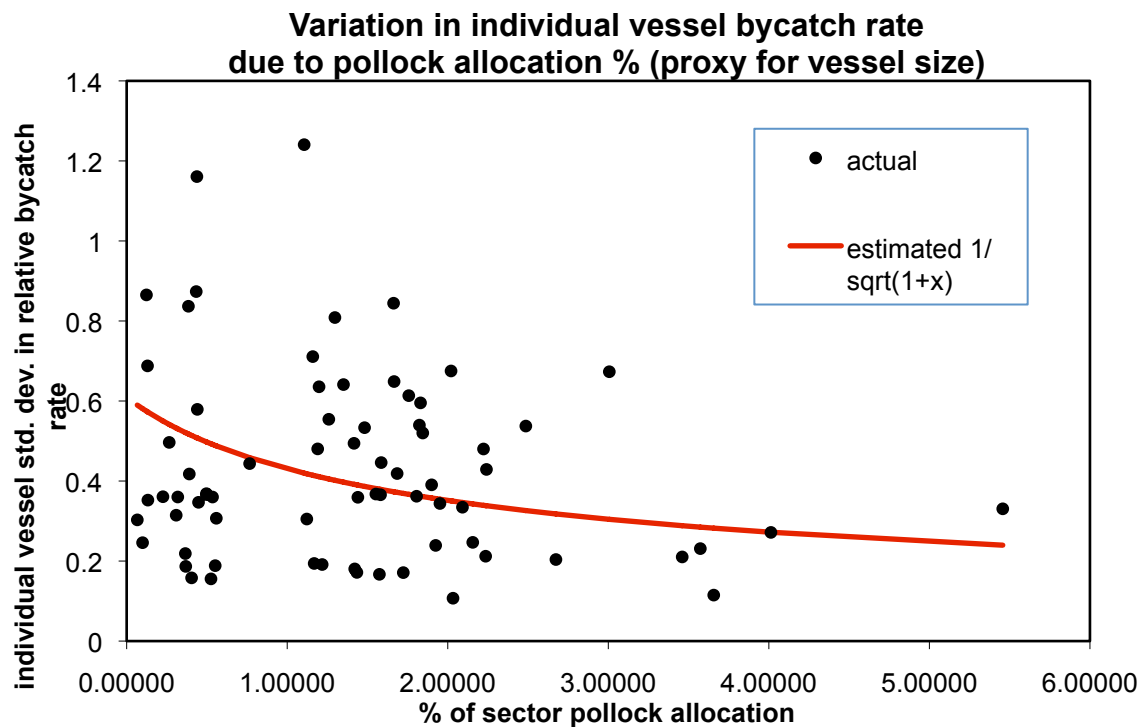


Figure 2. Smaller vessels show higher variability in bycatch rates. (annual data)

II.2.5 Scaling to Avoid Penalizing Competitive Improvement Through Time

In addition to various forms of sampling variation, the variance in bycatch rates between vessels can also be attributed in part to *consistent behaviors* shown by vessels that appear to directly influence bycatch rates (caution in gear deployment, locational choices, timing etc).

One reasonable expectation of the Industry Market-Incentive Plan is for the variance in the distribution of bycatch rates among vessels to decrease over time as vessels exploit the same behavioral changes to reduce bycatch rates. As this happens bycatch rates would fall and a larger proportion of the variation in bycatch rates would then be due to random chance and not intentional behavior on the part of vessels. Indeed, as shown in figure 3 below for all of the sectors combined, there is a clear tendency for lower variance in bycatch rate to accompany a lower sector bycatch rate, reinforcing the idea of a narrower distribution of rates accompanying lowered rates. This suggests rescaling variances to keep a level playing field (see Appendix A-4 for details).

This scaled variance, is intended as a simple correction for the fact that with time the variance in bycatch rates should decline, meaning that the effects of equivalent random variation on subsequent allocations will grow. Basically, this rule keeps incentives from increasing artificially as the variance in bycatch distributions falls over the years. That is, as the distribution of bycatch rates within a sector becomes narrower, vessels will need to effect smaller changes in bycatch rates to see the same change in ITEC allocation. It was implemented in order to ensure that variance in relative bycatch rate continues to reflect behavioral differences rather than noise, as the fleet converges to lower bycatch rates.

Industry is concerned with vessels getting punished or rewarded due to chance encounters when the distribution of bycatch rates for the fleet become narrow. Rather than thinking of this as “diluting” incentives, it is better to think of this as preventing the potential artificial amplification of incentives due to systematic declines in variance. We do not want to penalize vessels because the fleet is getting better.

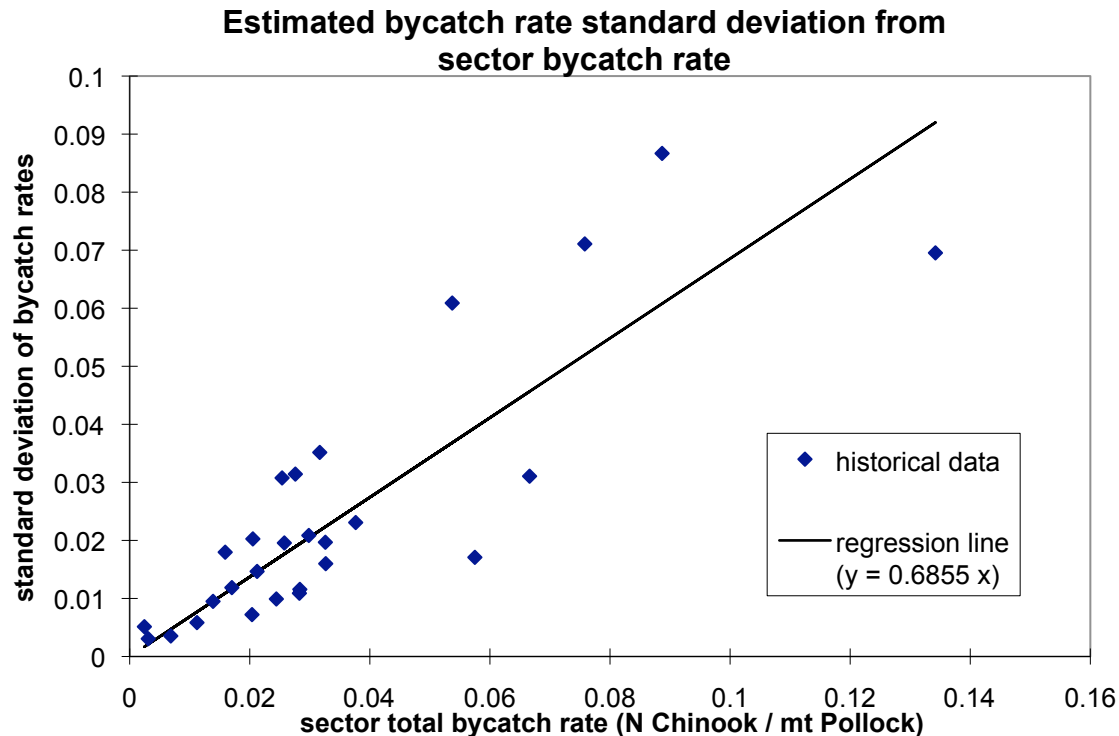


Figure 3. Standard deviation of bycatch rates as a function of sector total bycatch rate. (Annual data from multiple sectors. Provided by Sea State). Narrower distributions of bycatch among vessels accompany lower sector bycatch rates, meaning equivalent actions a lower bycatch levels produce larger effects in ITEC allocation (higher incentives at lower bycatch levels).

As we shall discuss again in section III.2, this figure shows that allocation incentives are stronger during periods of low encounters, in that as the distribution of bycatch rates within a sector becomes narrower with lower bycatch rates, vessels will need to effect smaller changes in bycatch rates to see the same change in ITEC allocation

II.2.6 Legacy Incentives with this parameterization

Given the specific bounds $[2/3, 4/3]$, the magnitude of the financial incentives created by Legacy Allocations can be large in terms of the value of Pollock quota left unharvested when vessels run out of ITEC and credits are not readily available for sale (See ppt slide 21 and 22 and figures 5 & 8).

A vessel that fishes cleaner can realize more value per Chinook bycaught. Likewise a less skillful vessel with high encounter rates realizes less value. Thus, ITEC has a higher

intrinsic value to a cleaner vessel than to one with high encounter rates. In the short term, clean vessels will be net sellers of ITEC and will perceive a higher value, while vessels with high bycatch rates will be net buyers of ITEC. The allocation scheme steadily puts more ITEC in the hands of cleaner vessels so that overall fleet bycatch will decline with time.

3) Transfer Rules

ITEC Supply and Pricing Considerations:

The price of encounter credits will be determined by market perceptions of supply and demand and these in turn will be driven mainly by the perceived risk of running out of ITEC or of needing one's full complement of credits to finish the season.

Because this uncertainty is greatest at the beginning of the season, the price of credits is likely to be highest at that time. Credits will generally be unavailable for sale early in the season. Indeed, vessels are more likely to offer credits for sale only after completing their Pollock harvest, when the cost of running out of credits is no longer at risk.

As individual vessel owners become willing sellers of credits once their Pollock quota is complete, the supply will increase which will put downward pressure on ITEC prices toward the end of the season. During times of moderate to high Chinook encounters this rising supply will be met with rising demand and prices could actually increase toward the end of the season. However, during times of low encounters this could result in a glut of credits at the end of the season. The potential for an end-of-season glut could cause a fall in credits prices, and a reduction in short-term incentives, paving the way for abuse (i.e. diminished incentives to reduce bycatch). Thus, transfer rules are required to regulate the demand and supply of credits.

We will examine two types of transfer rules for ITEC:

- 1) "Buy side" transfer rules
- 2) "Sell side" transfer rules (fixed tax on transfers vs. dynamic salmon savings)

We recommend that the best outcome is likely to come from using both kinds of transfer rules together to support incentives for Chinook bycatch avoidance, especially during times of low salmon encounters.

Buy Side Transfer Limits:

So that a poorly performing vessel (one at the 2/3 allocation level) can never obtain more than its original allocation through purchase we recommend the following buy side transfer limit: "in each season only an amount less than 1/3 of a vessel's credits allocation for that season may be purchased." This means that the worst performers (with lower allocations) will be able to buy fewer credits, while the better performers, with larger initial allocations, are further rewarded with the ability to potentially buy more if needed.

This fixed buy-side transfer limit is simple to implement and should not affect the profitability of the sector.

The benefits of this simple rule are:

- (i) It addresses *individual vessel* incentives. (C-2- requirement 1)
- (ii) It addresses the possible abuse of abundant encounter credits during low salmon abundance years. (C-2 requirement 4: influences decisions at levels well below the hardcap).
- (iii) It will not affect the completion of Pollock harvest (as shown in historical simulations)
- (iv) It reinforces the incentives provided by the legacy allocation system because vessel ITEC allocations (P) and buy side limits move in tandem. (C-2 requirement 2: rewards vessels that avoid bycatch and penalizes those that do not).
- (v) Insofar as it depends on the allocation proportion, P, the buy-side limit is more vulnerable to readjustment during times of low salmon abundance, placing more incentive there. (C-2 requirement 3: creates incentives at all levels of abundance in all years).
- (vi) It provides additional incentives for the worst performing vessels to reduce bycatch, in order to increase their proportional allocation factor and enable the purchases of additional credits. (C-2 requirements 3 & 4)

Again, a buy side transfer limit means that the worst performers (those with lower allocations) can buy fewer credits. (C-2, R-2). Thus, it resonates with the legacy system, and it augments incentive for salmon avoidance during periods of low encounters. (C-2, R-3)

Sell Side Transfer Limits: (Dynamic Salmon Savings)

Fixed Transfer Tax:

A fixed sell-side transfer tax is not desirable to industry as it can potentially limit the Pollock harvest. Neither is it desirable to Chinook conservation as it is dependent upon transfers taking place. During years of low salmon encounter, very few transfers will take place, reducing the effectiveness of a fixed transfer tax exactly when it is most needed. Conversely, transfers of ITEC occur more frequently and in greater volume during years of moderate to high salmon encounter; at these times, a fixed transfer tax will increase the burden of an already limited ITEC supply. Such times are when credits are most needed by the Pollock industry. Fixed transfer taxes are not a good fit to this problem.

Dynamic Salmon Savings (DSS):

Thus, we will consider a Dynamic Salmon Savings rule that is adaptive to salmon encounters and will apply to each vessel after it completes its Pollock harvest. This is more complicated to implement, but more desirable to Chinook salmon interests than a buy side rule alone or a fixed tax, as it represents a true salmon savings rule (**i.e., a**

salmon exclusion rule) that creates much more protection for Chinook during times of low encounters.

The Dynamic Salmon Savings rule imposes a constraint on the “sell” side of transfers. It includes a sector specific “salmon savings rate” (SSR) that is applied to each vessel’s “remainder” credits upon completion of fishing. Remainder credits = a vessel’s credits left after filling its B-season quota + credits sold prior to filling quota + A-season carry-forward. The sector specific SSR calculated near the end of the B-season should have the following characteristics:

- (i) Address the possible abuse of abundant encounter credits during low salmon abundance years.
- (ii) Will not adversely affect the completion of Pollock harvest.
- (iii) And is a function of Chinook salmon abundance.

The idea is to set the sector SSR at some reasonable time before the end of B-season, and do this as a function of how much of the sector pollock TAC has been caught. There is a trade-off between how accurately the SSR can be calculated and how soon in the season the fraction can be determined. This tends to happen later in the B-season during low salmon abundance years and earlier in moderate to high abundance years. This enforces more conservation in low abundance years and encourages higher ITEC prices.

The simple dynamic salmon savings rule suggested here consists of two parts:

- (i) A provisional savings rule that applies to vessels that sell credits before finishing fishing in the B-season. The provisional savings rule requires that ITEC savings must be held in reserve to meet the maximum SSR. This promotes salmon savings early in the year.
- (ii) Determination of a valid SSR far enough in advance of the end of the season to be useful. SSR is the fraction of “remainder credits” that must be retired when a vessel completes its fishing. Remainder credits are credits that a vessel did not use to fish its full quota of Pollock.

1) Provisional Salmon Savings Rule (PSSR = max SSR = withholding tax):

Note that prior to setting the seasonal SSR rate, transfers are allowed “from” boats but only up to some fixed percentage of their “remainder” credits. Remainder credits = a vessel’s credits left after filling its B-season quota + credits sold prior to filling quota. Remainder credits include carry-forward vessel credits from the A-season. The provisional salmon savings rule (PSSR) would require that vessels selling credits early must have a reserve of credits set aside to accommodate the largest possible SSR. This covers the fact the remainder credits include credits sold. It acts as a withholding tax for credits sales.

