Analysis of an Incentive-Based Chinook Salmon Bycatch Avoidance Proposal for the Bering Sea Pollock Fishery

By

Levis A. Kochin[*]
Christopher C. Riley[**]
Ana Kujundzic[***]
Joseph T. Plesha[#]

Abstract

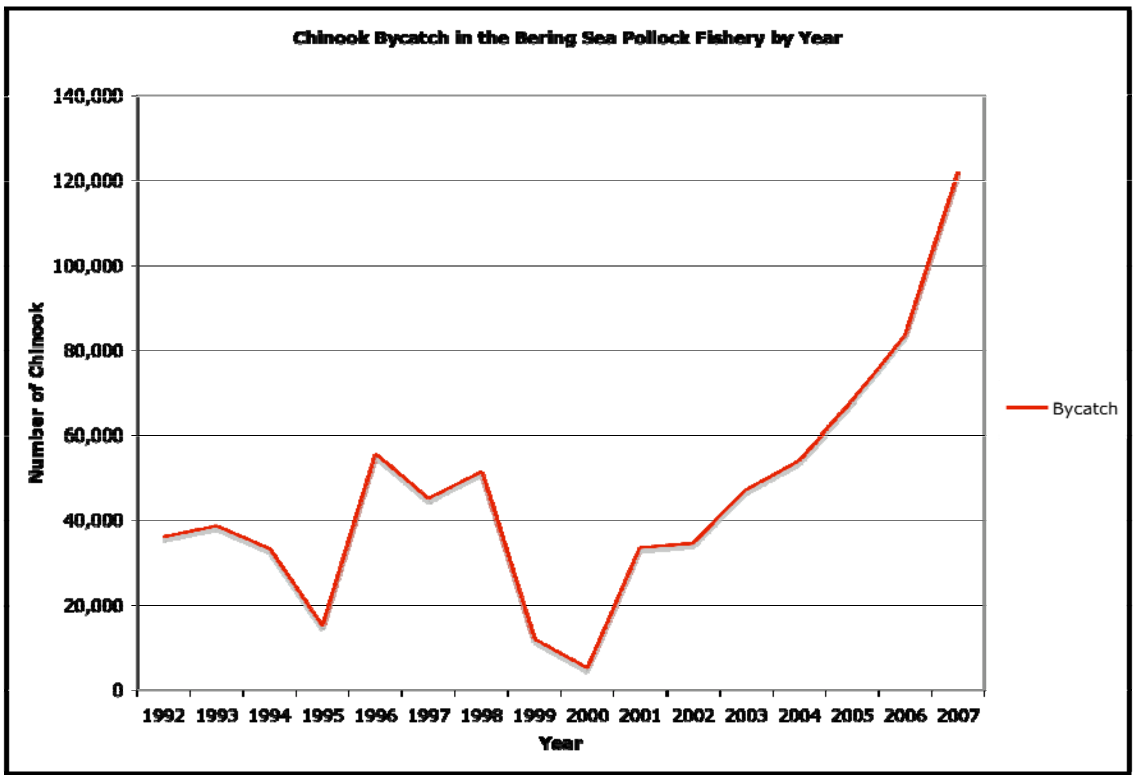
Too many Chinook salmon are incidentally harvested in the Bering Sea pollock fishery and in response the North Pacific Fishery Management Council is considering measures to reduce the bycatch of Chinook salmon. In June of 2008 the Council adopted a Preferred Preliminary Alternative that allows the pollock industry, on its own initiative, to develop a program that "provides explicit incentives for each participant to avoid salmon bycatch in all years." This paper is a response to that invitation. The concept at the heart of this paper is an incentive-based proposal in which each pollock vessel puts up a financial ante that is redistributed among the pollock harvesting fleet in proportion to each vessel's success in avoiding Chinook salmon. This incentive-based proposal operates to provide very strong incentives to avoid Chinook, especially when Chinook abundance is low. The paper describes the incentive-based proposal and how it interacts with a transferable hard cap to create incentives to minimize Chinook bycatch. The paper also examines the reduction in bycatch predicted to result from these incentives.

I. Introduction

Chinook salmon found in the Bering Sea originate from a wide range of geographic locations including Alaska, British Columbia and the Pacific coast, but they are predominantly of Western Alaska origin. These salmon are highly valued for economic, social and cultural reasons. There is a general concern for the health of Chinook salmon stocks. Recent Chinook returns to river systems in Western Alaska have been at such low levels that restrictions have been placed on even subsistence harvest.

