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

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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 abundance[1] and can act cumulatively through time to further reduce overall fleet Chinook encounter rates. 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 (currently under discussion) that further strengthen C-2 incentives and prevent potential abuses (eg. Dynamic Salmon Savings[2]).

> **Summary of the C-2 Motion PPA Incentive Requirements**
>
> 1) Provide incentives 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 1: C-2 Motion PPA

[1] 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]).

[2] 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.

In overview, the Recommended Industry Market Incentive Plan is designed to *reward* individual vessels with low (relative to other vessels at that time) 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 *maximizes industry profits while minimizing 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 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 that 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.

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 SO_2 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 programs[3]. 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 rates[4]. 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. It is shown that with a hardcap of 68,392, an ITEC trading plan can increase industry revenues and

[3] 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

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

reduce bycatch even without explicit behavioral changes, and that more dramatic cumulative benefits accrue when the incentives are explicitly acknowledged.

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 provided by Sea State Inc. These data show that 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 example). *Therefore, in the Recommended Industry Market-Incentive Plan the best position for a vessel owner to be in is to have a 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.

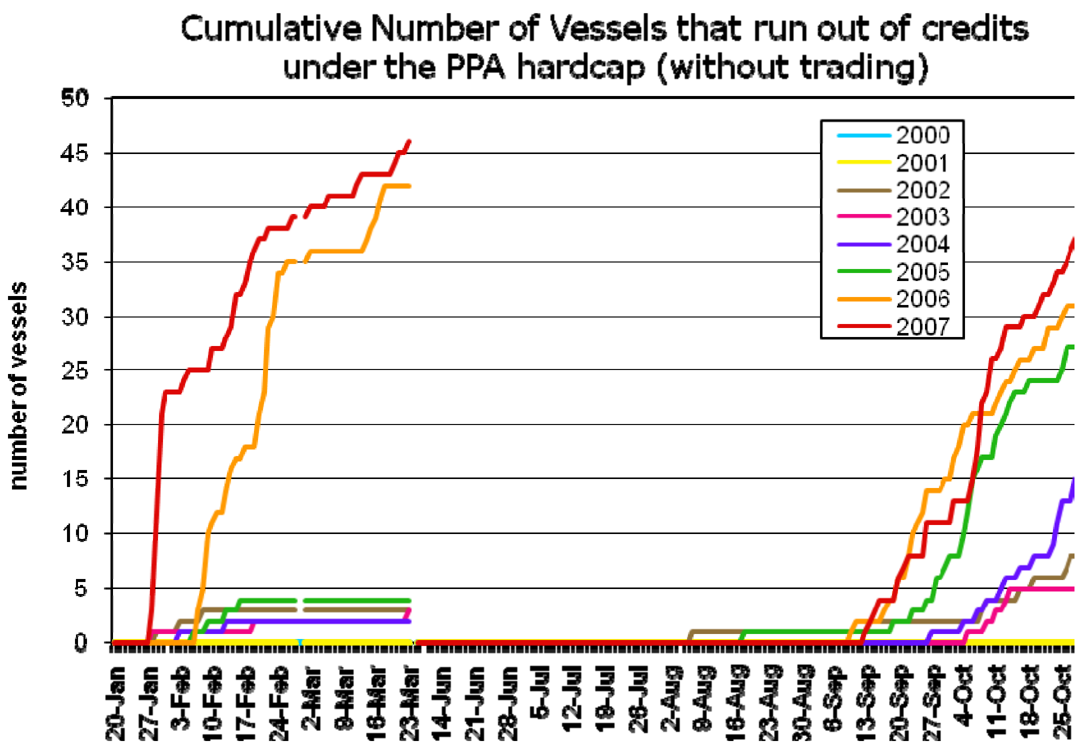


Figure 1. Timing and cumulative numbers of vessels in each season that would have run out of encounter credits under the PPA hardcap with no trading. (from Inshore sector daily data provided by Sea State Inc.) Note that vessels can run out of credits even in low encounter years (e.g. 2002, 2003).

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)[5] 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). <u>The cost of unfished Pollock due to a shortage of credits can be considerable.</u> 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:

(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:

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

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). 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 is the weight given to the Pollock quota, 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

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

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.

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, 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

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

or the (1/3, 1/3, 1/3) "equal" weighting.

And,

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

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.[6] 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. (See Appendix A for a discussion of bounds and weighting formulas). These specific bounds [2/3, 4/3] are the lower and upper bounds that industry is currently considering.

Most of the analyses here are based on the minimal model having equal weights (2). 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 (3) (see Appendix A-5 for a discussion of convergence). However, 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. That is, a larger β in eqn (1) helps to sort out the behavioral 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.

[6] 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 that industry is currently considering.

Again, it is assumed that these allocation factors are computed separately for each season and that there is100% 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 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).

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 <u>only</u> 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 loose 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 and do not change (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 it's behavior closer to the mean.

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

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

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 $P_{y\text{-}1}$, 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-ho*c 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. 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.

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.

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 seller's of ITEC and will perceive a higher value, while vessels with high bycatch rates will be net buyer's 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

<u>ITEC Supply and Pricing Considerations:</u>

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.

<u>Buy Side Transfer Limits:</u>

A good buy side transfer limit might be as follows: "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 a 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)

<u>Sell Side Transfer Limits:</u> (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.

<u>Dynamic Salmon Savings (DSS):</u>
Thus, we will consider a Dynamic Salmon Savings rule that is adaptive to salmon encounters and will apply to each vessel <u>after</u> 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 <u>sector specific "salmon savings rate" (SSR)</u> 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.

<u>1) Provisional Salmon Savings Rule (PSSR = max SSR):</u>

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.

For example, if a cap is set so that the maximum SSR is 40% (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 60% of their remainder credits. The PSSR = 40%, or the maximum SSR. Thus, if a vessel wishes to sell 60 credits early in the year, it must keep 40 ITEC *in reserve* until the SSR is calculated. This PSSR reserve acts as a *defacto* conservative salmon savings rule governing transfers 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 hardcap on Chinook salmon bycatch is that it is set too high. This level of hardcap poses the problem of satisfying the C-2 requirement of incentivizing reduced salmon bycatch at all levels of abundance. A lower hardcap, 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 hardcap can pose significant financial difficulties on the Pollock fishery during years of high salmon encounter (68,392 hardcap creates financial burden even during years of moderate salmon abundance: Figure 1). Conversely, a high hardcap 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 Figure 2a). 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 2b) 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.

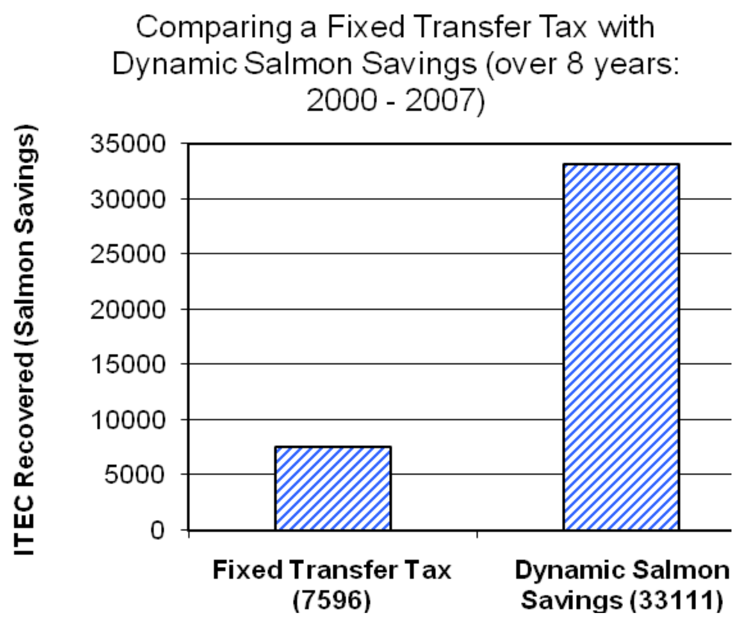


Figure 2a. Number of retired credits over 8 years (2000 – 2007) under two different sell-side transfer rules: a fixed transfer tax and dynamic salmon savings.