For example, if a cap is set so that the maximum SSR is 60% (a number that historically will not limit the harvest), then prior to setting the dynamic savings rule (eg. throughout the A-season), boats that have finished fishing early can only sell up to 40% of their remainder credits. The PSSR = 60%, or the maximum SSR. Thus, if a vessel wishes to sell 40 credits early in the year, it must keep 60 ITEC *in reserve* until the SSR is calculated. This PSSR reserve acts as a *de facto* conservative salmon savings rule governing transfers until the SSR is posted. It operates like “tax withholding” and protects (holds ITEC in reserve) a large fraction of salmon until the SSR is posted.

A provisional savings rule prevents potential abuses that may occur if vessels sell credits before they “finish” fishing. Since credits would not be retired until a vessel “completes” fishing, a vessel could sell all of its credits before fishing its complete Pollock allocation as a strategy to avoid having ITEC retired. A provisional savings rule prevents this exploitation by requiring that the appropriate ratio of credits be set in reserve for each transfer that occurs before a vessel finishes fishing or before the SSR is set (as in the preceding example).

2) Calculating a Salmon Savings Rate:

Numerical experiments with the Inshore sector daily data over an 8 year period suggest that calculating the SSR when 2/3 of the B-season sector Pollock quota are caught (2/3 sector TAC) gives the best result, in terms of estimating the credits needed to complete the season (see Appendix B for details on calculating the SSR). This is the “estimated total sector by-catch for the B-season.” This estimate normally occurs between August 29 and Sept 16 (Appendix B). This tends to happen later in low salmon abundance years (when fewer transfers are needed) and occurs earlier in moderate to high abundance years (see Table B - 1).

Discussion:

A dynamic salmon savings rule should increase the effectiveness of a market-incentive plan with regards to protecting Chinook salmon and meeting the C-2 Motion requirements. One of the primary criticisms of the 68,392 hard cap on Chinook salmon bycatch is that it is set too high. This level of hard cap poses the problem of satisfying the C-2 requirement of incentivizing reduced salmon bycatch at all levels of abundance. A lower hard cap, as advocated by some salmon interest groups is one possible solution. However, historical data show that salmon encounter rates vary over a wide range. A low hard cap can pose significant financial difficulties on the Pollock fishery during years of high salmon encounter (68,392 hard cap creates financial burden even during years of moderate salmon abundance: Figure 1). Conversely, a high hard cap can result in excess credits (and the potential for abuse) during years of low salmon encounter. The ideal solution to this problem would be to develop sophisticated methods for accurately forecasting salmon abundances and encounter rates. A much more feasible alternative is an adaptive rule, such as Dynamic Salmon Savings (DSS) which is adjusted each year, taking into account that season’s level of salmon encounter seen so far. Unlike a Fixed Transfer Tax, DSS retires credits during times when credits are abundant and the

potential for abuse is high. A fixed tax can only retire credits when transactions occur. During low-encounter years, few transactions take place (because most vessels have enough credits to fish their own Pollock allocation). Thus, a fixed tax will fail to be effective during times of low salmon encounter, precisely when a transfer rule should be most effective.

In our simulations of the number of credits retired under a fixed transfer tax scheme and DSS, we found that DSS retired significantly (over 4 times) more credits over a span of 8 years (2000 - 2007) for the Inshore Catcher-Vessel sector (using daily data, see 4a). Not only does DSS save more credits than a fixed transfer tax over this 8 year period, but the savings occur during years of low salmon encounter under a DSS scheme. (see Figure 4b) Details regarding the implementation of both the fixed transfer tax and dynamic salmon savings can be found in Appendix B, along with more detailed simulation results.

One potential issue related to DSS is the estimation of the number of credits needed. Because this is an estimate of the amount of bycatch that the industry might experience for the rest of the season, it has the potential to influence fishing behavior. We believe that it will not adversely affect bycatch rates (i.e. elevating bycatch rates above what they would be without such an estimate). Like all estimates of bycatch, it is subject to error: the large fluctuations in bycatch levels and salmon abundances from year-to-year and season-to-season should make individual vessels cautious about running out of credits. Furthermore, although some vessels may become less careful in avoiding bycatch if the estimate of bycatch is too high, they can be taken advantage of by vessels that are rigorous in avoiding bycatch. Since vessels are competing with each other for increased allocations, vessels that have lower bycatch relative to other vessels will see increased allocations. The competitive aspect of the legacy plan means that an estimate of bycatch will adversely affect bycatch rates only if *all* vessels are lax about reducing bycatch. Seeing even one vessel outperform the rest will incite the rest of the fleet to catch up.

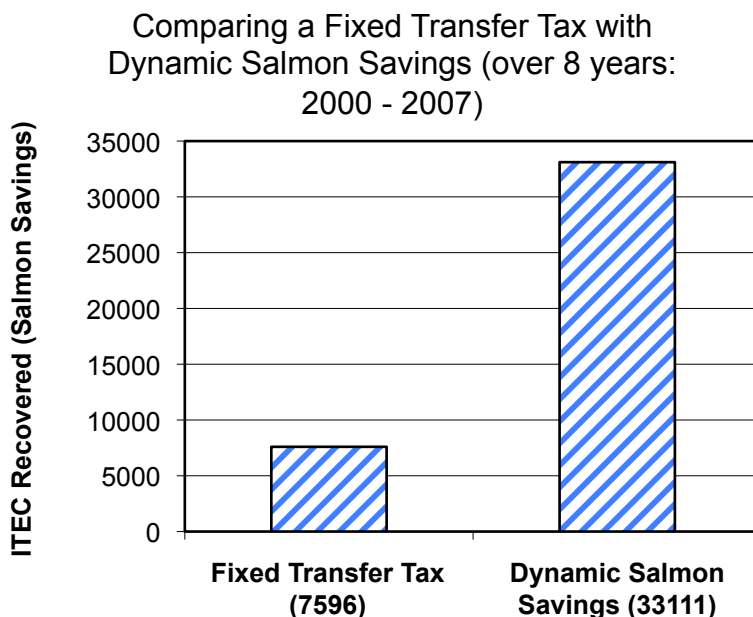


Figure 4a. Number of retired credits over 8 years (2000 – 2007) under two different sell-side transfer rules: a fixed transfer tax and dynamic salmon savings.

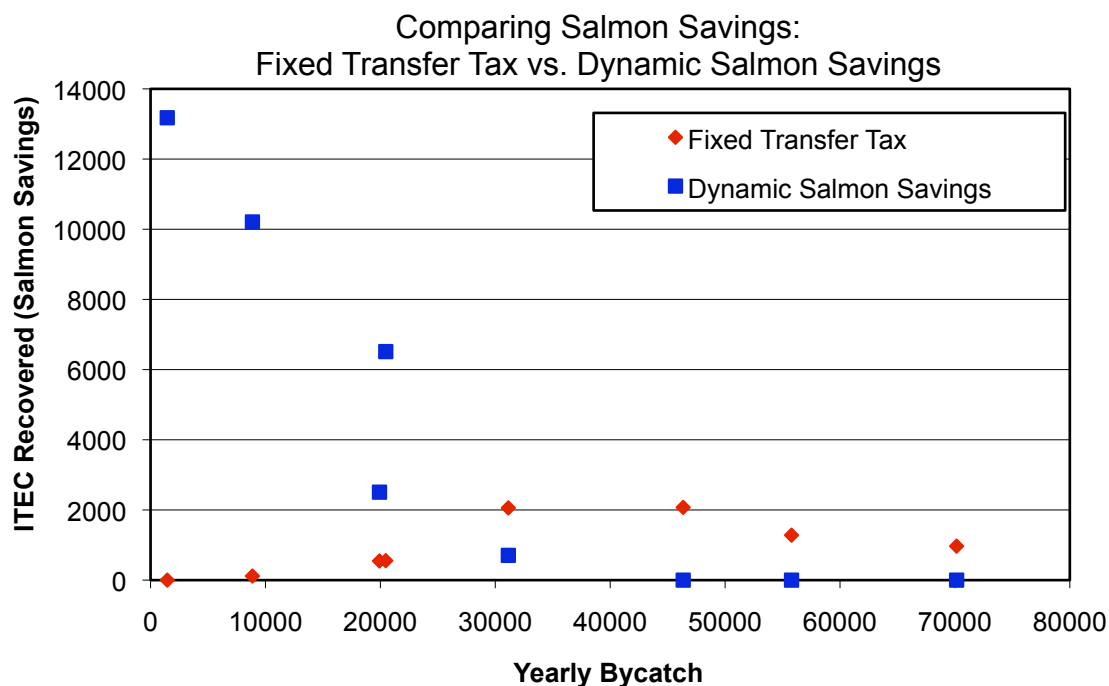


Figure 4b. Number of ITEC recovered vs. yearly bycatch (proxy for salmon abundance) for two different sell-side transfer rules. More ITEC is saved during low salmon abundance years using Dynamic Salmon Savings.

III. Incentives/Issues

III.1 Expected value of chinook bycatch:

The expected value of Chinook bycatch will be a function of many factors, including (among others) an individual vessel's current ITEC allocation, time of year, the probability that an individual vessel will run out of ITEC, the amount of ITEC that may be available for sale, and expectations about the probability of high-encounter years in the future. Similarly, any effort to model the expected variance in Chinook bycatch would require an estimate of the stock levels of Chinook in the Bering Sea, which would be difficult with our current knowledge. As a simplified alternative, it is possible to create a rough upper bound on the price of credits by looking at the intrinsic value to individual vessels from being able to catch additional Pollock with each additional ITEC.

III.2 Industry costs associated with non-transferability of credits.

Without a system for transferring Chinook salmon encounter credits individual vessels will run out of ITEC, and Pollock could go unfished, resulting in significant revenue losses for the Pollock industry. These losses can happen even during low to moderate

salmon encounter years. Figure 1 below illustrates the timing of how many vessels run out of credits in each season under the proposed Inshore sector hard cap of 38,059 assuming no behavioral change in response to a hard cap (includes 100% A to B carry forward). Note that this zeroth order indication shows the result

What is interesting here is that in 2000 and 2001 apparently no vessels would have run out of ITEC (hence no trading would be required). However, in other low salmon encounter years, 2002, 2003 and in the moderate salmon abundance years 2004, 2005, an increasing number of vessels would have run out of Chinook salmon encounter credits. This suggests that while no trading was required in 2000 and 2001, that it would have been required in all of the following years to minimize the Pollock that industry must leave unharvested.

The sector revenue loss associated with not being able to trade encounter credits under a hard cap scenario can be considerable. These costs are illustrated below in Figure 5, and can exceed \$62m in one year. The risk of catastrophic losses due to unharvested Pollock in any given year should provide strong financial motivation for industry to adopt a plan for transferring credits, in addition to incentivizing individual vessels to lower bycatch rates so that they may be rewarded additional ITEC allocations. In addition, vessels that may run out of credits, even in moderate encounter years, will be incentivized to lower their bycatch rates to make maximal use of their ITEC allocation and to secure a sufficiently high ITEC allocation in subsequent years.

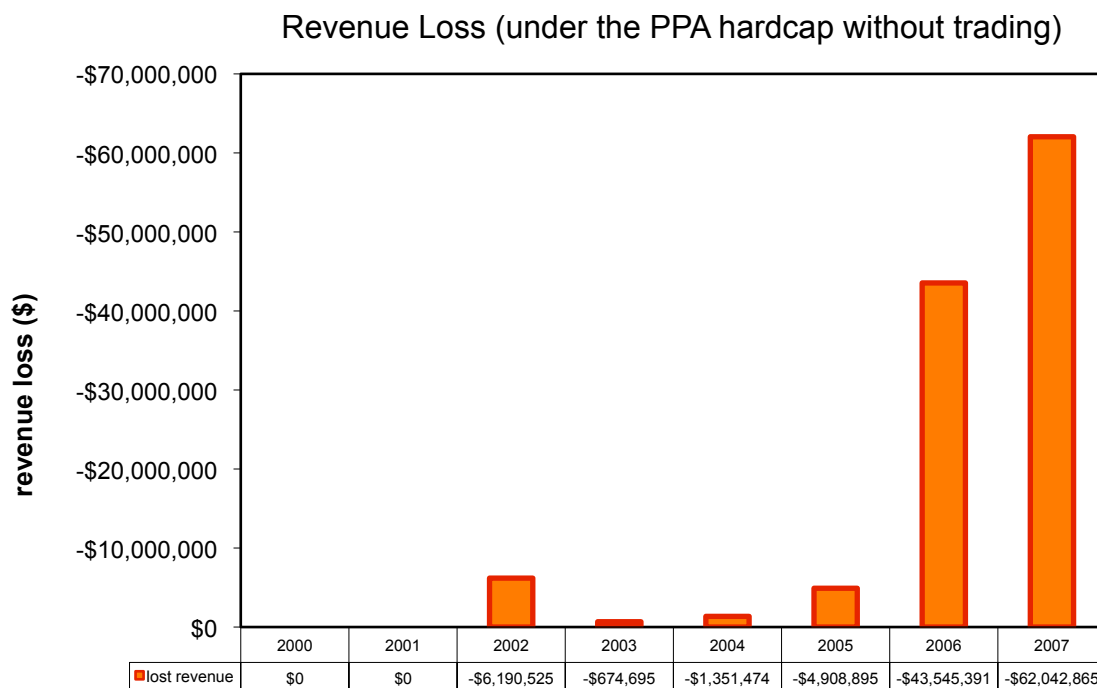


Figure 5. Annual sector revenue losses that would have been incurred under the maximum hard cap (as specified in the PPA) if no reallocation, no trading, and no

bycatch avoidance incentives were in place. This calculation is based on daily catch data from Sea State Inc. and the assumption that the A-season price for Pollock is \$0.20/lb and the B-season price is \$0.12/lb.

Trading encounter credits even without explicit incentives to avoid bycatch can increase industry revenues and reduce fleet bycatch.

The following figure (6 below) illustrates a hypothetical scenario where reallocation (using eqn 2 above) and trading occurs by the following simple rules:

- (i) Credits are only made available to trade when a vessel finishes its quota for the season. The only sellers are those who have finished fishing that season.
- (ii) Credits are transferred as soon as they are needed and available to the vessel(s) that have run out of credits and for whom the intrinsic value (non-market value) is highest, thus will be most likely to want to buy them. As credits are made available, transfers are made in that order. Basically, as they become available, credits go to those vessels who ran out of credits and for whom they have the highest value (like water running down the tiered basins of a fountain).

The remarkable thing here (Figure 6 below) is that this shows that there can be significant revenue advantages to credits trading for the sector as a whole, despite the fact that there is no explicit individual motivation to avoid bycatch. Although the effect is modest, the natural dynamics of the allocation scheme and the trading model by itself can enhance revenues, and reduce bycatch for the fleet as a whole.