Despite general concerns over the recent low levels of Chinook returns to Western Alaska river systems, the bycatch of these salmon in the Bering Sea pollock fishery has grown dramatically, with the total catch of Chinook in the pollock fishery reaching a historic high in the year 2007 at 120,808 salmon.

Figure 1. Chinook Salmon Bycatch in the Bering Sea Pollock Fishery, 1992-2007.



The total Alaska harvest of Chinook salmon has averaged approximately 600,000[i] fish since 1970, so the bycatch of Chinook in the pollock fishery represents a significant percentage of all salmon harvested in the subsistence, commercial and recreational fisheries statewide.

Although Chinook bycatch in the pollock fishery has decreased in 2008, the reasons for the reduction are not known. It may be because of increased industry efforts to avoid salmon, that there are fewer Chinook salmon commingling with schools of pollock, that salmon abundance in general has declined, or some combination of these factors.

The rationalization of the Bering Sea pollock fishery by the American Fisheries Act (AFA) has made it the most valuable fishery under federal management. The AFA allocates the privilege to harvest pollock to the Western Alaska community development quota program, and fishing vessel cooperatives in the inshore, catcher/processor and mothership sectors of the industry. Through these pollock cooperatives, owners of AFA-eligible pollock harvesting vessels have received quota of great value.

There is currently no limit on the number of Chinook salmon that can be taken in the pollock fishery; consequently, the North Pacific Fishery Management Council is in the process of recommending measures to protect Chinook salmon stocks. Under the National Standards of the Magnuson-Stevens Act (MSA), Fishery Management Plans shall achieve "optimum yield" from each fishery while minimizing bycatch, "to the extent practicable." In other words, the MSA seeks the optimal balance between maximizing reductions in Chinook salmon bycatch and minimizing damage to the pollock industry.

In June of 2008 the Council adopted a Preferred Preliminary Alternative (PPA) (See Appendix A.) that provides a well-designed program to reduce Chinook bycatch while offering the opportunity for the Bering Sea pollock fishery to be fully harvested. The Council's motion provides that a hard cap of 47,591 salmon will be imposed upon the pollock fleet if the pollock industry does not adopt a voluntary incentive-based program to avoid Chinook bycatch.

The Council will consider a more liberal hard cap of 68,392 if the pollock industry can develop an incentive-based program that will reduce Chinook bycatch ***better than*** a hard cap of 47,591. The industry's proposal must also provide these incentives during all years and at all levels of salmon abundance, even when Chinook salmon are at chronically low abundance levels. That is a hard standard to meet.

Hard bycatch caps (some assigned and transferable, and some not) are a traditional method employed by managers to place limits on bycatch. A hard cap of 47,591 appears to be a reasonable balance between protecting Chinook salmon and allowing the pollock fishery to be harvested. Chinook bycatch in the pollock fishery, however, is highly variable. Some years Chinook abundance in the Bering Sea is low and a hard cap of 47,591 will do little to create incentives for the pollock fleet to avoid salmon. In other years Chinook abundance is much greater, as evidenced by the fact that the pollock fishery has exceeded 47,591 Chinook in six of the past twelve years. In years of high Chinook abundance a hard cap at this level would likely close the fishery prior to the Total Allowable Catch (TAC) of pollock being harvested.

When Chinook salmon are scarce, the biological value of each bycaught salmon is high because each fish is important as brood stock for future generations; however, the scarcity of Chinook salmon also means that fewer will be caught in the pollock fishery and a hard cap of 47,591 would not be exceeded even if no efforts were made by the fleet to avoid salmon bycatch. Because the hard cap would not be reached, there would be no incentive for the pollock fleet to avoid catching Chinook salmon during the time they are of the greatest biological value.

Conversely, if Chinook salmon are extremely abundant, the biological cost to the salmon resource of catching one salmon would be lower. But this is precisely the time when a hard cap of 47,591 would be very costly to the pollock fleet. Enormous efforts will be devoted to avoiding catching Chinook salmon. If these efforts are unsuccessful, the pollock fishery would be shut down by the 47,591 hard cap well before the pollock TAC is harvested and precisely when Chinook bycatch might be doing the least damage to the salmon fishery.