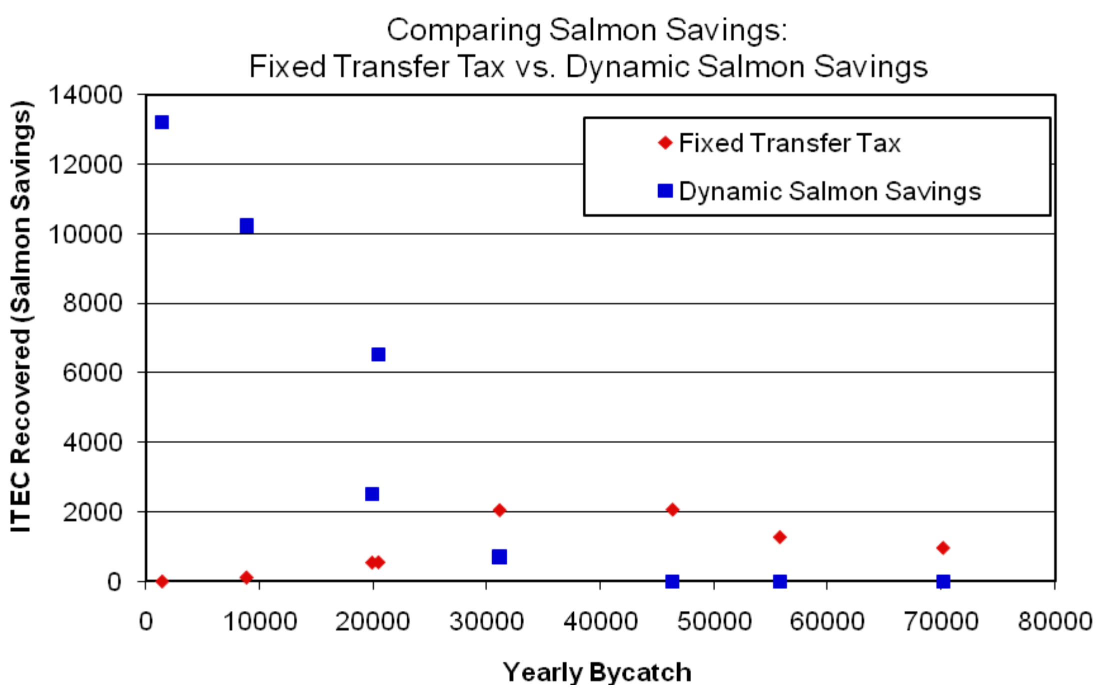


Figure 2b. Number of ITEC recovered vs. yearly bycatch (proxy for salmon abundance) for two different sell-side transfer rules. More ITEC is saved during low salmon abundance years using Dynamic Salmon Savings.

III. Incentives/Issues

1) 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 (including 100% A to B carry forward).

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 maximize industry revenues.

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 3, and can exceed $62m in one year. The risk of catastrophic losses due to unharvested Pollock in any given year should provide 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.

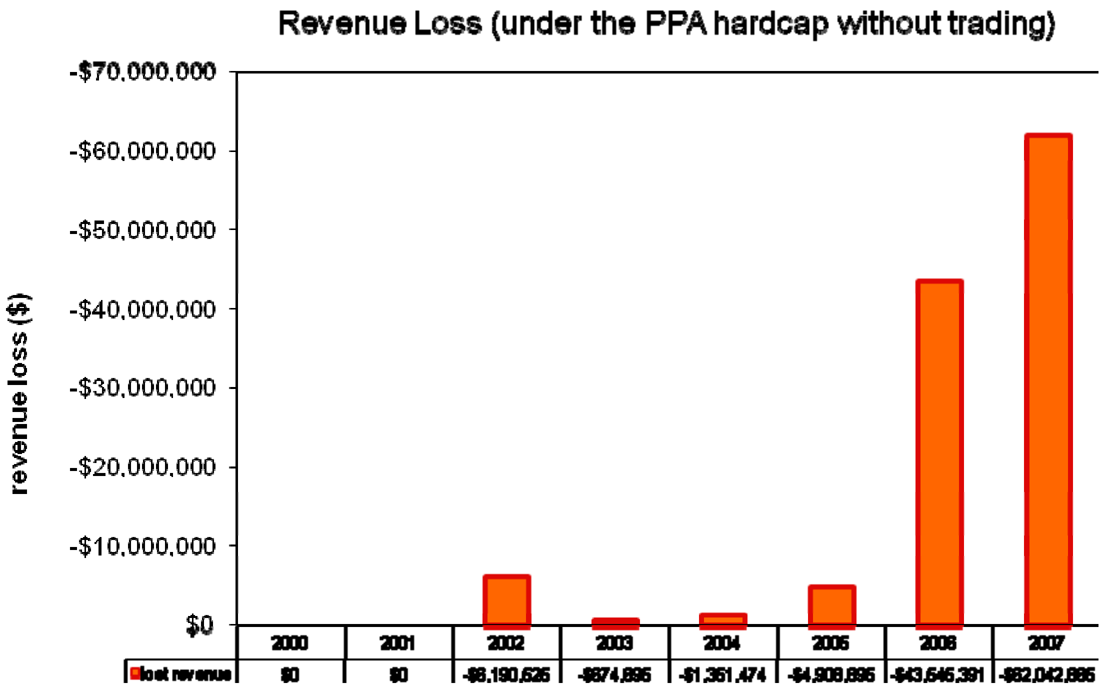


Figure 3. Annual sector revenue losses that would have been incurred under the maximum hard cap (as specified in the PPA) if no reallocation, no trading, and no bycatch avoidance incentives were in place. This calculation is based on daily catch data from Sea State Inc. and the assumption that the A-season 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 (Figure 4 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 4 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.

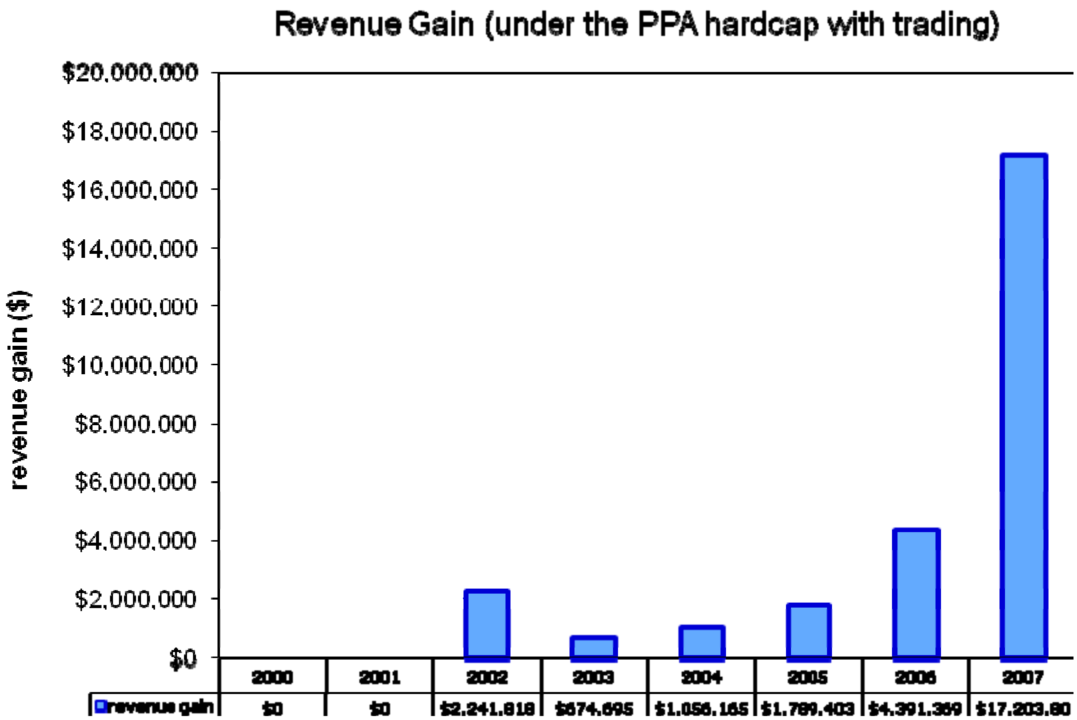


Figure 4. Potential revenue recovered from trading Chinook salmon encounter credits (ITEC's) under the PPA hardcap. Even without explicit incentives to avoid bycatch, Legacy Reallocation by itself can help to maximize industry revenues. Reallocation assumed "equal weighting" with Q = 4/3 p + 1/3 and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

2) 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.