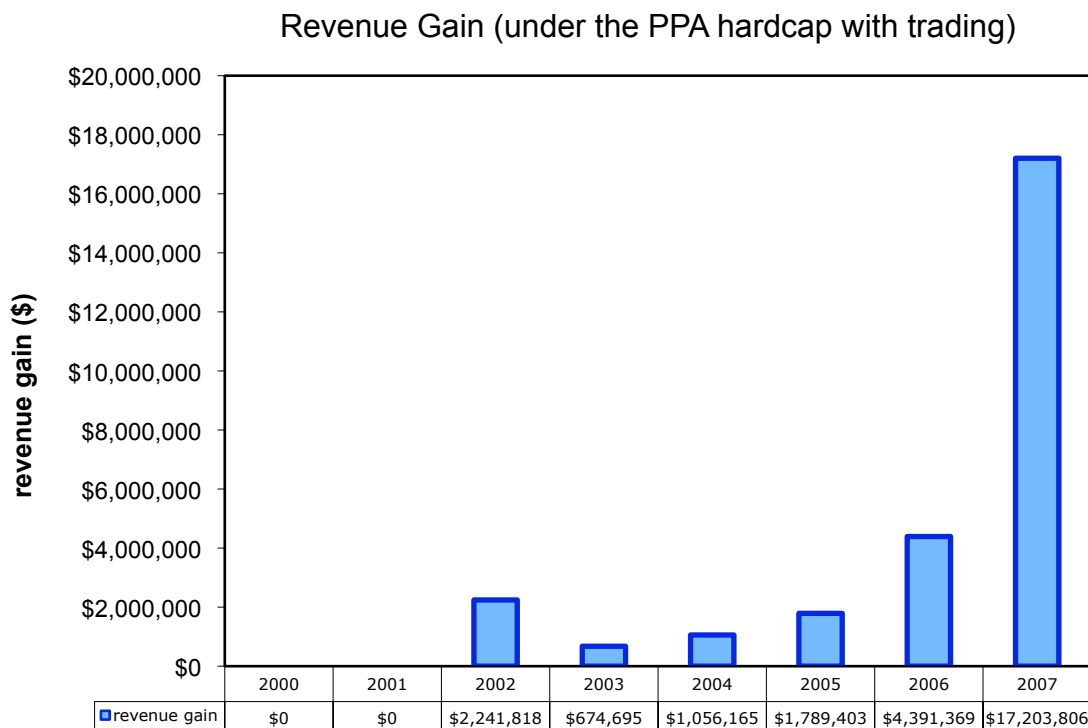


Figure 6. Potential revenue recovered from trading Chinook salmon encounter credits (ITEC's) under the PPA hardcap. Even without explicit incentives to avoid bycatch, Legacy Reallocation by itself can help to maximize industry revenues. Reallocation assumed "equal weighting" with $Q = 4/3 p + 1/3$ and a linear penalty function.

Note that no trading occurred in 2000 and 2001, as all vessels would have made it through the season without running out of credits.

III.3 Infrastructure for Accounting and Trading of ITEC

Perhaps the greatest long term benefit of the ITEC trading and allocation plan is the establishment of an independent (CFTC certified) electronic market place for conducting fishery business. An external (not in-house) trading site would make make gaming and manipulation difficult and illegal under current CFTC statues. Having an established trading infrastructure in place will provide a site for other transactions that industry may find desirable and convenient (such as a market place for posting and transacting bids and offers on intra-coop Pollock leases, or the negotiation of futures or option contracts to moderate risk and ITEC purchases). As a new infrastructural cornerstone it should be possible to find financial support from outside sources, and could involve a collaboration with an existing CFTC certified contractor such as the Chicago Climate Exchange. Having such certification would bring security and credibility to the enterprise. It would represent a significant transformative step forward toward market efficiency and transparency.

III.4 Handling Transfers Across Sectors

As originally conceived the Legacy Market-Incentive program would operate throughout an entire sector, however this can be modified. It would not be implemented with any other plan (UIP/FIP or otherwise) in the same sector. Trading of ITEC across sectors operating under different programs would be restricted as described in the report: sectors with Dynamic Salmon Savings can sell credits to any other sector, but may only buy credits from another sector with a Dynamic Salmon Savings rule with the same maximum Salmon Savings Rate.

From the point of view of maintaining rational incentives in the Legacy Market Plan the following rules should apply to transfers across groups or sectors that may or may not participate in the plan.

1. Unless otherwise regulated, sectors with Dynamic Salmon Savings (DSS) may sell credits to any other sector.
2. Unless otherwise regulated, sectors without DSS may buy credits from any other sector.
3. A sector with DSS cannot buy credits from a sector without DSS.

III.5 Incentives and Issues related to the allocation scheme.

A key incentive mechanism for the tradable encounter credits model is the allocation of credits based on current and past (legacy) encounter rate behavior. As we have already seen (Appendix B) the intrinsic fishery value of credits can be very high, and in years of high salmon abundance the cost of forgone Pollock under a Chinook hard cap can represent a catastrophic loss. Having extra Chinook encounter credits or so-called “bonus credits” over and above the initial allocation based purely on Pollock makes the value of avoiding current encounters high if in the future there are years of high or moderate salmon abundance. This requires forward thinking similar to buying insurance. Having extra credits reduces the risk of expenses associated with encountering years of moderate to high salmon abundance.

Of special significance is the fact that this allocation scheme operates more sensitively during years of low salmon abundance (Figure 3 and 7a,b). Figure 3 shows that That is, vessels are more strongly rewarded or penalized for fishing behavior during sparse salmon encounter years. Additionally, the intrinsic fishery value of the credits is higher at times of low salmon abundance (Appendix B).

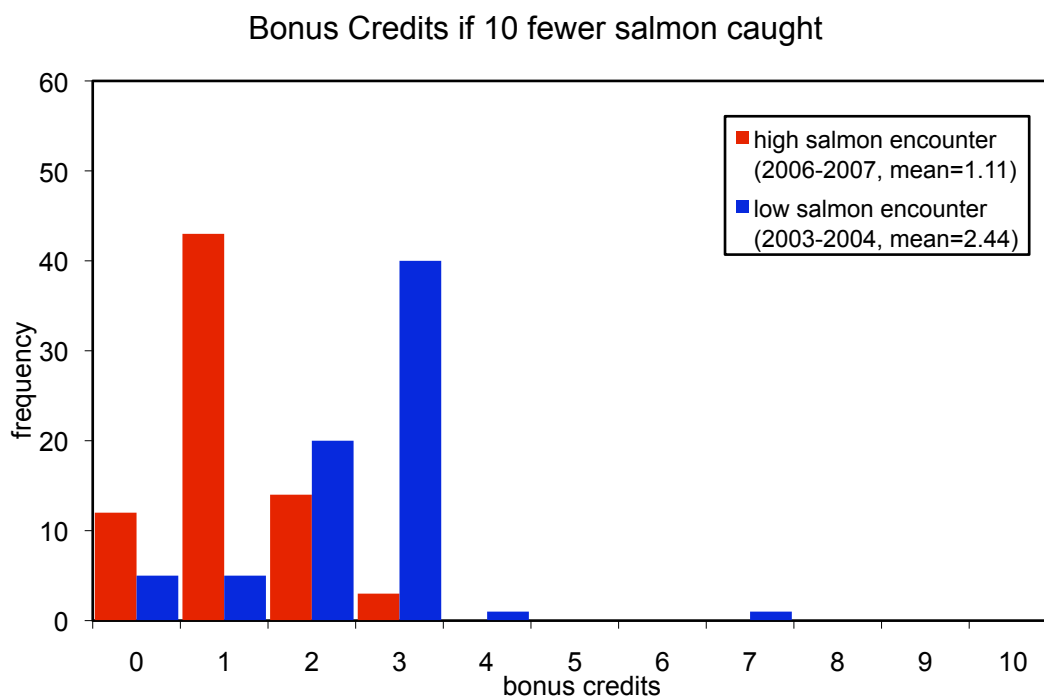


Figure 7a. Bonus credits (extra ITEC) achievable with 10 fewer Chinook salmon caught using the “equal weight” Legacy Allocation Formula (eqn 2) with a linear penalty function. This is analyzed vessel by vessel. (based on original annual data) The additional revenue per bonus credit in the 2007 A-season (assuming the vessel would have otherwise run out of credits) is ~\$7k-20k/credit. Allocation provides strong motivation in terms of potential cost.

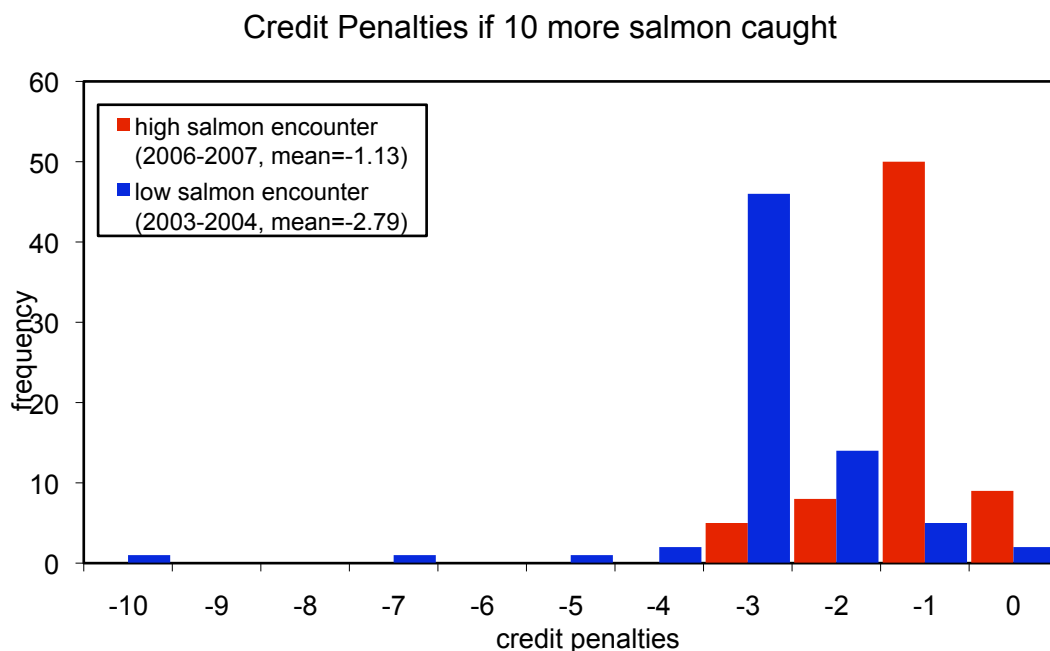


Figure 7b. Credit penalties (reduced ITEC) as a result of 10 more Chinook salmon caught using the “equal weight” Legacy Allocation Formula (eqn 2) with a linear penalty function. (based on annual data)

III.6 Incentives related to trading ITEC.

If vessel-owners believe they have excess credits in any given year they can post them for sale on the electronic market site. This could represent significant extra revenue, especially if there is significant asymmetry in performance among vessels. Similarly, if a vessel owner needs to buy credits he is required to pay the market price. This incentive structure is similar to the incentives for trading pollution offset credits, however it also involves a Dynamic Salmon Savings (and a maximal withholding tax (PSSR) of 60% on early credits sales) to control possible excess supply at times of low salmon abundance. It is not known whether credit pricing will be sufficient to deter chronic bad performers who respond only to current incentives as trading is not always required (eg. 2000 and 2001). Monitoring and adjustment will be required (a withholding tax of up to 60% can be tolerated without directly harming the Pollock harvest). However, these are times where the legacy incentives are strongest.

III.7 Legacy Incentives

The second term of the allocation formula 1 is the so-called “legacy” component that incorporates past behavior into the current allocation scheme. This component serves three important functions:

- (i) It moderates the random component in seasonal year-to-year variability in seasonal bycatch that is due to chance, and tends to amplify the behavioral component. One of the problems with any performance related reward/penalty

system is that it is almost always subject to randomness in some form. Chance is part of life, but one wants to minimize this as much as possible without also destroying the incentives created by rewarding/penalizing differences in performance. Separating out such random variation in bycatch rates (e.g. sampling error or bad luck), from variation due to behavior is difficult but is handled somewhat by the Legacy component, which rewards and penalizes consistent behavior. This problem is addressed in the present system in several ways (see Appendix A for a fuller discussion), but it is usually problematic to try to separate natural sampling variation, from variability due to behavior without using historical data that can capture consistent patterns of behavior. Thus, boats in the same area may have different bycatch rates partly due to sampling variation and partly due to behavior and this is difficult to sort out without assumptions that may be questionable. The legacy component dampens out variation due to accident and tends to highlight variation that identifies behavior.

- (ii) The legacy system provides carrot and stick incentives for long-term accountability in behavior. It encourages forward thinking and a chance to improve toward the upper bound allocation of $4/3$ the initial allocation. It also provides the “stick” of having only $2/3$ the initial allocation to fall back on. The catastrophic costs associated with insufficient ITEC represent a strong financial incentive on behavior. The legacy system makes the full hardcap available to the fleet only when it is absolutely necessary, but at the same time it provides strong financial and competitive incentives to minimize bycatch whenever possible.

The legacy system provides cumulative competitive incentives (incentives that begin year 1 and continue in all years) that should result in a steady evolution toward fleet-wide improvement in encounter rates (figure 8). This is in contrast to static incentive plans (e.g. UIP/FIP) and to hard cap reduction proposals that do not explicitly encourage a cumulative fleetwide evolution toward lower bycatch rates and that do not promote the development of fishing methods and technologies that will encourage this desirable ever-improving result of constant competition. Such constant improvement in avoiding bycatch is a unique hallmark of the legacy plan.

IV. Hypothetical Modeling of Incentives: Modeling the Magnitude of Bycatch Reduction

The actual year-to-year magnitude of bycatch reduction in any bycatch reduction plan (where complex contingent human behavior must be quantified) cannot be known *ex ante*. It requires monitoring and/or experimental trial. That said, for heuristic purposes we attempt to illustrate a plausible qualitative outcome using a simple behavioral model to simulate the evolution of bycatch patterns. This is intended only to inform intuition. Rather than presenting a complicated analyses having large structural uncertainty (not all relevant variables are accounted for or represented correctly, and where human behavior is often ignored), we decided on the honest presentation of a humble qualitative result

that matches what can realistically be known without experimental implementation. Our parameterization is transparent and intended to be conservative.

We examine a simple behavioral self-correcting model as a qualitative guide to model the action of cumulative incentives to lower bycatch. The model assumes that a vessel's motivation to improve behavior will be directly related to its recent bycatch rate. The allocation-transfer simulation described in 2 above (fig. 4) was combined with an incentive model that was fit to reflect "maximum" intentional changes on the order of 25% of the observed changes in bycatch rate. That is to say, that *the model is parameterized so that the directional changes in bycatch rate are maximally 1/4 the magnitude of historically observed variations in bycatch rate*. This was reckoned to be a conservative figure.