The PPA recognizes the shortcomings of a simple 47,591 hard cap. The Council's motion invites the pollock industry, on its own initiative, to develop a program that "provides explicit incentives for each participant to avoid salmon bycatch in *all years*." The program must create incentives for "each vessel to avoid salmon under *any condition of salmon abundance in all years*," and the incentive measures "*must include rewards for salmon bycatch avoidance and/or penalties for failure to avoid salmon bycatch* at the vessel level." If such an incentive-based program is developed and carefully analyzed by the industry, the Council will consider recommending a Chinook salmon hard cap of 68,392, a level which is unlikely to be constraining on the pollock fishery.

Prior to its final vote on measures to manage Chinook bycatch, the Council will have the opportunity to judge whether any programs developed and fully analyzed by the pollock industry achieve its intent for an incentive-based program.[ii]

This paper describes and reviews a proposal that we believe is responsive to the Council's concerns for Chinook salmon protection and its request for a powerful incentive-based Chinook salmon avoidance program. The proposal includes three basic elements: Continuation of the current Chinook bycatch avoidance measure (the Rolling Hotspot Closure program), a hard cap of 68,392 which will be allocated through the pollock cooperatives to each vessel and is transferable, and an individual vessel incentive-based bycatch avoidance program that "provides explicit incentives for each participant to avoid salmon bycatch in all years" by creating a high marginal value for each Chinook salmon taken by the fleet.

The intent of the proposal is to create strong economic incentives for all vessels harvesting pollock to avoid Chinook salmon bycatch at all levels of salmon abundance, even during periods of chronically low Chinook abundance. In other words, the proposal's goal is to have the pollock industry — "to the extent practicable" — minimize its bycatch of Chinook salmon while achieving the "optimum yield" from the extremely valuable pollock fishery.

II. Discussion of Command and Control vs. Market Based Incentives

Prior to 2007 Chinook salmon bycatch was managed by a triggered closure of a large area of the Bering Sea when 29,000 Chinook salmon were taken in the pollock fishery. Starting in the "B" season of 2006, smaller areas of the Bering Sea with relatively high Chinook bycatch were closed on a weekly basis to pollock cooperatives whose vessels did not achieve low bycatch rates. (This program is called the "Rolling Hotspot Closure" (RHC) program and it is described in detail and briefly analyzed in Appendix B.) The RHC program and the prior triggered closure area are examples of "command and control" regulations.

Under command-and-control regulations, an agency establishes compliance goals and then dictates the means that regulated firms must use to meet those goals. The Clean Air Act, for example, calls for a reduction in emissions in order to fight ozone depletion. The Environmental Protection Agency then defines what technology must be used to achieve that goal. Under the RHC program, the Council seeks to reduce Chinook bycatch in the pollock fishery by defining areas in which pollock fishing effort is to be limited.

The distinction between command-and-control and market-based regulations is often found in pollution control schemes. Economic theory and actual experience indicate that regulations which attempt to internalize and privatize the social costs of pollution through the market-based approach almost always achieve a given level of pollution reduction at a lower cost than the command-and-control approach. In the market-based approach, the individual firm is incentivized to reduce emissions by whatever means are least costly; whether in its own operations or by paying other firms to reduce emissions beyond target levels.

The market-based approach to fishery management has been successful around the world. By providing private incentives to those who receive allocations of transferable harvesting quota, large economic gains have been achieved, together with reduced ecological impacts. No case provides a better example of this than the Alaska pollock fishery. Prior to passage of the AFA, for example, fishery managers attempted to maximize the value of output from the pollock fishery by a command-and-control regulation: the banning of "roe stripping." This regulation was only partially successful. The AFA incorporated a market-based approach to fishery management, allocating to private entities transferable shares of the total pollock catch, giving those entities the discretion to fish without racing against one another. The pollock fishery now yields a considerably greater volume of edible product with increased value per volume of raw fish. After enactment of the AFA, product recovery in the pollock fishery increased from approximately seventeen percent to over thirty percent. (In addition there has been a reduction in the use of inputs such as vessels and fuel.)

Market-based regulatory systems, such as the two that will be discussed in this paper, all have one thing in common: They influence behavior by making desirable actions more profitable and those actions deemed undesirable less profitable. The workings of market-based regulatory systems can be described in the language of costs and benefits. To help describe the market-based mechanisms for bycatch reduction proposed in this paper, definitions of two frequently used terms are provided below:

Marginal Value. Marginal value is the change in total value (before deducting any incremental cost) that arises when the quantity produced changes by one unit. The marginal value of avoiding a Chinook salmon is the expected gain to the vessel as a result of avoiding that salmon. It is expressed in "dollars per avoided Chinook salmon." The marginal value of avoiding a Chinook salmon could be, among other things, the proceeds from the sale of any transferable bycatch allowance or the avoided cost of having to buy bycatch allowance from someone else. Marginal value could also be the expected proceeds from the incentive-based program described in this paper for avoiding one Chinook salmon.