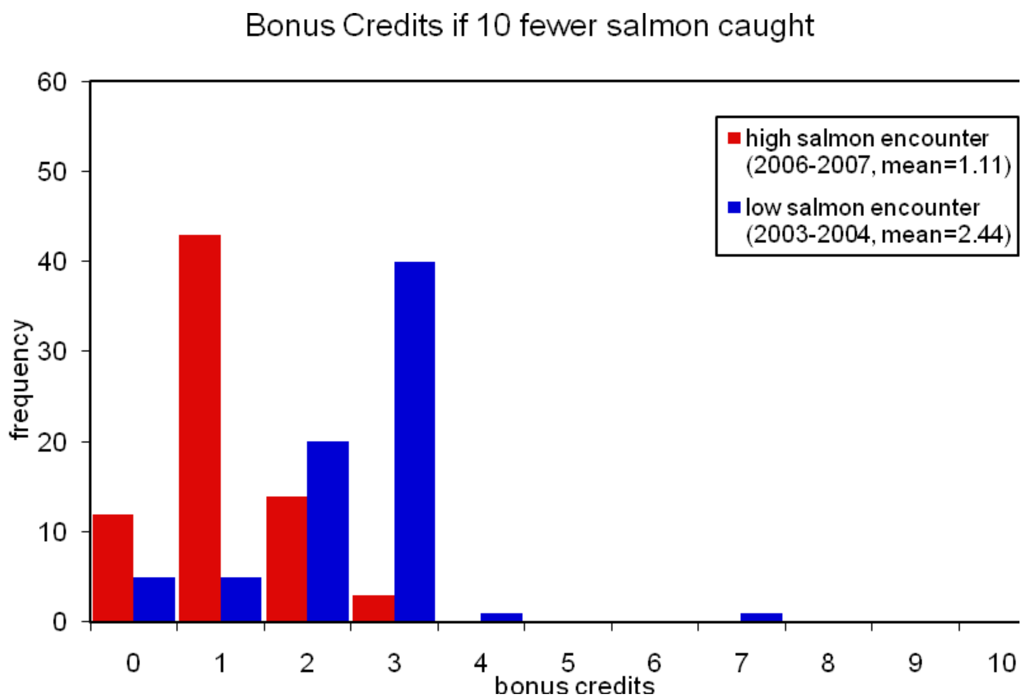


Figure 5a. Bonus credits (extra ITEC) achievable with 10 fewer Chinook salmon caught using the "equal weight" Legacy Allocation Formula (eqn 2) with a linear penalty function. This is analyzed vessel by vessel. (based on original annual data) The additional revenue per bonus credit in the 2007 A-season (assuming the vessel would have otherwise run out of credits) is ~$7k/credit. Allocation provides strong motivation in terms of potential cost.

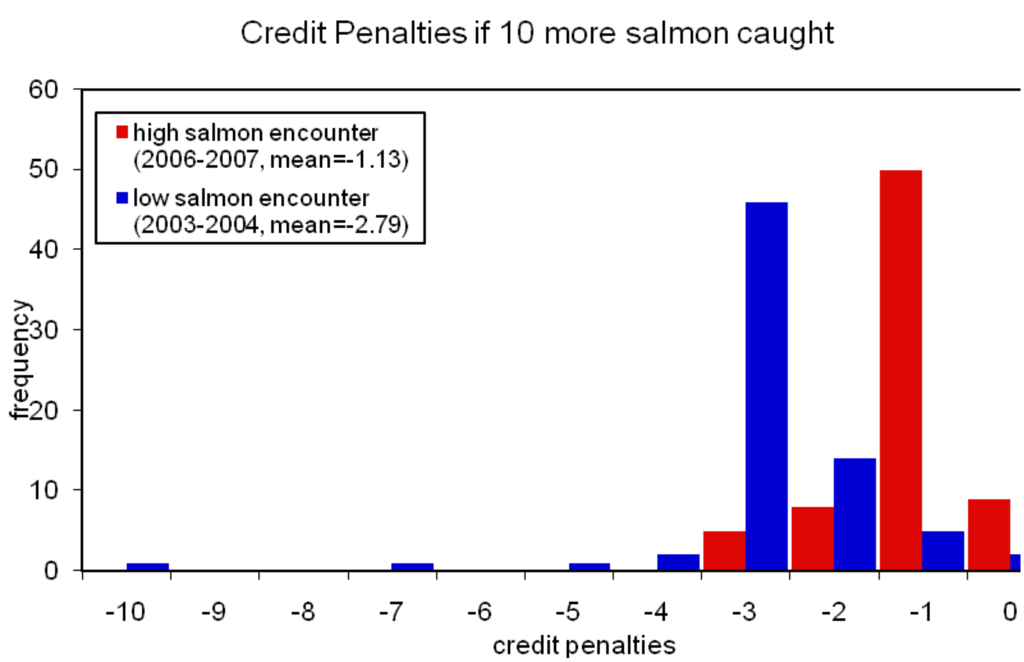


Figure 6b. Credit penalties (reduced ITEC) as a result of 10 more Chinook salmon caught using the "equal weight" Legacy Allocation Formula (eqn 2) with a linear penalty function. (based on annual data)

Of special significance is the fact that this allocation scheme operates more sensitively during years of low salmon abundance (Figure 5). 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).

3) Incentives related to trading ITEC.

If vessel-owners believe they have excess of credits in any given year they can post them for sale on an 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 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).

4) 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 (eg. 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 can be a strong incentive on behavior.

(iii) The legacy system provides cumulative incentives (incentives that begin year 1 and continue identically in all years) that should result in a steady evolution toward fleet-wide improvement in encounter rates.

IV. Hypothetical Modeling of Incentives:

A simple behavioral self-correcting model is examined to model the action of cumulative incentives to lower bycatch. The model assumes that a vessel's motivation to improve behavior will be inversely related to it's 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 ¼ the magnitude of historically observed variations in bycatch rate.*

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:

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

incentive multiplier = 1 – incentive.

And the cumulative incentive multiplier CIM is simply

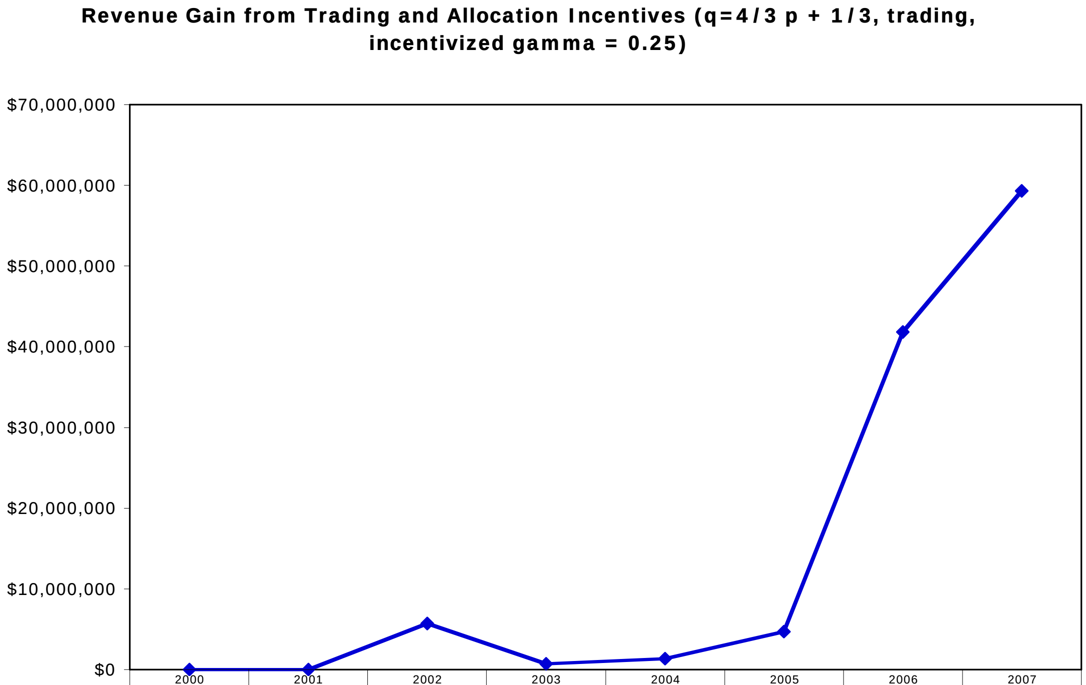
CIM(t+1) = CIM(t) * incentive multiplier

And,

Market incentive adjusted bycatch = CIM(t) * 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 7 and Figure 8. The results are similar but more dramatic than the earlier simple allocation and trading results (Figure 4) without rational incentives to improve relative standing in the fleet with respect to TEC 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.