Note that we did not literally assume a 25% reduction in bycatch. Rather we scaled the "maximum allowable" or upper bound amount of bycatch reduction that could possibly be effected through behavioral changes to be some conservative fraction of the observed historical variation without incentives (the magnitude of changes actually observed). That is, we used observed variation as a benchmark to scale possible behavioral changes accordingly. Thus, if bycatch varies historically by X percent, our conservative assumption is that 25%X is the maximum possible change in bycatch that could be attributed to behavior. More specifically, we analyzed the historical data by taking the median values of the changes for individual vessels across many years. The minimum of these median values was around 50%, so to be conservative we set half of that, or 25%, as the maximum possible reduction in bycatch attributable to behavior (with the majority of behavioral changes in the simulation being far less). Furthermore, this 25% is scaled by the relative values of Q for each vessel: vessels with a lower value of Q (i.e. relatively high bycatch) were simulated to have greater reductions in bycatch due to a greater incentive to make up for bad performance in the year before. Given the formulation for Q (as $4/3 p + 1/3$), the maximum reduction was actually 18.75%, and the minimum reduction was 9.375%. Again, these are only simulated reductions in bycatch, based on a conservative estimate of the amount of reduction that individual vessels are capable of, when properly incentivized. It is likely that larger changes due to active incentives will be witnessed. Again, this is intended as a somewhat conservative guideline.

Briefly, the incentive to reduce bycatch is modeled as a simple function of bycatch rates as follows. We used actual vessel bycatch rates and defined the simple incentive function:

$$\text{incentive} = 1/[1+Q] * \psi,$$

where $\psi = 1/4$ in this simulation to represent the plain assumption that 25% of the variation in observed encounter rates can be due to behavior. Here the

$$\text{incentive multiplier} = 1 - \text{incentive}.$$

And the cumulative incentive multiplier CIM is simply

$$\text{CIM}(t+1) = \text{CIM}(t) * \text{incentive multiplier}$$

And,

$$\text{Market incentive adjusted bycatch} = \text{CIM}(t) * \text{actual bycatch at time } t.$$

These dynamics are then incorporated into the simulation in II- 2 above, and run forward to produce the following results shown in Figure 8 and Figure 9. The results are similar but more dramatic than the earlier simple allocation and trading results (Figure) without rational incentives to improve relative standing in the fleet with respect to ITEC allocation.

It is important to note that even though the model was roughly scaled to fit observed variation, the results are highly dependent on the basic model assumption of self-correction and should be treated only as a plausible scenario to guide expectations. Actual implementation of the plan should allow one to retrospectively construct a more accurate incentive model, and the flexibility of model parameters should allow adjustments to suit desired performance criteria.

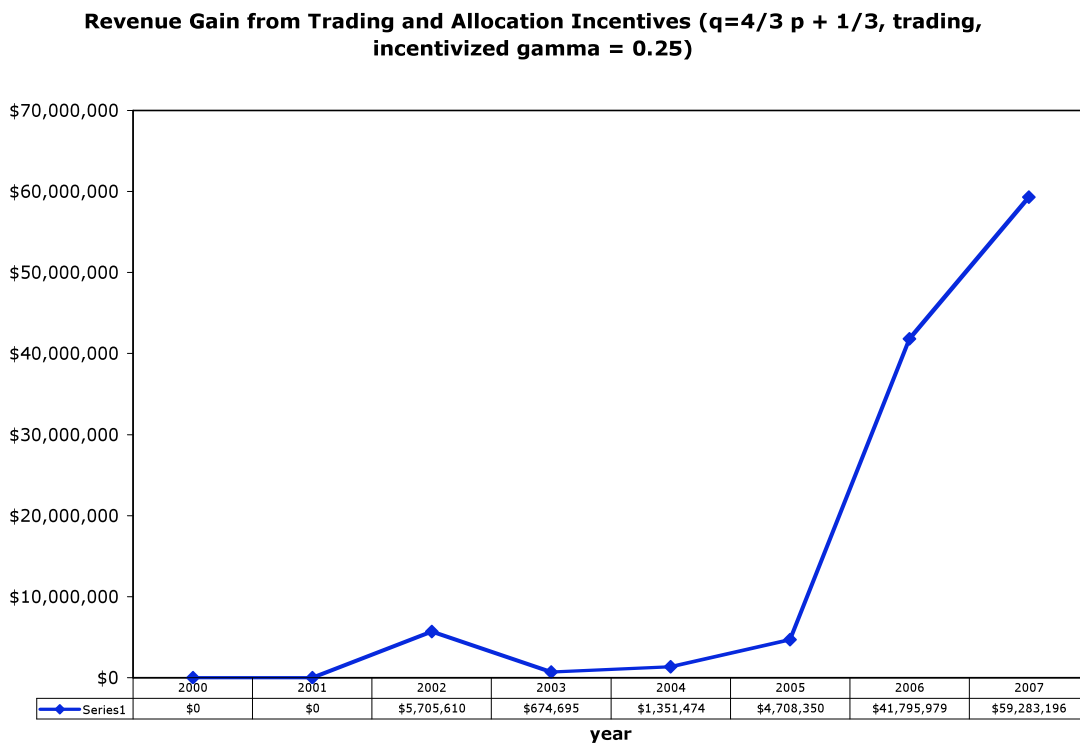


Figure 8. Hypothetical revenue gain (i.e., avoided revenue losses due to unharvested Pollock resulting from hitting a hard cap) for the Inshore sector from

trading and allocation incentives to avoid bycatch assuming a sector maximum hard cap of 38,059.

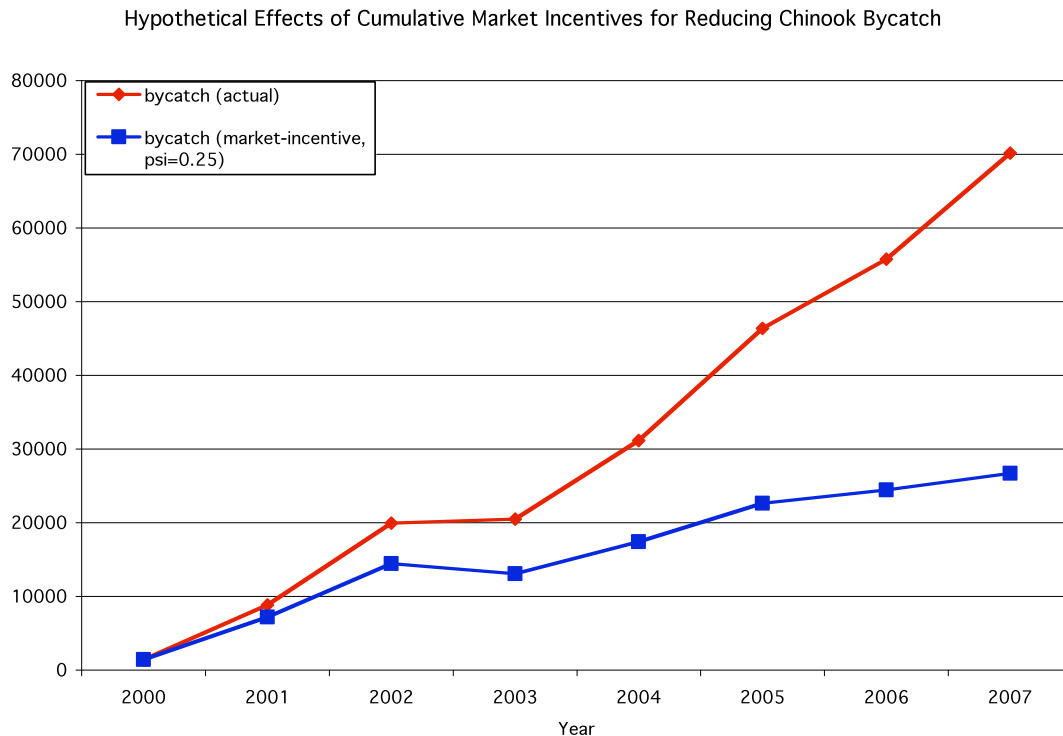


Figure 9. Effects for the Inshore sector of cumulative market incentives for reducing Chinook salmon bycatch under the PPA hardcap.

V. MONITORING AND PERFORMANCE MEASURES

V.1 How will the implementation of the plan be monitored over time?

The infrastructural aspects of implementation (of computing reallocation, trading interface, verification and back office accounting) will be done by a legitimate third party as discussed above. We expect that Sea State will continue to monitor to provide live spatial information as to by catch rates which will be used by the fleet as well as by the exchange to provide market-relevant information and live verification of credit balances.

One expectation for the plan is to have reduced variance in bycatch rates: we expect vessels to adopt the strategies (e.g. fishing time and location, equipment) of the vessels with the lowest bycatch rates in order to increase ITEC allocations. These behavioral changes (trackable by questionnaire) along with reduced variance are two ways to monitor the effectiveness of the plan to reduce bycatch.

A decrease in salmon encounter (over the short-term or long-term) would not necessarily be a valid indication that the program was successful in incentivizing vessels to reduce

bycatch. Without independent stock assessments of Chinook in the BSAI fishery, it would be incorrect to assume that lower-than-average (or higher-than-average) levels of salmon encounter indicate the success or failure of an incentive plan. Similarly, the lack of a well-investigated causal link between Chinook bycatch and returns to Western Alaskan rivers would also disqualify any assessments of the effectiveness of the program from that perspective. This speaks to the necessity of gathering base line data on Chinook runs so that more definitive scientific results can be produced. I believe this kind of fundamental research should be carried out and that all parties would benefit from a better scientific understanding.

However, acknowledging these problems, we still need to be pragmatic. Given our current state of knowledge, the first indicator (variance in bycatch rates) seems to be a reasonable method for monitoring the plan: the cleanest fishing vessels have no reason to change their behavior to *increase* bycatch rates, so in the worst case scenario, their bycatch behavior would remain the same. Meanwhile, the vessels with the worst bycatch rates would seek to improve their behavior (and reduce potential ITEC allocation decreases) by reducing bycatch. Thus, the variance can plausibly be expected to decrease over time.

Additionally, as the data in Figure 3 indicates, historically, bycatch rate and variance are closely related. One could imagine constructing an index that measures significant departures from this relationship in the right direction. Such a departure might be a preliminary indicator that an incentive plan is working.

V.2 Research Funding

Information regarding independent stock assessments of chinook in the BASI fishery would help to directly evaluate the performance of the Legacy Market Incentive Plan in reducing bycatch. Thus, gathering basic information on Chinook population dynamics (eg. runs counts and stock assessments) to better understand the impacts of the Pollock Industry on Chinook populations should be a priority to validate industry actions in bycatch reduction. Therefore, we suggest an industry sponsored research component to monitor and evaluate the Legacy Market Incentive Plan performance in reducing bycatch as well as to obtain basic information on Chinook population dynamics.

VI GENERAL QUESTIONS AND ANSWERS:

- *Can the plan be gamed by any of the companies?*

Any plan could potentially have loopholes that could be exploited by companies or individual vessels. We believe that with a legitimate outside firm handling the allocation accounting, verification and trading of ITEC, that Legacy Market-Incentive Plan is, for the most part, resistant to manipulation. Reallocations of ITEC are based on a vessel's relative bycatch performance, which is a function of the full distribution of sector-wide average bycatch rates. This fact makes it extremely difficult for individual vessels or

small groups to manipulate. Also, CFTC certification makes such manipulation illegal under current statutes. Direct manipulation may be more likely to arise if allocation, ITEC accounting and trading were done in-house (non transparently). Thus, we suggest the use of a properly certified third-party firm to handle transfers, verification, accounting and ledgers (the front and back office operations).

Having an established trading infrastructure in place will provide a site for other transactions that industry may find desirable and convenient (such as a market place for posting and transacting bids and offers on intra-coop Pollock leases, or the negotiation of futures or option contracts to moderate risk and ITEC purchases). The possibility of using Scripps name to an exchange specifically aimed at creating organized rational markets that help to reduce industry risk and promote sustainability and conservation may be a reasonable approach for discussion. Membership with this exchange could carry an important marketing advantage similar to an MSC certification, and may indeed become part of that certification. There are currently a number of firms that can be approached who provide similar services (eg. CCX).

One potential source of manipulation that we saw and addressed was the possibility of firms employing strategies to evade the Dynamic Salmon Savings rule. Our solution was to implement a provisional salmon saving rule which prevents such abuse (the PSSR is askin to a maximum withholding tax in dynamic salmon savings). This rule ensures that vessels are unable to evade certain restrictions on ITEC trading (such as Dynamic Salmon Savings). We encourage both the SSC and the public to examine the plan for weaknesses, so that it may be continually revised and strengthened over time.

- *Can dynamic savings be gamed, especially by large companies?*

If we assume that the estimation of the number of needed credits is accurate (neither too low to cause credit shortages, nor too high so as to be ineffective), then it does not appear as though Dynamic Salmon Savings (DSS) can be gamed. The provisional rule prevents companies with multiple vessels from evading DSS by shuffling around credits before they are “retired”. The only way I can see that DSS can be gamed would be to manipulate the estimate of the number of needed credits. The only way this works in the favor of a large company would be to make the estimate too high (reduce the effectiveness of DSS). Based on the current method for constructing the estimate, this would be accomplished by elevating bycatch early in the B season. This does not seem like a very rational strategy, even for large companies, since the gains (reduced DSS) are shared across all vessels, whereas the costs (spending extra credits in the current season AND reduced allocation in subsequent years from increased bycatch) are only seen by vessels manipulating DSS. The gains would need to outweigh the costs for this strategy to be viable, which seems highly unlikely.

- *How will this plan interact with the UIP/FIP?*

The Legacy Market-Incentive program would operate throughout an entire sector. It would not be implemented with any other plan (UIP/FIP or otherwise) in the same sector.

Trading of ITEC across sectors operating under different programs would be restricted as described in the report: sectors with Dynamic Salmon Savings can sell credits to any other sector, but may only buy credits from another sector with a Dynamic Salmon Savings rule with the same maximum Salmon Savings Rate.

- *To what extent does this analysis rely on the assumption that each vessel acts as an independent entity? How will the results change when some vessels are able to collude through their parent company, while other vessels lack an opportunity to collude?*

Vessels would collude if it is in their best interest to do so. Because the mean and variance in bycatch rates is relatively independent of the performance of any individual vessel or group of vessels, it would be very difficult to manipulate the mean and variance to affect ITEC reallocations.