Marginal Cost. Marginal cost refers to the incremental cost that arises when the quantity produced changes by one unit. The marginal cost of avoiding one Chinook salmon is the expected cost to the vessel as a result of avoiding that salmon. It is expressed in "dollars per avoided Chinook." The marginal cost of avoiding a Chinook salmon could be the cost of fishing at a more distant location, or where the catch of pollock is less. It could be harvesting pollock with a lower roe content or lower recovery rate for primary product. It could be the cost of fishing at a different time of year. It could also be the extra operational cost of fishing pollock with trawl gear that includes a salmon excluder device.

A rational pollock harvester will not knowingly take a Chinook salmon as bycatch when the expected marginal value of avoiding that salmon exceeds the marginal cost of avoiding it.

III. Transferable Bycatch Allowance Allocated To Vessels

<u>Description of the Proposal</u>

The Council's PPA creates a hard cap on the total number of Chinook salmon that can be taken in the pollock fishery. This hard cap is, by itself, a command-and-control regulation. Once the hard cap is reached, the pollock fishery will close. A simple hard cap, however, provides a very weak incentive to conserve bycatch because each individual vessel bears the entire cost of avoiding a Chinook salmon, while the benefit of its efforts will be spread among the entire fleet. A simple hard cap alone, therefore, will result in a "race-to-use-bycatch" which produces the same problems as the "race-to-fish" resulting from an open access fishery.

The second element of this paper's bycatch avoidance proposal is that the Chinook bycatch allowed under the hard cap be allocated through each pollock cooperative to individual pollock harvesting vessels based on those vessels' allocation of pollock under the AFA. In the case of the catcher/processor sector, the hard cap is allocated to each company in proportion to its pollock allocation under the Pollock Conservation Cooperative (PCC) agreement, and is assigned as appropriate to each vessel. To provide efficient incentives, bycatch allocations are transferable. For purposes of this paper, this allocation is referred to as Transferable Bycatch Allowance (TBA).

Brief Analysis of the TBA Program

Because TBA will be assigned to individual vessels, these vessels will obviously have a greater incentive to avoid Chinook salmon. Both the cost and the benefit of avoiding Chinook salmon bycatch will accrue to the individual vessel. The TBA induces an explicit marginal value on not catching Chinook salmon as it allows the vessel holding TBA to harvest its allocation of pollock and creates a privilege to take Chinook that can be sold to other vessels that may require additional bycatch.

TBA available after the pollock TAC is fully harvested, however, is valueless. TBA has value to vessels that avoid Chinook bycatch only if there is some chance of the industry-wide hard cap being reached. The value of TBA, at any given moment, equals the value of TBA if the hard cap reached is multiplied by the probability that the hard cap is indeed reached. If the probability of the industry-wide hard cap being reached is expected to be near zero, the marginal value of avoiding a Chinook salmon imposed by the hard cap is also near zero. The ability of TBA to induce marginal value therefore vanishes at chronically low bycatch rates where even at the start of a fishing season harvesters expect a very low probability of reaching the hard cap.

If Chinook salmon are in low abundance such that bycatch rates are extremely low, TBA from a hard cap of even 47,591 will not create large incentives for the pollock fleet to avoid bycatch. For example, if the hard cap were 50,000 Chinook and the TAC of pollock was 1,000,000 metric tons with a lease value of $300 per metric ton, and everyone believed that the TAC of pollock could not be harvested under the hard cap, then all of the $300,000,000 value of the pollock quota would accrue to holders of TBA. Each of the 50,000 Chinook TBA would then be worth $6,000.[iii] If there were only one percent chance that the TAC could not be taken under the hard cap, however, the value of each TBA would be one percent of $6,000, or just $60.

When Chinook and not abundant, the value of TBA is small because of the low probably that the hard cap will be reached. Yet it is precisely during periods of low Chinook abundance that Chinook protection is most urgent. The only way for TBA to securely protect Chinook during periods of low abundance is if the hard cap is set at levels appropriate for low abundance years (for example, 15,000 salmon). Any cap designed to protect Chinook in very low abundance years, however, will necessarily impose enormous costs on the pollock industry in the form of forgone pollock harvest when Chinook are more abundant.