	2000	2001	2002	2003	2004	2005	2006	2007
Series1	$0	$0	$5,705,610	$674,695	$1,351,474	$4,708,350	$41,795,979	$59,283,196

Figure 7. Hypothetical revenue gain for the Inshore sector from trading and allocation incentives to avoid bycatch assuming a sector maximum hard cap of 38,059.

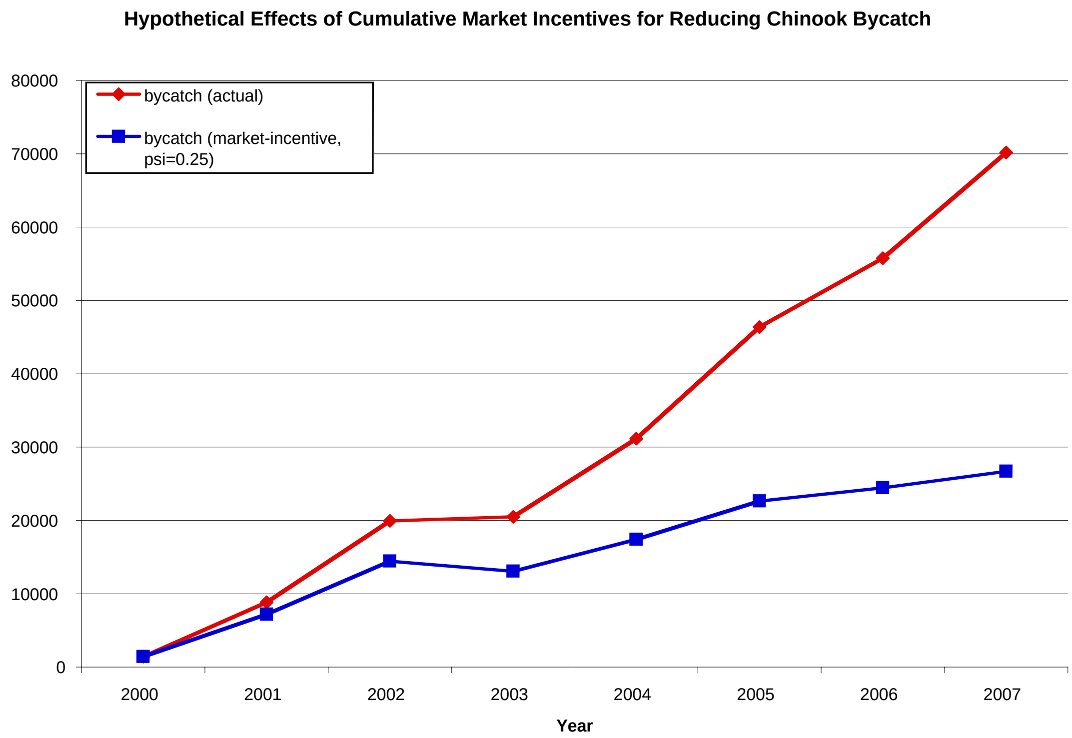


Figure 8. Effects for the Inshore sector of cumulative market incentives for reducing Chinook salmon bycatch under the PPA hardcap.

GLOSSARY OF TERMS:

1) Intrinsic Fishery Value = [(sum value of sector Pollock remaining at time t to the end of the season) / (sum sector actual bycatch remaining to the end of the season)] x [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: 68,000/ 1,000,000 mt = 0.068 = bycatch rate suggested by 68k HC and TAC of 1,000,000 mt.

Appendix A: Technical Issues Regarding the Allocation Formula

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

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

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

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

   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, ΣCredit Proportions. That is,

   # Credits_i = Credit Proportion_i / (ΣCredit Proportions) * # sector credits for the season

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

   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.

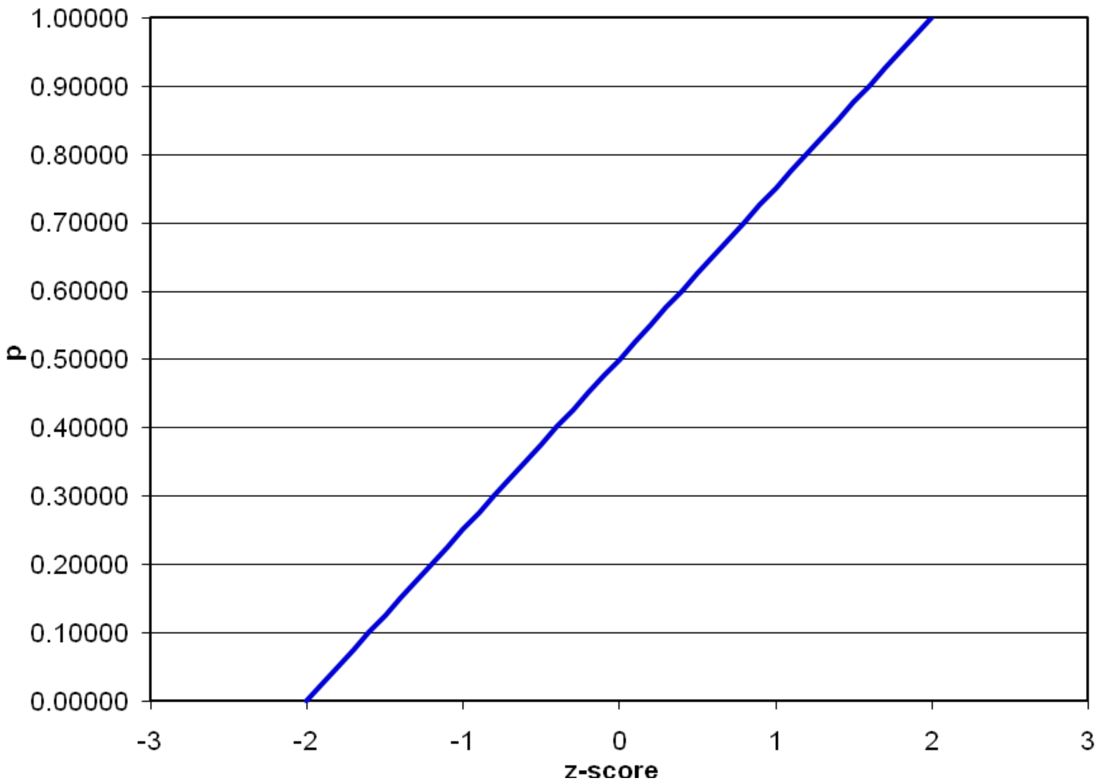


Figure A- 1. A linear penalty function truncated at z-scores of +2 and -2. Because the slope of the penalty function is equal for all z-scores, all vessels have equal incentive to reduce bycatch regardless of their position in the pack.

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.