The ability of vessels to collude will primarily be limited to having no-cost credit transactions. (I.e. vessels belonging to the same parent company would not charge each other for credits.) However, both transfer rules would still apply to individual vessels: vessels would be restricted to purchasing a fixed fraction of their original allocation, and Dynamic Salmon Savings would apply. Because vessels in a parent company see less risk by operating this way (i.e. with free credit transactions), the entire company would be treated as an individual entity for the purposes of ITEC reallocation.

- *Some vessels currently operate near their physical or regulatory capacity for pollock. If these vessels fish clean and acquire ITEC, they can sell the excess ITEC to other vessels, but cannot lease additional pollock to fish on their own vessel. How will this asymmetry affect the results? Will it tend to lower the price of ITEC?*

This asymmetry has the potential to lower the price of ITEC: however, we believe that the trading rules presented in the report prevent this situation from nullifying the incentives to reduce salmon bycatch. During years of mid- to high-salmon encounter, demand for ITEC would keep prices high. During years of low-salmon encounter, Dynamic Salmon Savings should lower the available supply of credits and also keep prices high.

- *Does the form of the distribution of bycatch rates affect the effectiveness of the plan in any way?*

Bycatch rates have a distribution that look like a gamma distribution (as opposed to a normal distribution). The specific ideal form of the distribution will not affect our results or the incentives, though it will affect how one interprets things like z-scores. The incentive structure of the program should not be dependent upon the shape of the distribution of bycatch rates. The lack of symmetry does pose some computational problems with operating under a fixed hardcap, which we resolve through a rescaling (as described above).

GLOSSARY OF TERMS:

1) Intrinsic Fishery Value = $\left[\frac{\text{(sum value of sector Pollock remaining at time } t \text{ to the end of the season)}}{\text{(sum sector actual bycatch remaining to the end of the season)}} \right] \times$
[fraction of vessels in sector still fishing]

Note: this last term averages in the 0's for the value when a vessel fills it's quota.
Thereby giving a weighted average to reflect the differences among vessel allocations and quota.

2) Instantaneous Expected Fishery Value = (value of Pollock remaining at time t) /
(cumulative bycatch rate at t)

3) Bycatch rate = #Chinook/mt Pollock

4) Back-of-the-envelope Upper Limit Bycatch Rate: $38,000 / 600,000 \text{mt} = 0.063 =$
bycatch rate suggested by 38k HC and TAC of 600,000 mt for the inshore sector.

Appendix A: Technical Issues Regarding the Allocation Formula

Here we examine several technical issues related to the allocation formula (1)

$$P_{s,y,i} = \alpha + \beta P_{s,y-1,i} + \gamma Q_{s,y-1,i}$$

1) Scaling:

The proportional allocation formula (1) is transformed into number of credits as follows:

$$\text{Credit Proportion}_i = P_{s,y,i} * IFQ_{s,y,i}$$

Because the sum of this product across vessels does not necessarily = 1, it is necessary to divide by the sum of these credit proportions over all active vessels in the sector, $\Sigma \text{Credit Proportions}$. That is,

$$\# \text{Credits}_i = \text{Credit Proportion}_i / (\Sigma \text{Credit Proportions}) * \# \text{sector credits for the season}$$

Note that this scaling is necessary due to variation in vessel size and a fixed hardcap. In a simplified example with only two vessels (one large and one small), if the large vessel does well and increases its proportional allocation factor by 10% and the smaller vessel decreases its proportional allocation factor by 10%, the 10% increase for the larger vessel is a larger change in credits than the 10% decrease for the smaller vessel. Since it would be impossible to distribute more credits than the fixed hardcap, it is clearly not possible to actually give the larger vessel 10% more credits in the second year. Instead, the number of credits is scaled so that the credits that are distributed are done so in the proper ratios for each vessel.

2) Upper and lower bounds for proportional allocations:

When the weightings are such that $\alpha = \gamma$ the lower and upper bounds on P will depend only on the bounds for Q. Thus, for both equations (2) and (3) the bounds for P are the same $[2/3, 4/3]$ when the bounds for Q are $[1/3, 5/3]$ (obtained when $Q = 1/3 + 4/3 p_i$). The following bounds for P apply to the following parameter settings for δ and ε in Q: (in order of wide to narrow limits):

$$[1/2, 3/2] \quad Q = 2p_i$$

$$[2/3, 4/3] \quad Q = 1/3 + 4/3 p_i$$

$$[3/4, 5/4] \quad Q = 1/2 + p_i$$

When weightings are $\alpha = 0, \beta = \gamma = 1$ (Case 4), the upper and lower bounds are undefined, but can be set arbitrarily as absorbing boundaries to a random walk. They are independent of Q.

3) Specific forms for the penalty function p:

In general p can be any function having a range from 0 to 1 that rewards low bycatch behavior and that penalizes high bycatch behavior. The performance measure chosen here involves computing a z-score for bycatch rate and converting via linear scaling. Vessels with z-scores less than -2 receive a p of 0, and vessels with z-scores greater than 2 receive a p of 1. Vessels with z-scores in between -2 and +2 have p computed as $p = z/4 + 1/2$. Note that this penalty function provides equal incentive for the vast majority of vessels. Here, the incentive is directly related to the slope of the penalty function: a greater slope indicates a greater change in credit reallocation for the same change in bycatch rate.

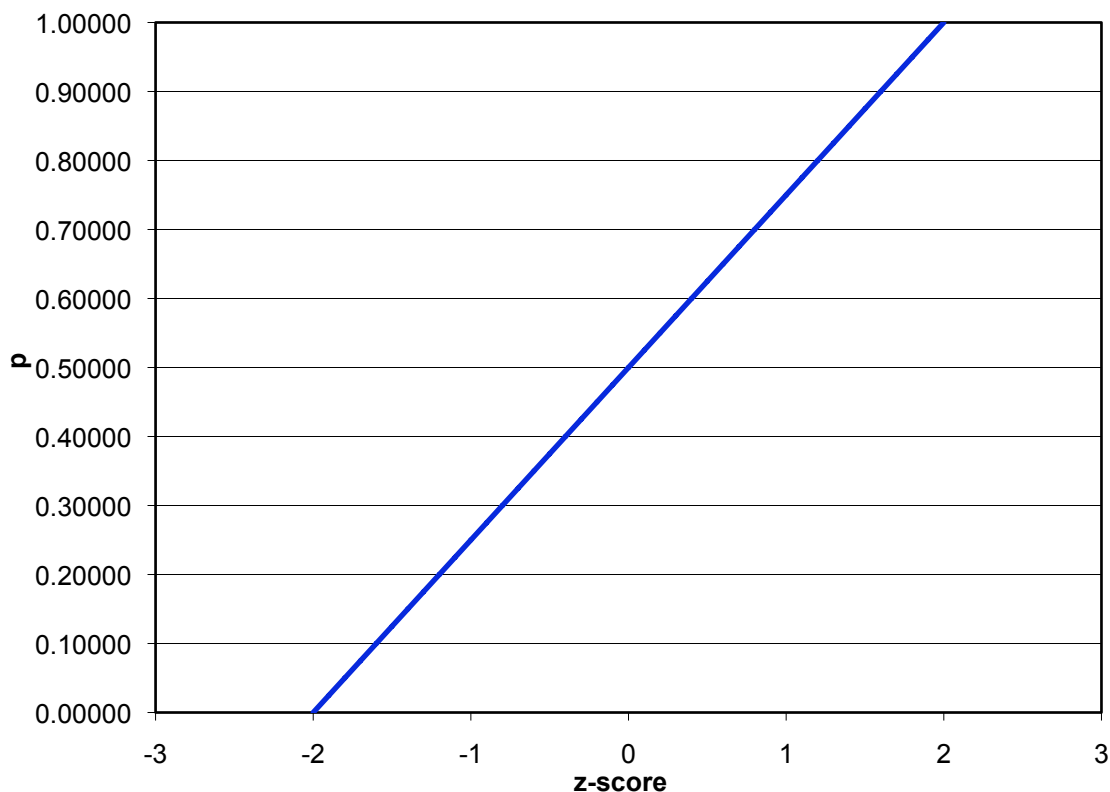


Figure A- 1. A linear penalty function truncated at z-scores of +2 and -2. Because the slope of the penalty function is equal for all z-scores, all vessels have equal incentive to reduce bycatch regardless of their position in the pack.

An alternative penalty function was considered that uses each vessel's z-score to compute a cumulative p-value based on a normal distribution. This penalty function would create the highest incentives in any year to the most vessels. These are the vessels in the middle of the pack can move up and down in Q value more quickly than those at the extremes. It also protects vessels that are at the extremes (in particular the lower extreme of high encounter rates). This is a way to helping to buffer against bad luck. That is, with this form of Q incentive to improve is large for the most vessels, and "occasional" accidents are buffered. The main disadvantage is that it exposes the average player to more variation. More incentive and more variation are two sides of the same coin.

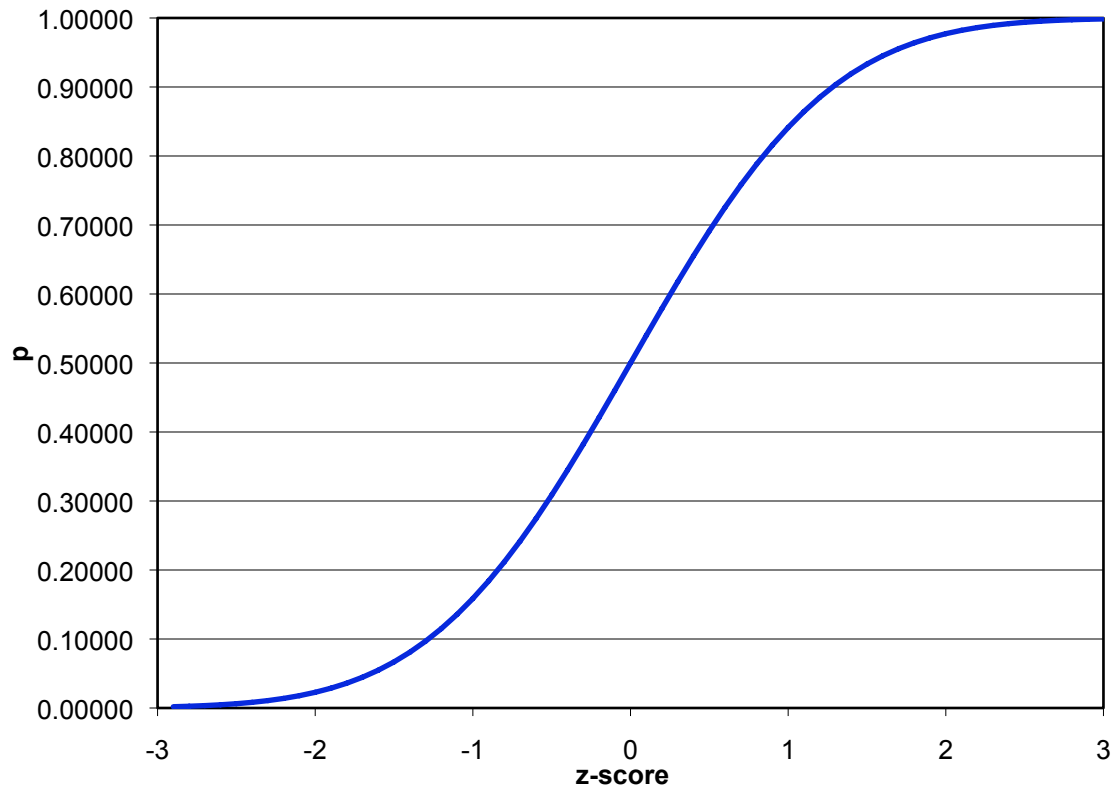


Figure A- 2. A penalty function computed as the cumulative p-value of the z-score. The slope is highest in the middle: therefore the largest incentives are for vessels in the middle of the pack.

Another possibility is to construct a function for Q that is flat in the middle so that average vessels will see very little change (the fleet will have less incentive) and so that the extreme bad luck year is more readily penalized. The advantage of this kind of function is that it will dampen the effects of random chance for the middle of the pack but at the cost of creating less incentive for the pack as a whole to improve. Overall, tinkering with Q makes more sense in systems that lack a legacy component to help buffer random events. Though modifying Q still might merit some additional experimentation, the main idea is to create incentives to shift the whole fleet over to have lower bycatch from year to year. That said, the real issue is not so much what the p-value is (how sensitive it is to changes in z-score) but how the "allocation" actually varies, and the legacy system gives some buffering capacity there.

3) Computation of z-scores:

The variance in bycatch rates between vessels can be attributed in part to *chance encounters* with patchy pockets of Chinook salmon (which is related in part to sample size effects or sampling variation and vessel size), and in part to *consistent behaviors* shown by vessels that appear to directly influence bycatch rates (caution in gear deployment, locational choices, timing etc).

One reasonable expectation of the Industry Market-Incentive Plan is for the distribution of bycatch rates among vessels to decrease over time as vessels exploit

the same behavioral changes to reduce bycatch rates. A larger proportion of the variation in bycatch rates would then be due to random chance and not intentional behavior on the part of vessels. Since z-scores are scaled to the standard deviation of the bycatch rates, large fluctuations in z-scores may become due to random chance. To mitigate this problem, we use an estimated standard deviation based upon a sector-wide bycatch rate. (equivalent to a weighted average of individual vessel's bycatch rates) This calculation is based on historical data across the Inshore Catcher-Vessel sector, the Mothership sector, and the Catcher-Processor sector. (Figure A- 3)

Because small vessels are subject to more sampling error (Figure A- 4), we also use a corrected standard deviation to reduce the effects of random noise due to vessel size. This random noise varies with the inverse square root of 1 + pollock allocation %. Thus, we correct standard deviation in the following way:

$$sd_i = sd * \sqrt{1 + \text{avg. pollock allocation \%}} / \sqrt{1 + \text{pollock allocation \% of vessel } i}$$

This adjusted standard deviation is then used to calculate the z-score for vessel i:

$$z_i = (\text{fleet wide bycatch rate} - \text{bycatch rate of vessel } i) / sd_i$$

Note that this calculation for z-score is of the opposite sign of the traditional calculation of z-scores. Thus, high bycatch rates (corresponding to poor performing vessels) map to low (i.e. negative) z-scores and low bycatch rates (corresponding to the best performing vessels) map to high (i.e. positive) z-scores.