Environmental conditions can severely impact the size of Chinook salmon stocks in both individual river systems and Western Alaska stocks in general. These environmental conditions can be persistent, potentially causing poor salmon abundance for long periods of time. For example, Pacific Decadal Oscillation (PDO) is a pattern of cold and warm water temperatures in the Pacific Ocean that shifts phases on at least an inter-decadal time scale, usually about 20 to 30 years. The climate regime we are in now is considered a “warm” phase. The prior “cold” phase started in 1946 and ended in 1977-78 (a period of about 30 years). In 2008 the very low surface and bottom temperatures indicate that the entire shelf water mass from top to bottom was exceptionally cold during the summer. Some researchers believe that the end points of the PDO’s phases are marked by extreme swings in temperature. The temperatures during 2000-2005 were extremely warm in a warm phase, and now very recently we have had a swing to cold temperatures. The range of high and low values has increased, indicating extreme temperature swings. We probably will not know for a few more years if this marks a shift of the PDO to a cold phase, but if so, then we will have just come through a warm phase that lasted about 30 years.

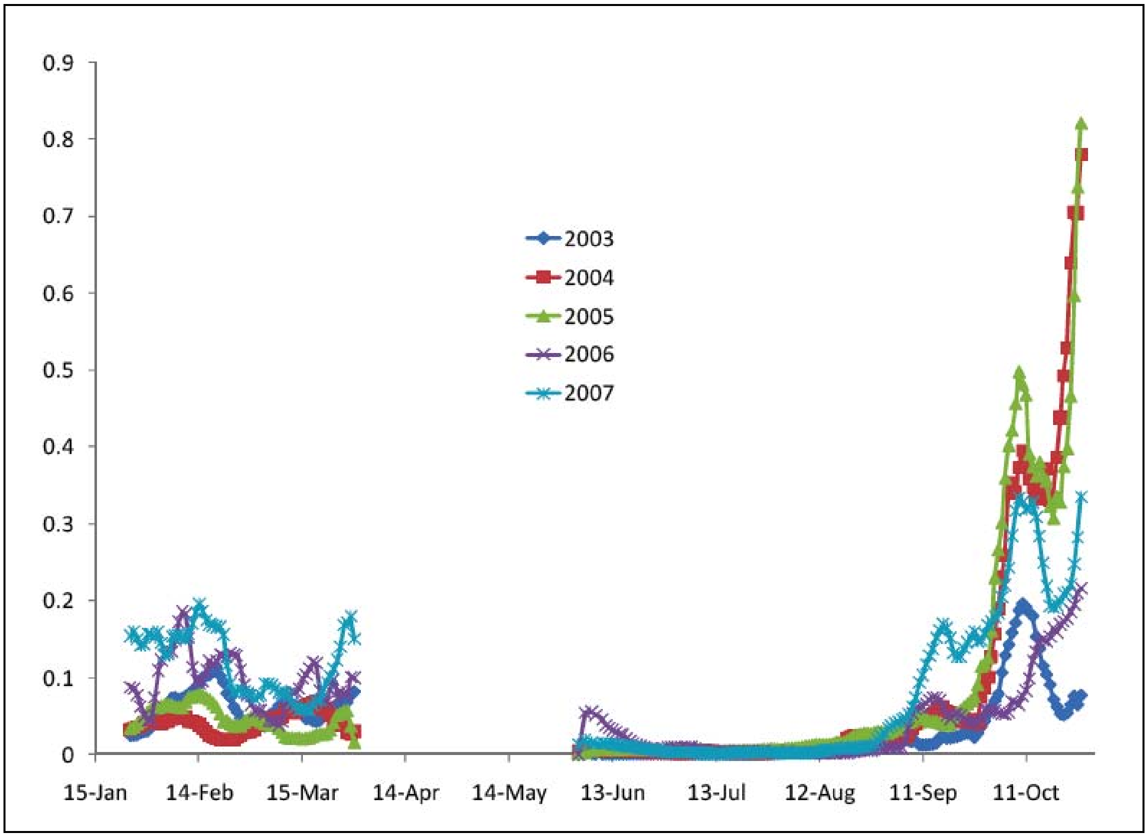
Salmon (and pollock) stocks do not fare as well in cold water temperatures as they in warm water conditions. PDO, in fact, was first noticed while studying salmon production patterns. A 1996 paper on the impacts of interdecadal climate oscillation on salmon production, notes, “a remarkable characteristic of Alaska salmon abundance over the past half-century has been the large fluctuations in interdecadal time scales which resemble those of PDO.”[iv] The abundance of Chinook and pollock stocks may well decrease significantly during the new regime. The environmental conditions that cause these lower Chinook and pollock abundance levels could persist for decades. Chronically low Chinook or pollock abundance would result in TBA alone inducing very minimal measures by the pollock fleet to avoid Chinook salmon bycatch because of the extremely low probability of reaching the hard cap.