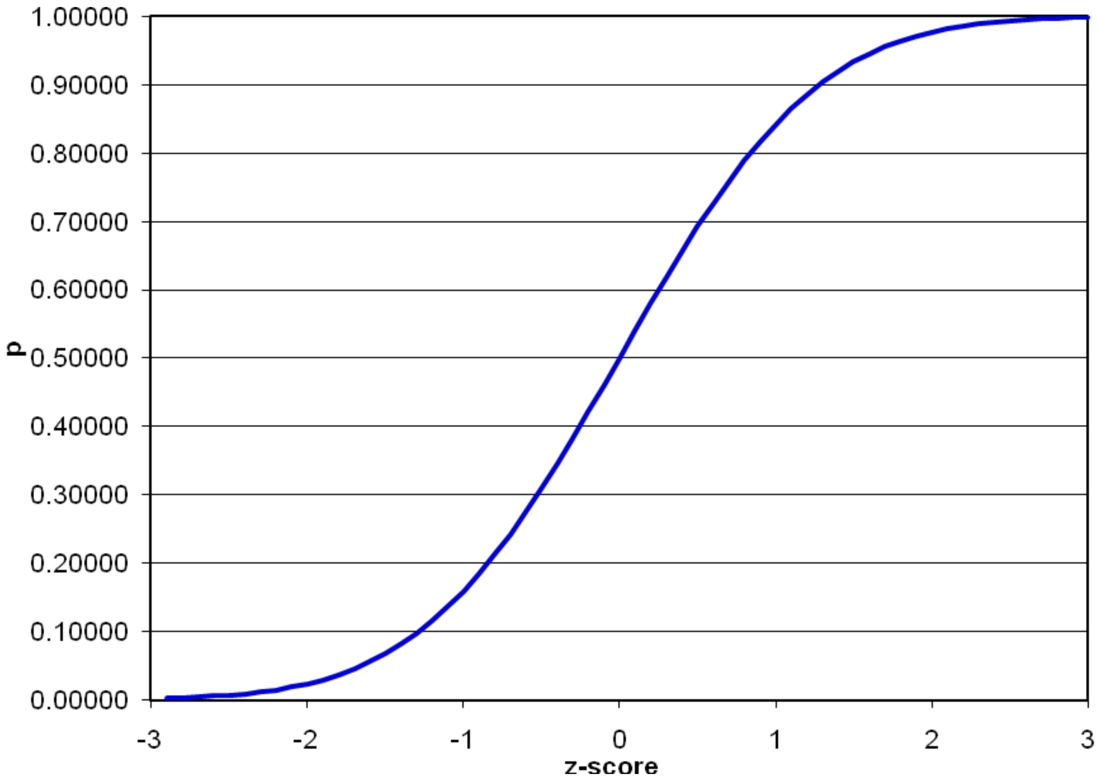


Figure A- 2. A penalty function computed as the cumulative p-value of the z-score. The slope is highest in the middle: therefore the largest incentives are for vessels in the middle of the pack.

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.

4) Computation of z-scores:
The variance in bycatch rates among vessels can be attributed to two factors: chance encounters with pockets of Chinook salmon, and consistent behaviors to reduce bycatch. 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 + avg. pollock allocation %) / sqrt(1 + pollock allocation % of vessel i)

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

z_i = (fleet wide bycatch rate – 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.

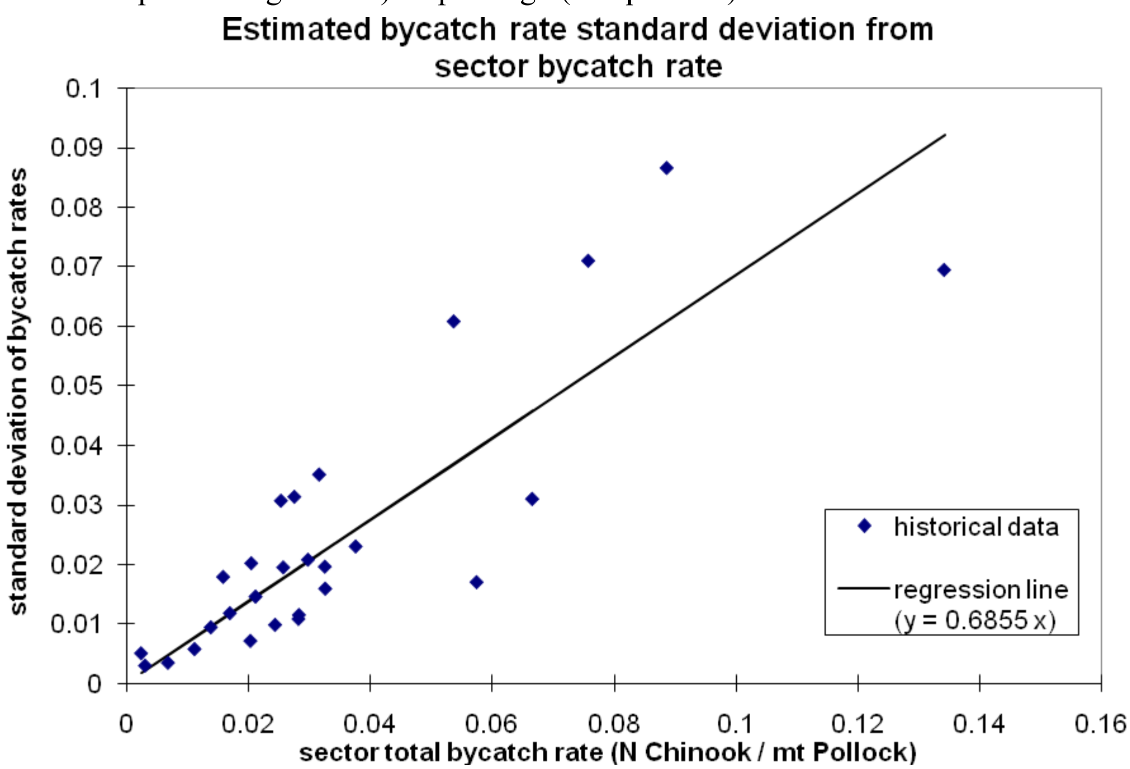


Figure A- 3. standard deviation of bycatch rates as a function of sector total bycatch rate. (Annual data from multiple sectors. Provided by Sea State).

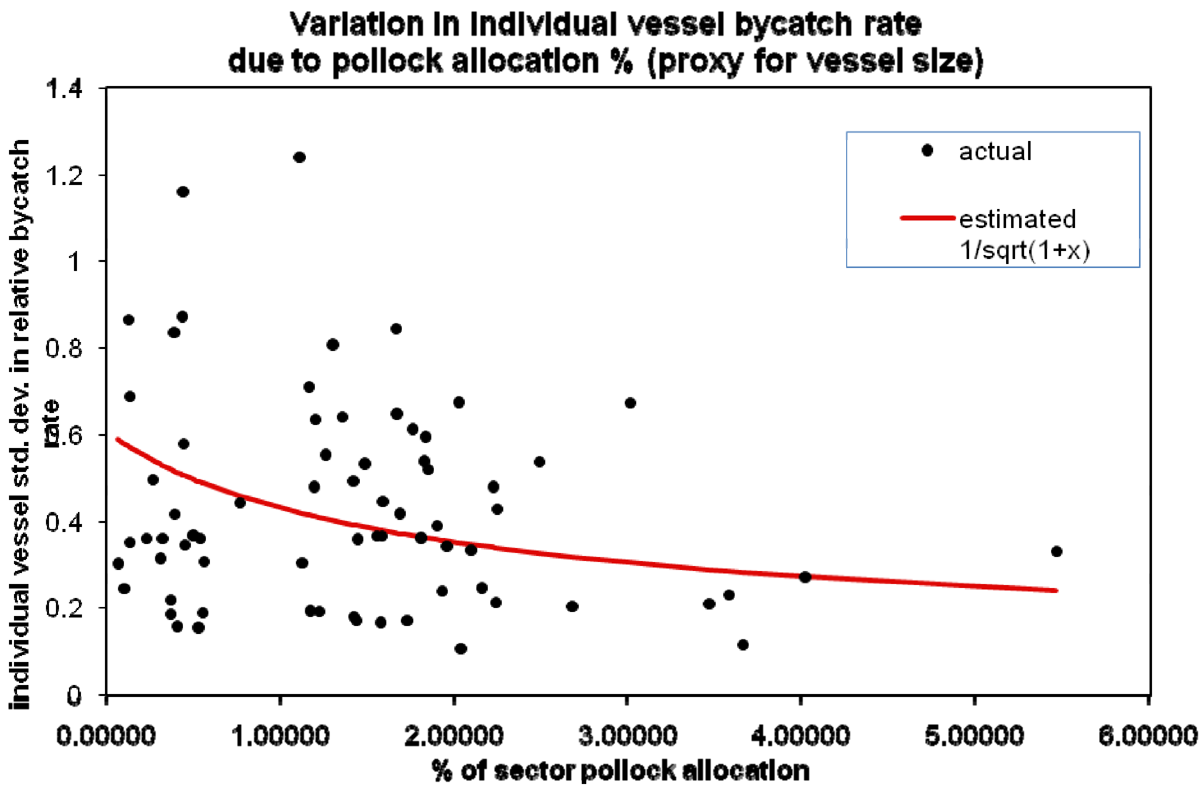
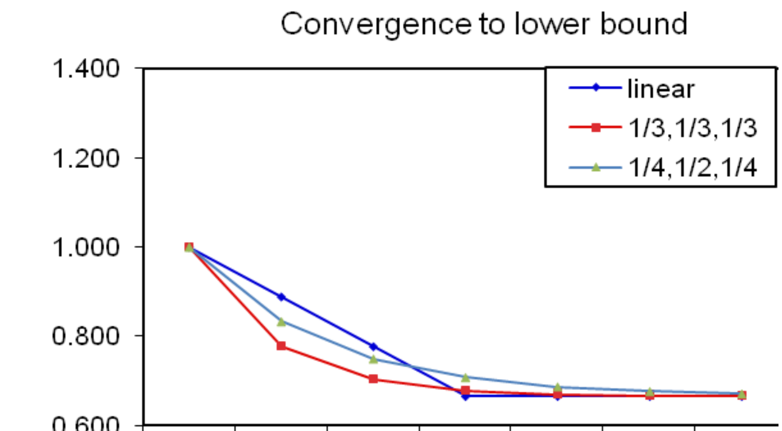