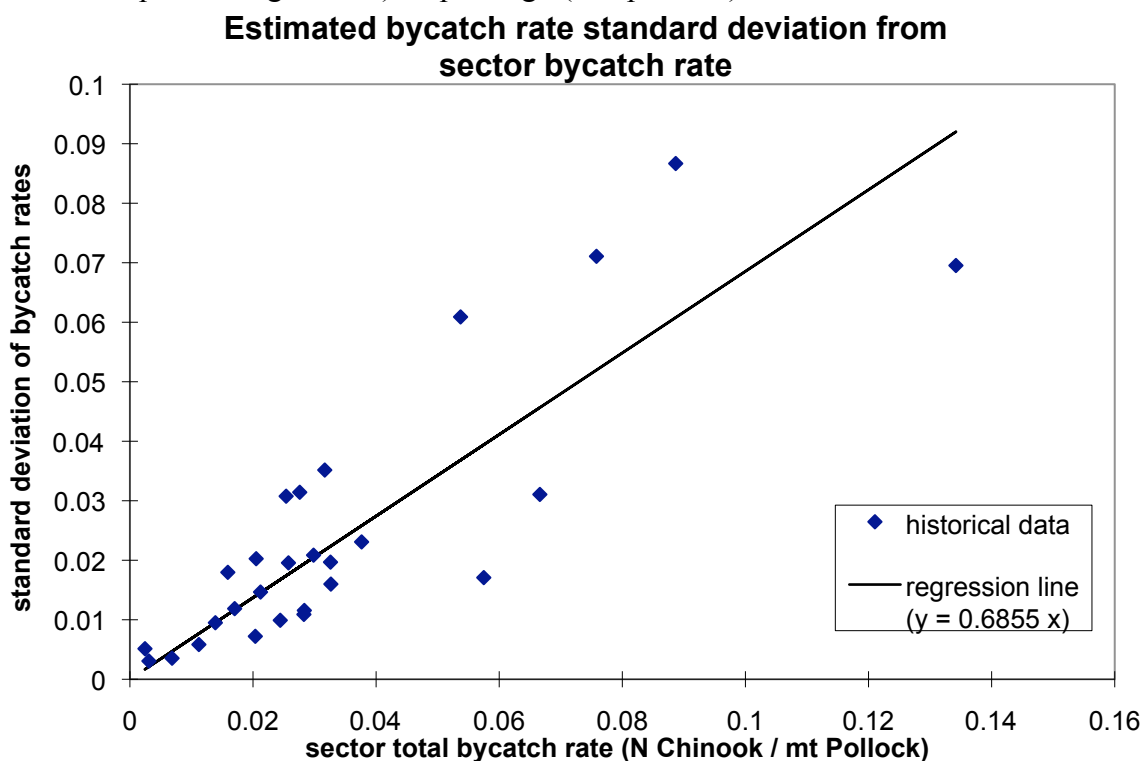


Figure A- 3. standard deviation of bycatch rates as a function of sector total bycatch rate. (Annual data from multiple sectors. Provided by Sea State).

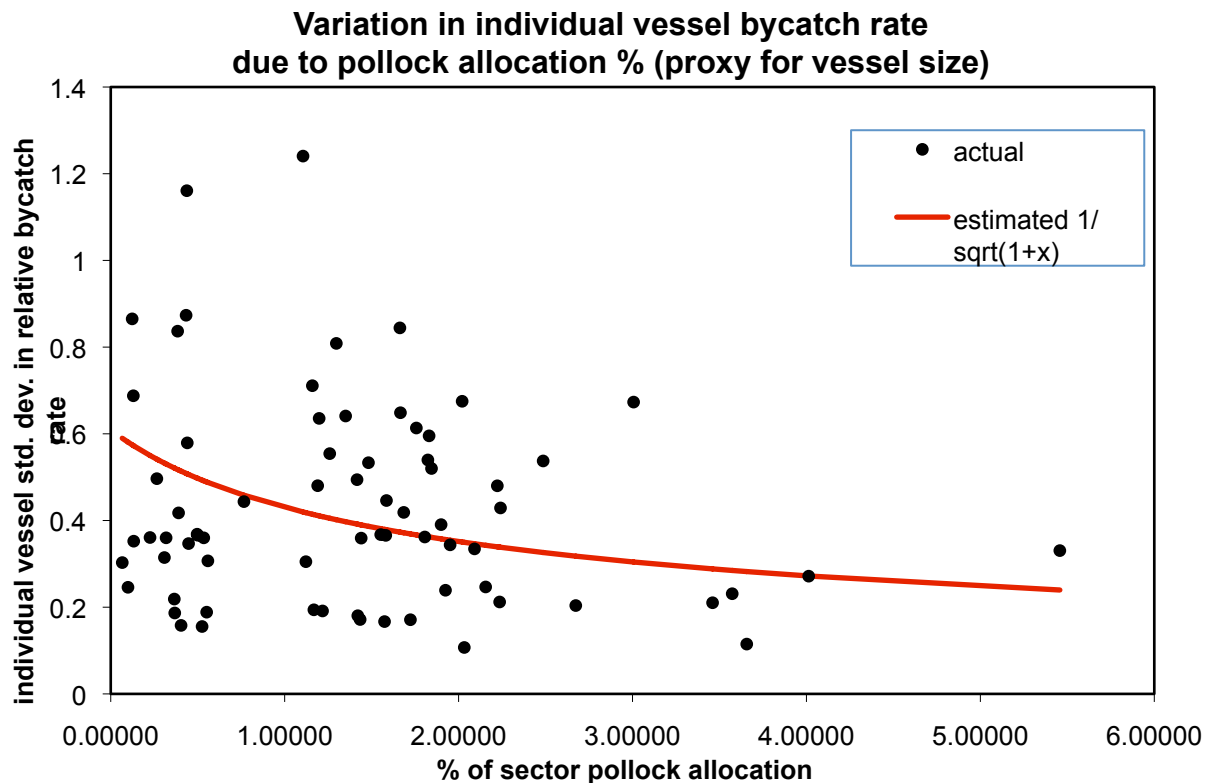


Figure A- 4. Smaller vessels show higher variability in bycatch rates. (annual data)

5) Convergence:

The legacy weighting not only affects the magnitude of the variance in credit allocations P , (a smaller γ results in lower year to year variation in P), but it also affects the rate at which one can move in the pack in terms of allocations due to directed behavior. The graphs below (Fig A-3a,b) show the extreme cases realized by the two different weighting schemes: (1/3, 1/3, 1/3) and (1/4, 1/2, 1/4). There is little substantial difference between these schemes and

If one uses the weighting scheme (1/3, 1/3, 1/3) the legacy component receives less weight than (1/4, 1/2, 1/4), and incentives are increased (larger change in allocations from year-to-year). However, fluctuations in allocation due to random noise affecting bycatch rates are similarly magnified and should be taken into account when choosing a weighting system

A degenerate form (eqn. 4) of the Legacy Allocation formula creates equal incentive for the same performance regardless of the previous season's credit proportion. This form has changes in credit proportion computed solely based on the current season's relative bycatch rate. In order to achieve the same asymptotic bounds of $[2/3, 4/3]$, we set hard limits on the values of P , the credit proportion.

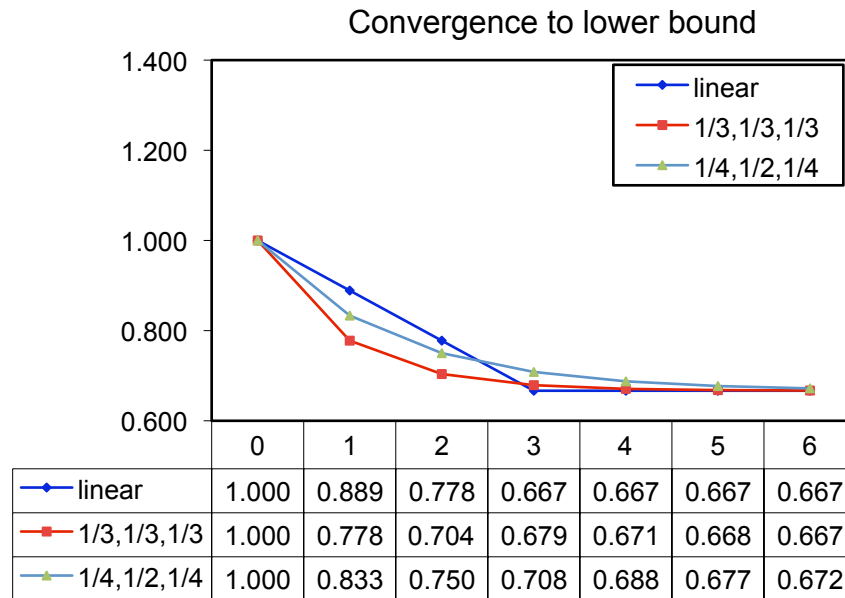


Figure A- 5. Comparison of two weightings of the legacy component. Assuming $p_i=0$, worst case. The more heavily weighted legacy component converges slower.

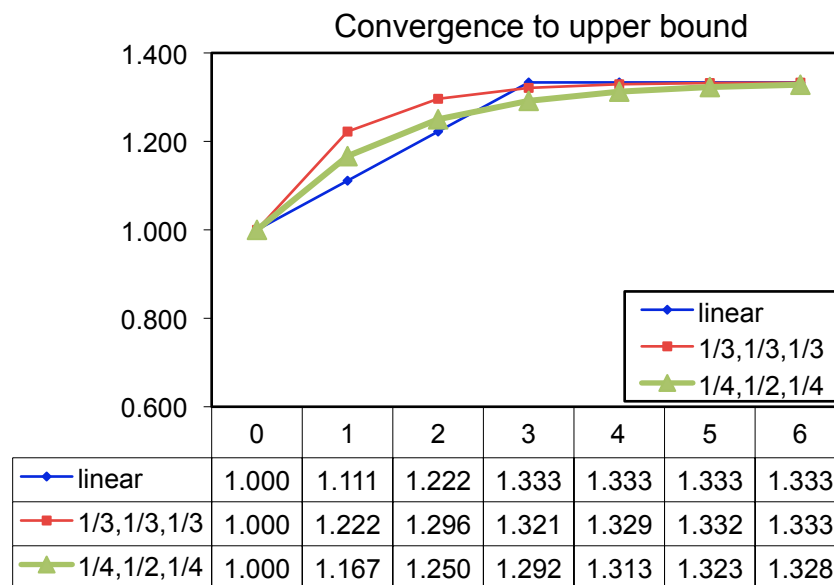


Figure A- 6. Comparison of two weightings of of the legacy component. Assuming $p_i=1$, best case. The more heavily weighted legacy component converges slower.

6) Incentives in the False Legacy Model:

$$P_{s, y, i} = P_{s, y-1, i} + Q_{s, y-1, i} \quad (4)$$

The "false legacy allocation" (eqn 4) does not contain cumulative incentives to continue improving bycatch rates. To see this, simply notice that having a bycatch rate near the middle of the pack results in no change in proportional allocation ($Q=0$). This property poses a problem for vessels that initially do well (have low encounter rates; improving proportional allocation) and then "slack off": as long as these vessels do not have bycatch rates *higher than average*, their proportional allocation factor will *not decrease*.

In addition, because of the fixed upper bound ($4/3$) on the proportional allocation factor, vessels that are at that upper bound *have no incentive* to have the lowest bycatch rates. As mentioned earlier, these vessels will not experience a decrease in proportional allocation as long as their bycatch rates are better (i.e. lower) than average.

Perhaps the more problematic issue is those vessels who are at the fixed lower bound ($2/3$) for the proportional allocation factor. These vessels may actually improve their bycatch rates from what they were before, but will see no change in proportional allocation factor unless they can bring these bycatch rates to be better (i.e. lower) than average. Thus, their incentive to change fishing behavior may be significantly reduced, as only a major change in bycatch rate can alter their position.

Appendix B: Technical Issues Regarding the Fixed Transfer Tax and Dynamic Salmon Savings

1) Fixed Transfer Tax:

With a Fixed Transfer Tax (FTT), a fixed percentage of credits are retired for every ITEC transaction. For our simulation, we used a FTT rate of 20%: if a vessel wished to buy 100 credits, 20% or 20 credits would be retired as the “transfer tax”, so that a total of 120 credits would be removed from a seller’s pool of ITEC, but only 100 would be transferred to the buyer.

2) Dynamic Salmon Savings:

Under a Dynamic Salmon Savings rule, a percentage of a vessel’s remaining credits are retired when that vessel finishes fishing its Pollock quota: this percentage is the Salmon Savings Rate (SSR). To prevent vessels from selling credits before finishing fishing and avoiding having credits retired, it is additionally required that vessels who sell credits before finishing fishing reserve the appropriate fraction of credits corresponding to the SSR (or the maximum upper bound on SSR if the SSR has not yet been determined). In our simulation, we used 40% as the maximum upper bound on SSR.

(i) Provisional Salmon Savings Rule:

Note that prior to the completion of fishing and having credits retired based on the SSR, vessels may still transfer credits provided that an appropriate number of credits are set aside to cover eventual retirement.

For example, if a cap is set so the largest Salmon Savings Rate is 40% (a number that historically will not limit the harvest), then prior to setting the SSR, boats that have finished fishing early can only sell up to 60% of their remainder credits. This means that if a vessel has wishes to sell 60 credits early in the season, it must keep 40 ITEC in reserve until the SSR has been determined.

Alternatively, if the SSR has been determined to be, say, 20%, vessels that wish to sell credits before fishing the entirety of their Pollock allocation must retire an additional 25% credits for each transaction. For example, if that vessel sold 80 credits, it would retire an additional 25% or 20 credits. This fraction is equivalent to applying the SSR of 20% on a vessel that finishes fishing Pollock with 100 credits remaining: for this hypothetical vessel, 20 credits would be retired, leaving it with 80 credits to sell, exactly the same as in the example.

(ii) Calculating a savings rate:

Numerical experiments with the Inshore daily data suggest that calculating the savings fraction when 2/3 of the sector Pollock quota are caught (2/3 sector TAC) gives the best result, in terms of estimating the credits needed to complete the season. This is the “estimated total sector by-catch for the B-season.” This estimate normally occurs between August 29 and Sept 16 (see figure and table below). This tends to

happen later in low salmon abundance years (when fewer transfers are needed) and occurs earlier in moderate to high abundance years.

The “estimated number of surplus credits” in the table below is the (current number of credits for the sector on the date that the salmon savings rate is calculated) - (estimated total B-season bycatch for the sector + buffer). Here the buffer is 5000, to account for error in the estimates of total sector by-catch.

The final “allowable salmon savings rate” would then be (the number of estimated surplus credits) / (current number of credits for the fleet). It is called an “allowable salmon savings rate” in that under this SSR, the Pollock harvest for the sector would not be limited by the availability of salmon encounter credits. These numbers are shown in the blue region of the table below. Notice that in high abundance years the SSR is 0%, and in low salmon abundance years the allowable SSR can be as high as ~79.6%. That is, in year 2000, we would be confident of fishing the entire Pollock quota (with margin for error) if the SSR were set at 79.6%. However such a high rate would put a damper on trading before the rate was posted (albeit, in 2000 no transfers were ultimately necessary). Alternatively, we can set a cap on this rate (say 40%), so that early trading can occur more readily if needed. Then any year where the estimated SSR is above 40% would automatically set the SSR at 40%. Agreeing to retire up to 40% would be thought of favorably by the Chinook salmon interests.