Figure A- 4. Smaller vessels show higher variability in bycatch rates. (annual data)

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

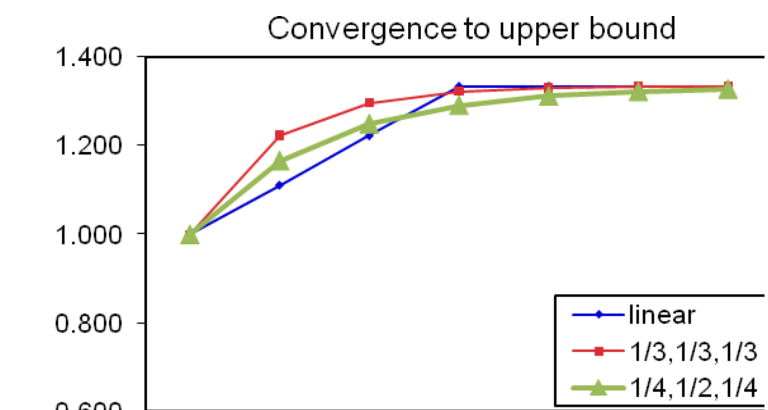
If one uses the weighting scheme (1/3/, 1/3, 1/3) the legacy component receives less weight than (1/4, 1/2, 1/4), and incentives are increased (larger change in allocations from year-to-year). However, fluctuations in allocation due to random noise affecting bycatch rates are similarly magnified and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



	0	1	2	3	4	5	6
linear	1.000	0.889	0.778	0.667	0.667	0.667	0.667
1/3,1/3,1/3	1.000	0.778	0.704	0.679	0.671	0.668	0.667
1/4,1/2,1/4	1.000	0.833	0.750	0.708	0.688	0.677	0.672

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.



	0	1	2	3	4	5	6
linear	1.000	1.111	1.222	1.333	1.333	1.333	1.333
1/3,1/3,1/3	1.000	1.222	1.296	1.321	1.329	1.332	1.333
1/4,1/2,1/4	1.000	1.167	1.250	1.292	1.313	1.323	1.328

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:

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

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.

   <u>(i) Provisional Salmon Savings Rule:</u>
   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.

   <u>(ii) Calculating a savings rate:</u>
   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

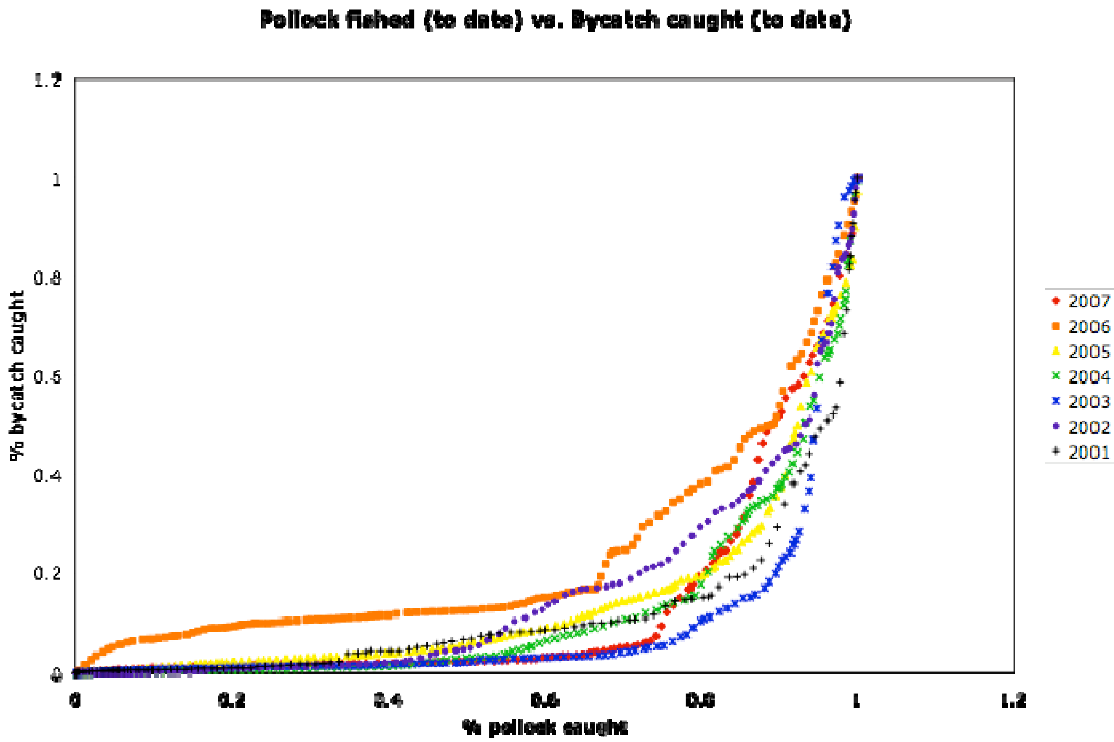


Figure B - 1. Cumulative bycatch as a function of % pollock harvested during the B season.

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 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.