	Dynamic Salmon Savings Rate (at end of B season)						UNKNOWN
year	A	B	C	D	E	F	G
2000	16-Sep	37001	254	7540	29461	79.6%	711
2001	11-Sep	31578	277	7770	23808	75.4%	2743
2002	5-Sep	24955	1655	21550	3405	13.6%	9622
2003	2-Sep	24318	256	7560	16758	68.9%	7144
2004	31-Aug	25859	1890	23900	1959	7.6%	20924
2005	29-Aug	21122	4142	46420	(25298)	0.0%	33734
2006	10-Sep	12182	3591	40910	(28728)	0.0%	21179
2007	2-Sep	14848	1465	19650	(4802)	0.0%	33813
A = date when 2/3 Pollock caught B = sector credits remaining (includes 100% carry-forward from A season) C = bycatch caught (up to the date in A) D = predicted total bycatch (for season) + buffer (computed as $D = 10 C + 5000$) E = estimated surplus credits (computed as $E = B - D$) F = allowable salmon savings rate (computed as $F = E / B$) G = actual total bycatch (for season)							

Table B - 1. calculation of SSR for the Inshore Catcher-Vessel sector for years 2000 - 2007

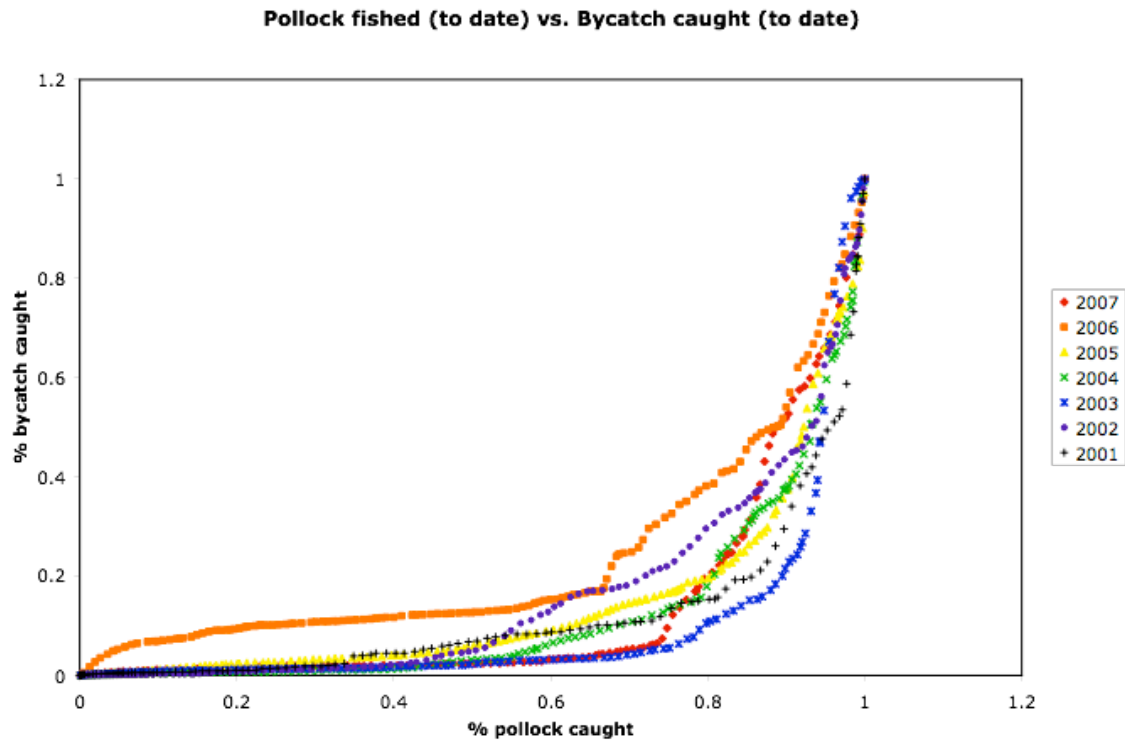


Figure B - 1. Cumulative bycatch as a function of % pollock harvested during the B season.

1) Simulation results:

The yearly data for quantities of ITEC retired as a function of yearly bycatch (a proxy for salmon abundance) under both the FTT and DSS schemes are shown in Figure B - 2 and Table B - 2. Not only is the total quantity of credits retired through DSS higher for this eight year period (2000 – 2007), but the number of ITEC retired is high in years of low salmon abundance: precisely when the potential for abusing extra ITEC is the highest! Conversely, the quantity of credits retired through FTT is highest in mid-abundance years: when the most transactions take place (due to a balance of availability and demand). Increasing the FTT rate to recover more ITEC has the potential of reducing credit transfers in mid-abundance years. The subsequent revenue loss can be extreme if a high FTT rate is chosen.

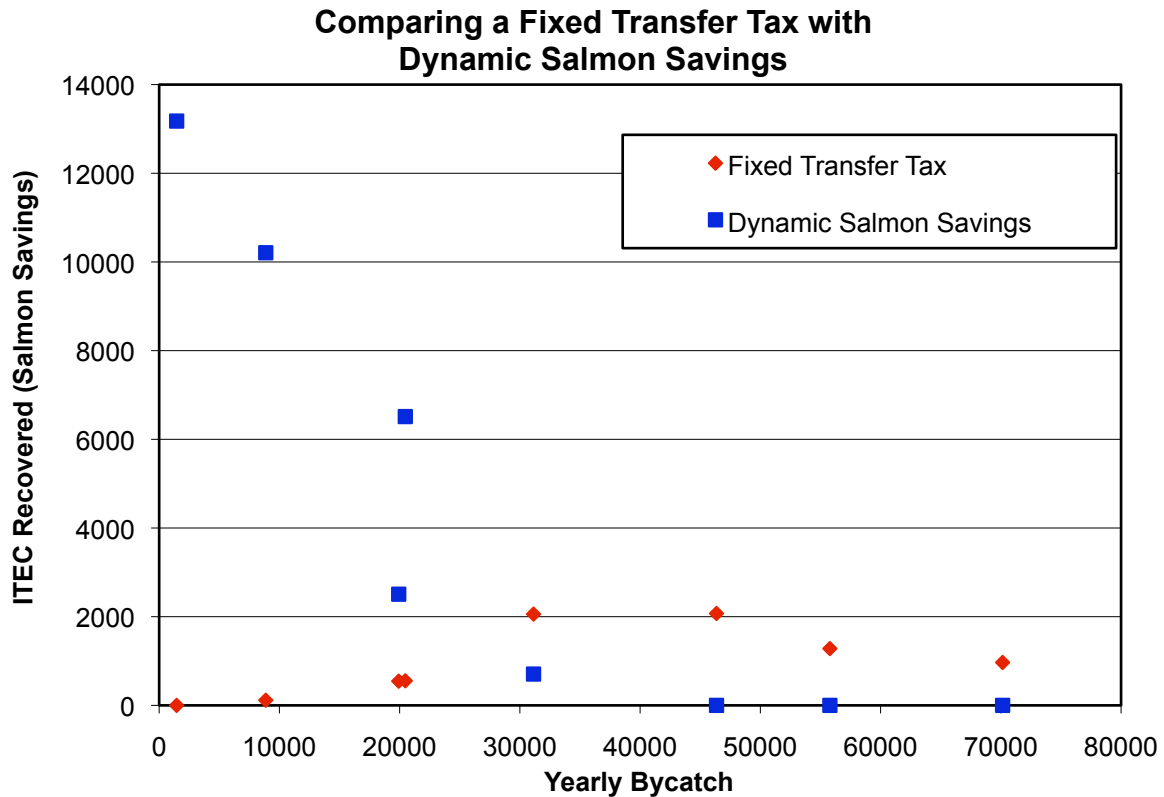


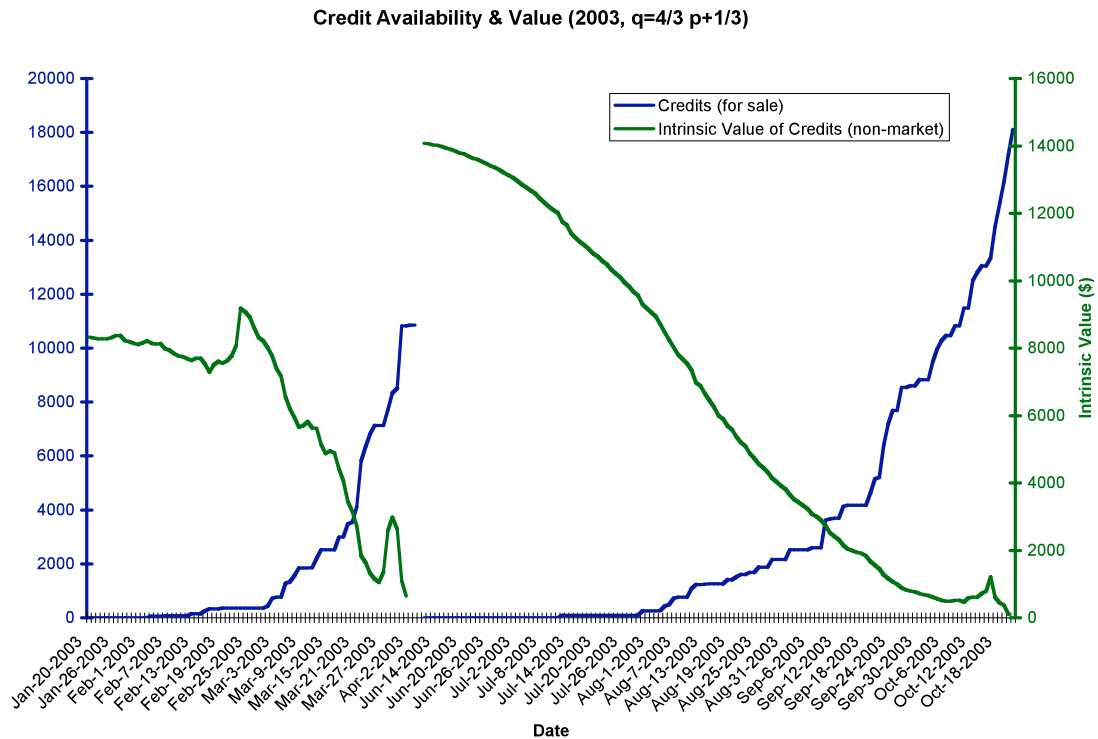
Figure B - 2. Number of ITEC recovered vs. yearly bycatch (proxy for salmon abundance) for two different sell-side transfer rules. More ITEC is saved during low salmon abundance years using Dynamic Salmon Savings.

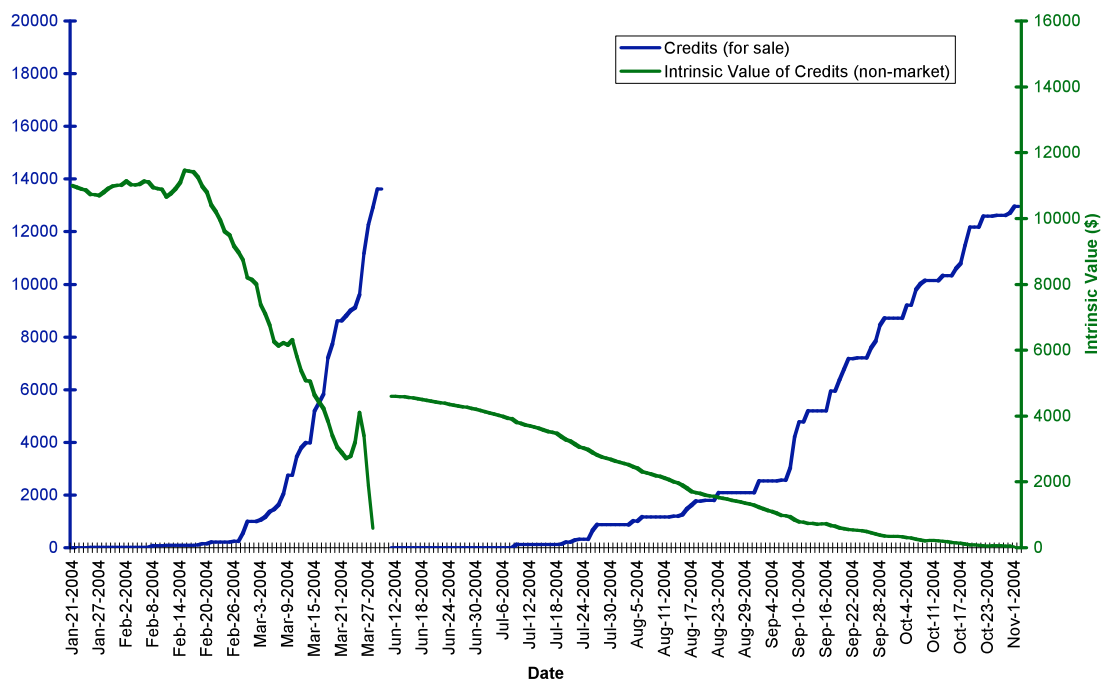
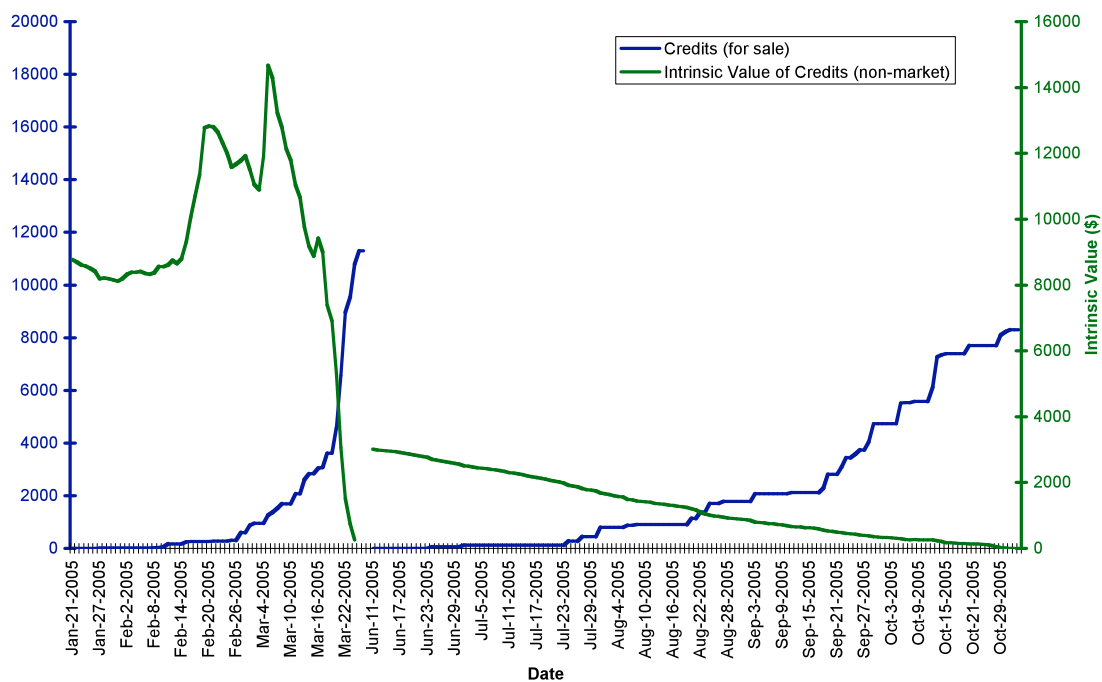
TOTAL BYCATCH	RETIRED CREDITS	
	Fixed Transfer Tax	Dynamic Salmon Savings
1454	0	13177
8866	116	10208
19923	546	2507
20471	554	6513
31136	2058	706
46354	2073	0
55782	1281	0
70148	968	0

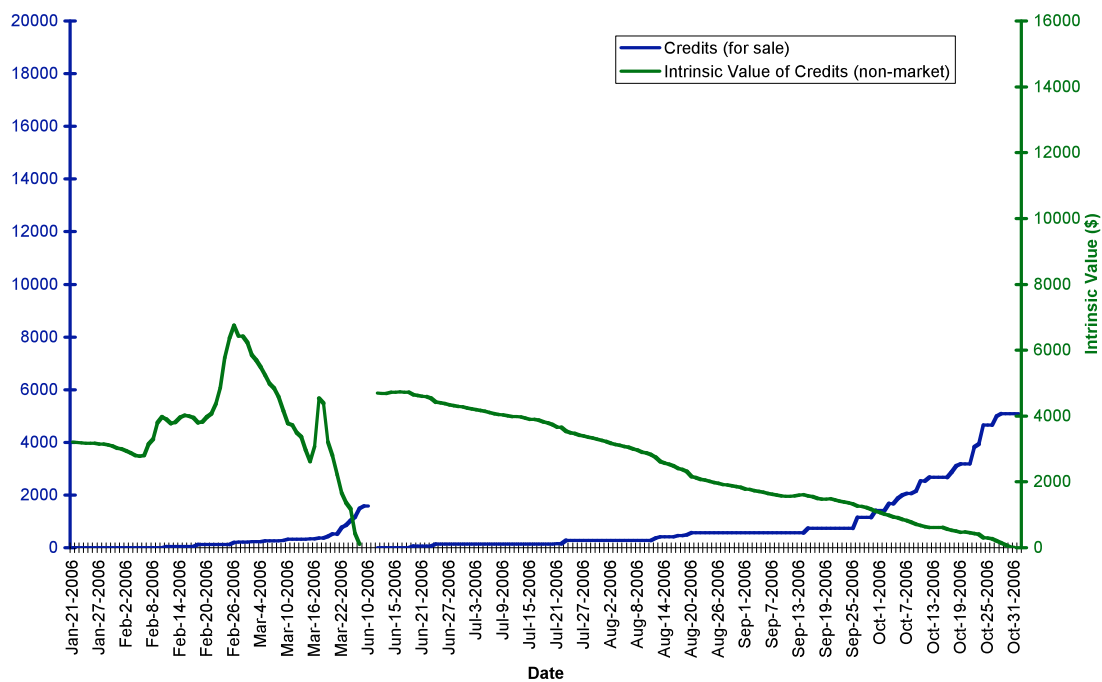
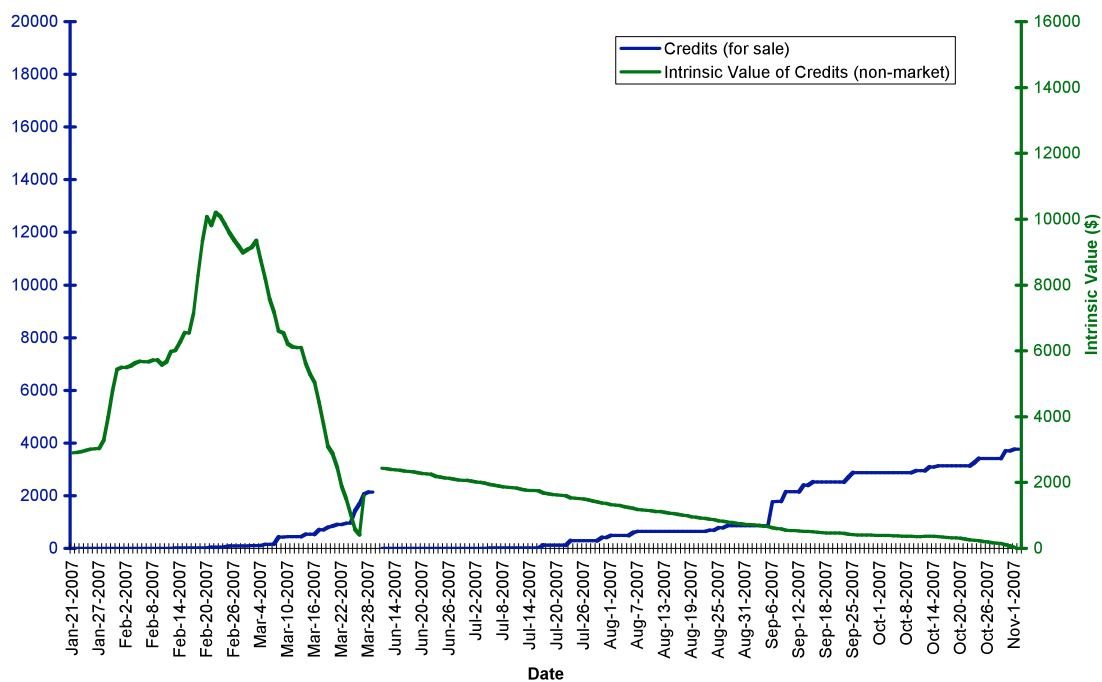
Table B - 2. Number of ITEC recovered vs. yearly bycatch (proxy for salmon abundance) for two different sell-side transfer rules.

APPENDIX C:

Temporal Analysis of Credits Supply and Intrinsic Fishery Value of Credits 2003 – 2007.



Credit Availability & Value (2004, $q=4/3$ $p+1/3$)Credit Availability & Value (2005, $q=4/3$ $p+1/3$)

Credit Availability & Value (2006, $q=4/3$ $p+1/3$)Credit Availability & Value (2007, $q=4/3$ $p+1/3$)

APPENDIX D: Auxiliary Features

- 1) It may be desirable to allow coops to impose a small 3% (not exceeding 3%) tax on all vessel credits allocations to create an Emergency Fund for extreme bad luck cases. This small "emergency fund" could be used to help bail out any vessel that the coop determines had genuine bad luck. Any remainder credits could be put on the market by the coop toward the end of the year to raise revenue. The bad luck event (as deemed by a coop, or better yet a sector) could be incorporated into the legacy system (or not) by adjusting the bycatch rate to not fully reflect this event (say cut the number in half for that tow). This can only happen occasionally per vessel (eg. once per vessel in 7 years).
- 2) Handling Chronic Offenders with the "2-Strikes Rule." (offered for consideration as an additional control for irrational players).

Chronic bad players who consistently have high bycatch rates relative to the rest of the fleet can place a drag on the overall performance of the fleet and harm its standing with regard to the Chinook salmon problem. They may be content with the minimal 2/3 allocation and be willing to wait until later in the season when credits could become more available as individual Pollock quota are filled and/or vessels are more comfortable with selling remainder credits at low prices. They may not care about the risk that next year may be a moderate to high abundance year, when credits will not be readily available, and may be willing to put their businesses at risk. Moreover as discussed, the **credits may be uneconomic for the worst players, because they are worth less in terms of expected return on Pollock** (having a lower intrinsic fishery value, see glossary and discussion in section II-5).

One possible way to handle this is to implement a 2-Strikes Rule that suspends credits trading privileges from such repeat offenders in all seasons until they can demonstrate that they can move out of the worst category in any one season. It is ultimately up to the industry to decide the details of this rule and what defines this worst category (eg. 3 standard deviations below the mean for 2 years running, or near the bottom of the list for 2 years running). Such a rule could quickly weed out the few worst players, and would likely only need to be in effect for some initial period. It has not been implemented in the current study.

To summarize, being a chronic offender is risky and uneconomic for several reasons:

- 1) They will tend to run out of credits quickly because of their lower allocation.
- 2) They will need to buy credits at a price that may not be economic given their high bycatch rates.
- 3) They risk losing trading privileges.

APPENDIX E: Questions from January 20 and Answers

Questions from Jan 20 (from the public and the Council), and answers from Sugihara and Ye:¹⁰

1) Q1: *Given that this is a market-based system which only works if a cap is low enough that there is a real chance it will be hit and therefore some people will need to buy credits, creating a financial incentive, how is there an incentive when the cap is unlikely to be hit in most years?*

The question raises an important concern but starts out with an initial statement that reflects two misconceptions.

First, based on historical data, it is clear that even in low and moderate abundance years (where the cap is not hit) many vessels would have run out of credits under the PPA hardcap. In high abundance years vessels run out of credits long before the cap is hit. Any vessel that runs out of credits suffers a potential catastrophic financial loss if the supply of ITEC is not there. A high hard cap is required because Chinook encounters are so highly variable from year to year. Even with a high cap and low encounters it is likely that most vessels will not want to risk selling credits until they have finished fishing, on the chance that they will not be able to complete their harvest. There is a lot of uncertainty, and this uncertainty (with the prospect of large financial losses that accompany an incomplete harvest) will keep ITEC supplies in check and support financial incentives (as will Dynamic Salmon Savings).

Second, There are 2 parts to the plan: 1) a legacy component, and 2) a transfer component (regulating trades). The legacy component regulates reallocation of credits based on bycatch behavior, and carries strongest incentives when Chinook encounters are low. This part of the plan works best if you are well under the cap.

The transfer component has provisions to maintain financial incentives (both short and long-term) during low chinook abundance years. In particular the Dynamic Salmon Savings Rule is designed to prevent an over supply of credits during low encounter periods, thus addresses the important concern raised by this question.

2) Q2: *How does a high cap assist the recovery in WAK [Western Alaska?] streams? It is not apparent what the incentive is to minimize bycatch below this level.*

A high cap with this Legacy Market-Incentive plan would be better in terms of protecting salmon, than a lower cap without this incentive program. Without incentives this lower

¹⁰ Note that the questions were addressed to John Gruver's Jan 20 2009 presentation of the Legacy Market-Incentive plan, which may differ in detail from the Recommended Industry Legacy Market-Incentive Plan in the SSC report. Our responses here refer to the latter. -GS

cap could always be hit. With incentives Dynamic Salmon Savings being proposed protects up to 40% of traded credits and is roughly 4X better than a 20% fixed tax on transfers in terms of the numbers of salmon protected.

3) Q3: *If the cap were 47,500 would there be an incentive program to stay within the cap?*

Not according to the C-2 Motion agreement. There would be no required incentive program with a 47,500 cap and the potential cost to Chinook populations would be large, especially during periods of low abundance.

4) Q4: *If the cap were set at 68,000 is there any type of step-down approach from this level that industry is willing to do?*

The beauty of the Legacy Market-Incentive plan is that it works cumulatively to promote individual incentives to cause the fleet bycatch rates to decline through time. Skill at bycatch avoidance should improve through time without having to readjust the hardcap. Getting this in place (as opposed to the alternative, which would be bad for everyone) is essential now.

5) Q5: *Could bad performers get credits from a non participating vessel?*

Credits can be sold to a nonparticipating vessel (sector) but cannot be purchased from one. If all vessels (sectors) adopt Dynamic Salmon Savings with the same maximum savings rates (same Provisional Salmon Savings Rule), then trades could occur in both directions. The effect of DSS on pricing and availability of ITEC means that trades will tend to occur within the groups: within the participating group and within the nonparticipating group.

6) Q6: *What about Buy Side limitations in addition to sell side limitations?*

The Legacy Market-Incentive plan suggests a buy-side limit of 1/3 to 1/2 above the vessel allocation. If a vessel has earned a low ITEC allocation then it's buy-side limit is lower. That is the buy-side limit moves in tandem with the ITEC legacy allocation. This coupling increases incentives in both components of the plan. Buy-side limits are intended to prevent abuse in low encounter years.

7) Q7: *Is there a limitation on transfers within cooperatives?*

The buy-side limit and DSS should apply to all transfers. This includes those occurring within cooperatives, or among vessels working for the same companies.

8) Q8: *Given that the incentive is to provide additional profit for boat, could an increase (or decrease) in pollock allocation be used rather than ITECs?*

Vessels who run out of ITEC can lease their Pollock to other vessels belonging to the same coop. Leasing out Pollock is a likely outcome if a vessel runs out of credits early, as ITEC will not be available then. The vessel that leases the extra Pollock is likely to be one that can realize the most profit (value) per ITEC. These are the cleanest fishing vessels (they get the most Pollock value per Chinook encounter). This means Pollock will move away from high bycatch vessels toward vessels that are cleaner, and this will increase fleet efficiency with respect to lowered bycatch.

9) Q9: *If punishment is based on a vessel's performance in relation to the mean, how is there an incentive to reduce bycatch as specified in the PPA versus just having similar bycatch?*

This could be a problem with revenue pool systems, but not this plan. In a transparent market-based system with many players it is difficult to control or nullify incentives. A handful of vessels cannot collude and have much effect on the outcome.

The Legacy allocation component rewards those who have lower by-catch relative to the mean with higher subsequent ITEC allocations. If you are better than average you get more ITEC as insurance against accidents and a moderate to high encounter years when credits are generally unavailable. If only one vessel does not go along with the plan to be average and fishes clean, that vessel wins. The rational incentive is to win.

10) Q10: *Is the impact different on single boat companies versus on companies with significant market shares?*

This is an excellent point.

We find that the risk is different for small boats than for large ones. Bycatch rates are more variable (less predictable) for small vessels than large ones (see figure A-4 of the SSC Report). This is a reflection of statistical sample size variation.

For boats that fish for companies, the financial incentives operate at the company level. For all practical purposes a company is like a single large vessel. For example, with regard to ITEC because zero-cost transfers can occur within companies, a company is for all practical purposes a large vessel.

We address the size issue explicitly in how the allocations formula is computed (Appendix A of SSC Report). The advantage of larger sized vessels is taken into account to rescale how allocations are made. This simple statistical normalization helps to “level the playing field” and distributes the risks involved more fairly among all vessels.