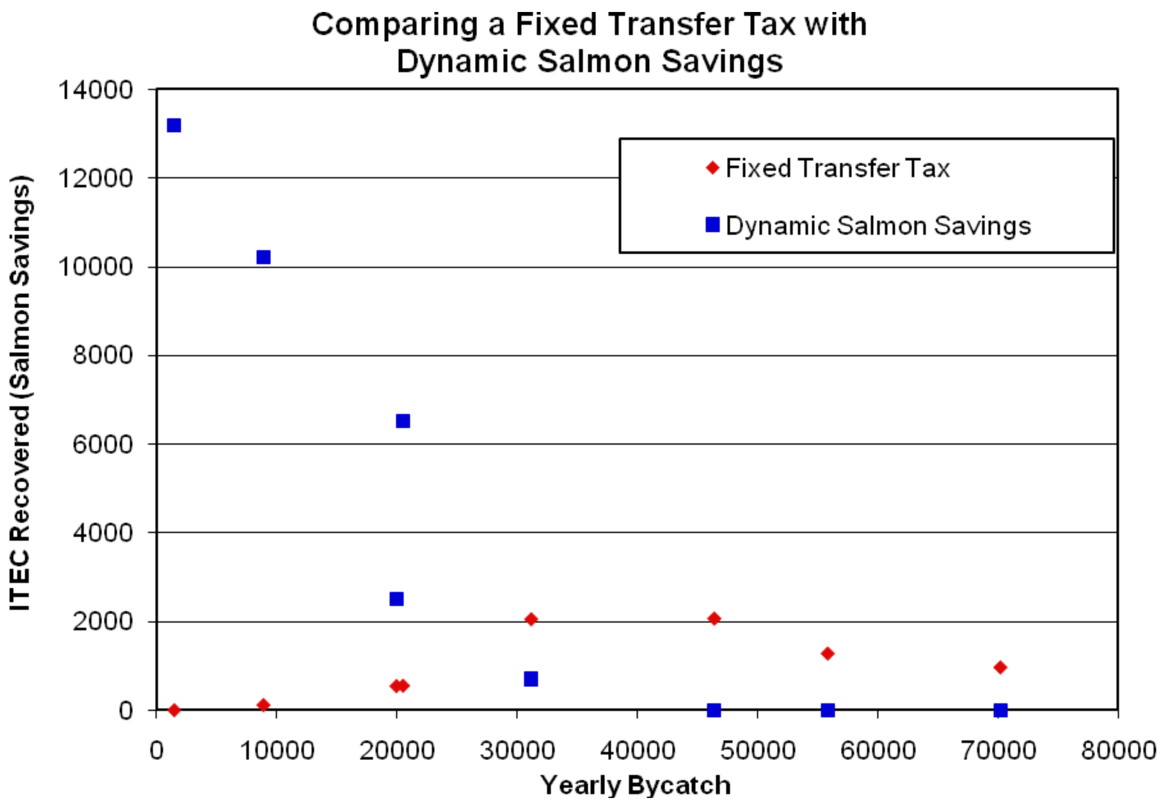


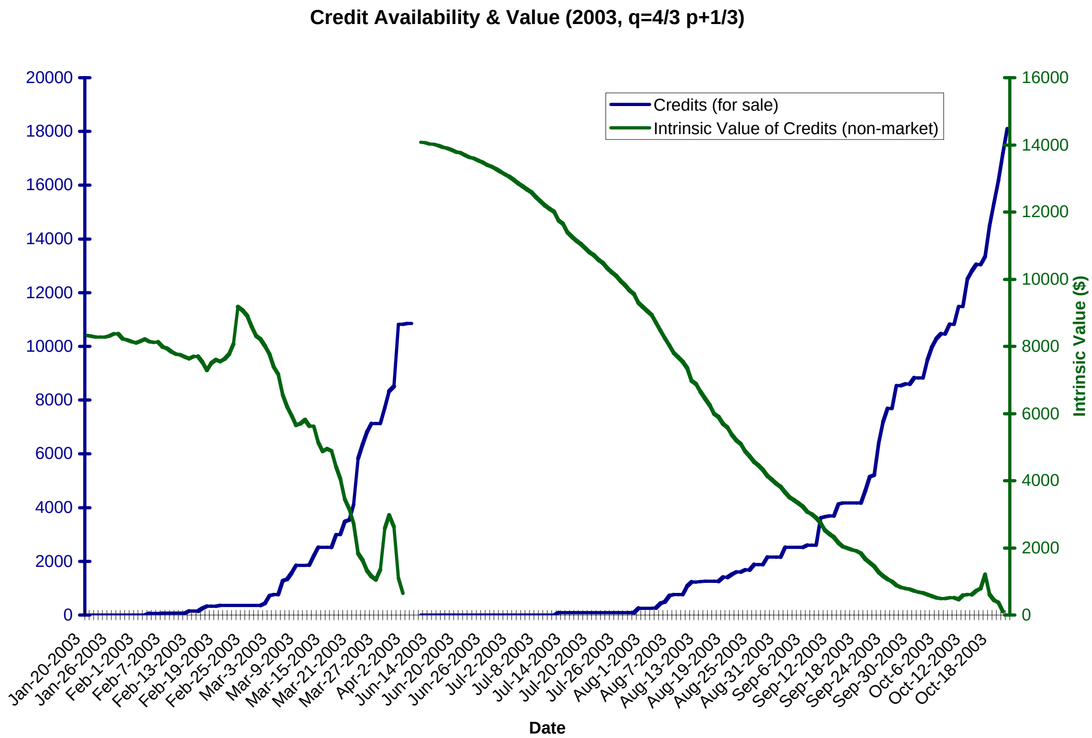
Figure B - 2. Number of ITEC recovered vs. yearly bycatch (proxy for salmon abundance) for two different sell-side transfer rules. <u>More ITEC is saved during low salmon abundance years using Dynamic Salmon Savings.</u>

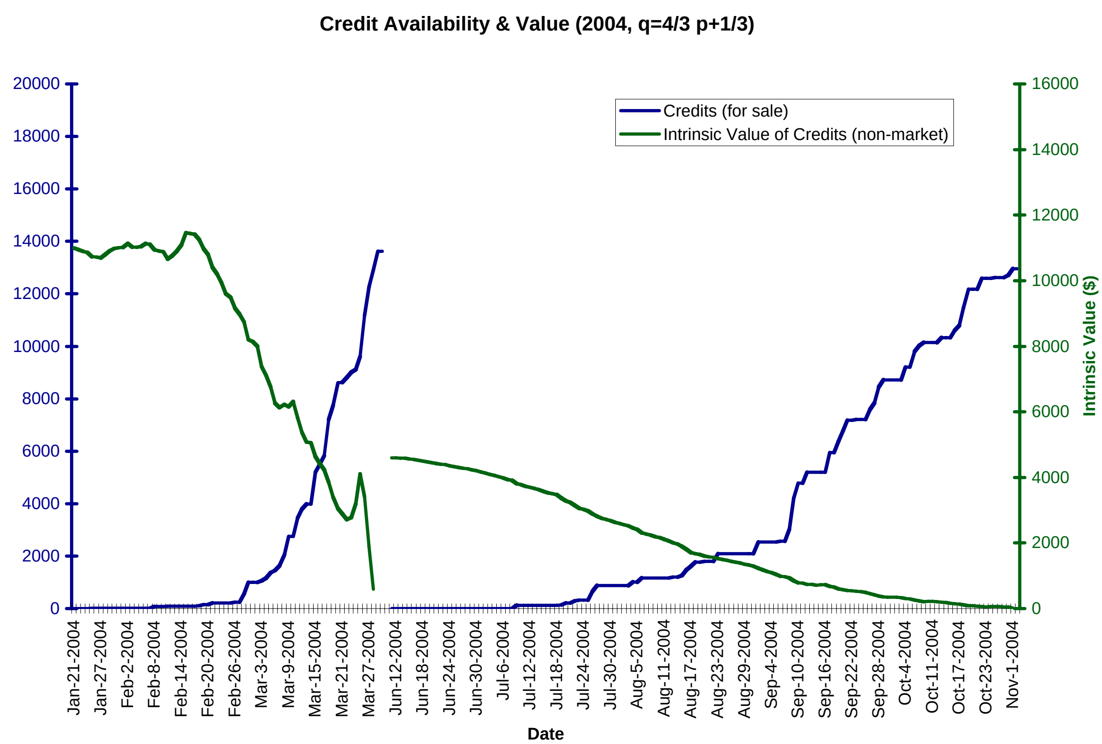
	RETIRED CREDITS	
TOTAL BYCATCH	**Fixed Transfer Tax**	**Dynamic Salmon Savings**
1454	0	13177
8866	116	10208
19923	546	2507
20471	554	6513
31136	2058	706
46354	2073	0
55782	1281	0
70148	968	0

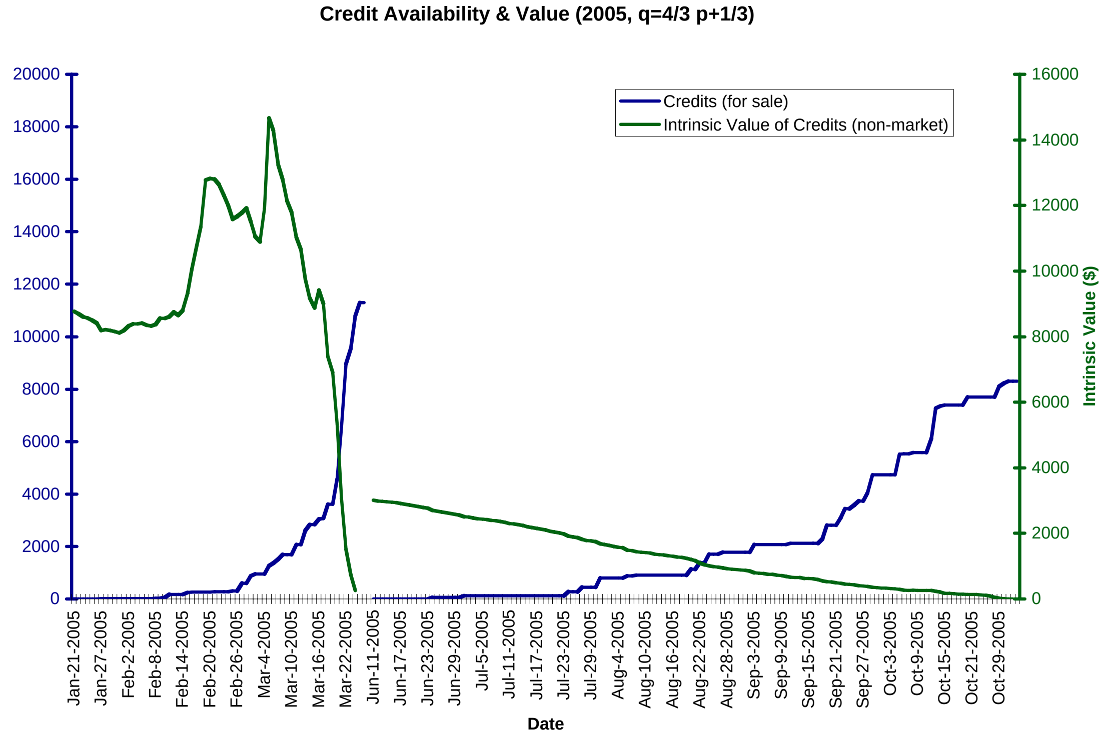
Table B - 2. Number of ITEC recovered vs. yearly bycatch (proxy for salmon abundance) for two different sell-side transfer rules.

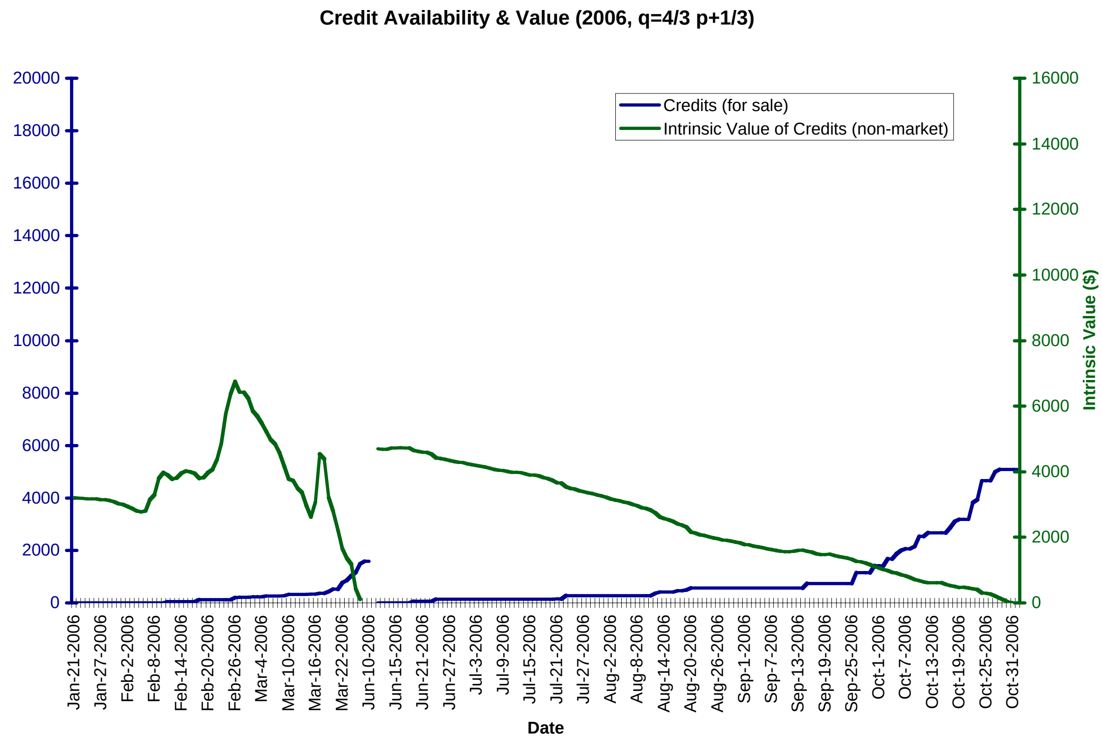
APPENDIX C:

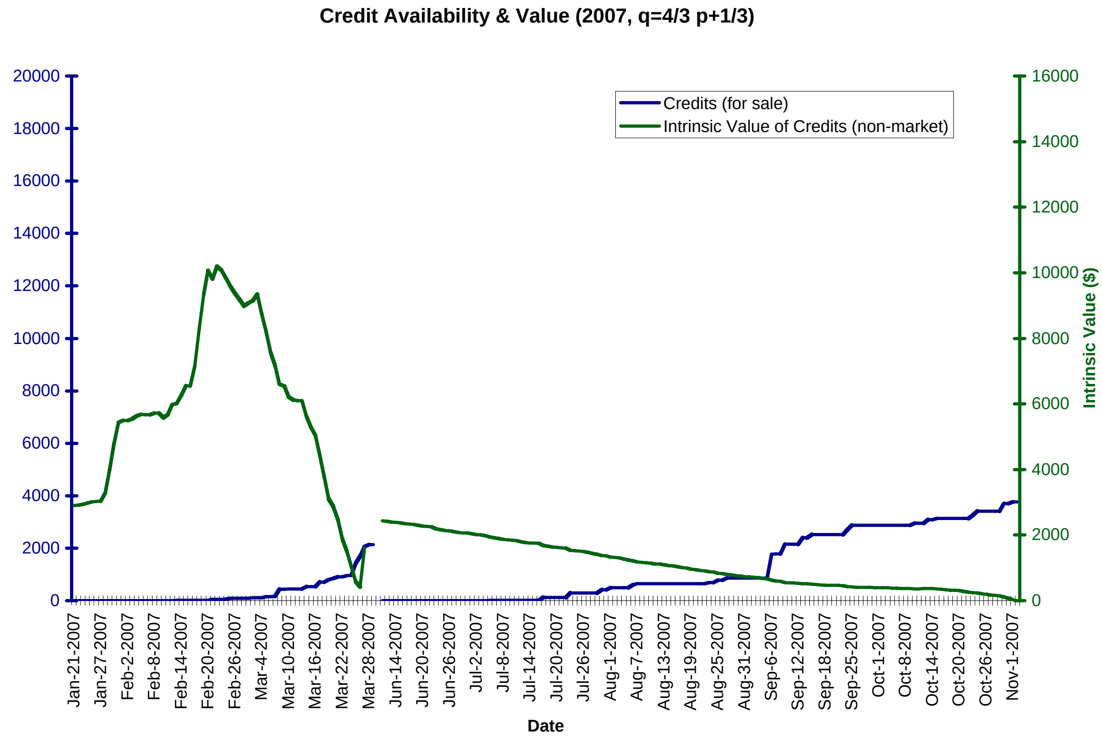
Temporal Analysis of Credits Supply and Intrinsic Fishery Value of Credits 2003 – 2007.






Credit Availability & Value (2005, q=4/3 p+1/3)
Credits (for sale)
Intrinsic Value of Credits (non-market)
Intrinsic Value ($)
Date


Credit Availability & Value (2006, q=4/3 p+1/3)
Credits (for sale)
Intrinsic Value of Credits (non-market)
Intrinsic Value ($)
Date


Credit Availability & Value (2007, q=4/3 p+1/3)
Credits (for sale)
Intrinsic Value of Credits (non-market)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
16000
14000
12000
10000
8000
6000
4000
2000
0
Intrinsic Value ($)
Jan-21-2007
Jan-27-2007
Feb-2-2007
Feb-8-2007
Feb-14-2007
Feb-20-2007
Feb-26-2007
Mar-4-2007
Mar-10-2007
Mar-16-2007
Mar-22-2007
Mar-28-2007
Jun-14-2007
Jun-20-2007
Jun-26-2007
Jul-2-2007
Jul-8-2007
Jul-14-2007
Jul-20-2007
Jul-26-2007
Aug-1-2007
Aug-7-2007
Aug-13-2007
Aug-19-2007
Aug-25-2007
Aug-31-2007
Sep-6-2007
Sep-12-2007
Sep-18-2007
Sep-25-2007
Oct-1-2007
Oct-8-2007
Oct-14-2007
Oct-20-2007
Oct-26-2007
Nov-1-2007
Date

APPENDIX D: Afterthoughts for Consideration by Industry

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.