Another characteristic of TBA is that it is inherently self-limiting. To the extent TBA reduces bycatch rates, it also reduces the probability that the overall hard cap will be reached and thereby reduces the marginal value of avoiding bycatch.

The larger the hard cap, the less the marginal value created by TBA because for TBA to induce a marginal value, the pollock industry must have some expectancy of reaching the hard cap. It is likely that a hard cap of 47,591 will be reached in some years. Even in the year 2007, however, when bycatch in the pollock fishery was a record high 120,848 Chinook salmon, it <u>may</u> have been possible to stay under the 68,392 hard cap.

For example, SeaState estimates that had the now fixed closed area been in place during the 2007 “A” season, about 13,400 fewer Chinook salmon would have been taken.[v] During the “B” season, the Chinook salmon bycatch rate spikes dramatically after September 15th.

Figure 2. Chinook bycatch rates per metric ton of pollock, 2003 through 2007.



In 2007 there were 37,592 Chinook salmon taken as bycatch in the pollock fishery after September 15th. Given that the pollock industry would have been aware of the likelihood of approaching a 68,392 hard cap, the fleet would have taken extreme measures to harvest all of its pollock from June to early September, when Chinook bycatch can be extremely low. If just the estimated savings from the newly closed area in the "A" season and "B" season bycatch after September 15th is subtracted, the Chinook bycatch in 2007 would have been reduced by about 51,000 salmon. Given these assumptions, the 68,392 Chinook hard cap would still have been exceeded by about 1,400 salmon. But it appears that even in 2007, a year that was far-and-away the worst bycatch year on record (the bycatch of Chinook salmon in 2007 was 149% of the *second* highest Chinook bycatch year on record[vi]), it may have been possible for the industry to be under the 68,392 hard cap. The marginal value induced by TBA from a hard cap of 68,392, therefore, would be relatively small in most years.

It will be easier in the future, furthermore, for the pollock fleet to concentrate more of its fishing effort in June and July because the Pacific whiting fishery will soon be rationalized.[vii] There are a large number of pollock catcher vessels and catcher/processor vessels that also participate in the whiting fishery. Currently there is a "race-for-bycatch" caused by very low rockfish hard caps, which are not allocated among the catcher/processor, mothership and inshore sectors. As a result, the harvesting of Pacific whiting currently occurs predominantly in the spring and summer months (ironically, when rockfish bycatch is highest and product recovery from the whiting fishery relatively low). With rockfish bycatch allocated by sector and the whiting fishery rationalized, it will be possible for the pollock fleet, which also fishes whiting, to concentrate its whiting effort in the fall — when whiting is most valuable and rockfish bycatch nonexistent — and fish pollock during the summer, when Chinook salmon bycatch is minimal.

<u>Bycatch Avoidance cost as a function of bycatch rates</u>

It appears that the differences in bycatch rates between different areas are proportionally constant across time and distance. In other words, when the bycatch rate is fifty percent of the normal bycatch rate, it is about fifty percent at both the "hot spot" and a clean fishing area. Therefore, we should expect the marginal cost of avoidance to be proportional to the inverse of the bycatch rate. So if the bycatch rate falls in half, the marginal cost of avoiding Chinook salmon doubles. As Chinook become scarce, the cost of avoiding them rises hyperbolically. Examples 1 through 5 in section seven illustrate this point.

This has important implications. The biological value of a Chinook salmon is higher during seasons of low abundance. It will be shown later in this paper that incentives induced by TBA diminish as bycatch rates fall. If the marginal cost of avoidance rises hyperbolically as bycatch rates fall, any incentive system that is intended to complement the induced incentives inherent in a TBA program, will be either targeted at low bycatch rate conditions, extremely expensive, or ineffective. A simple fee of $500 per Chinook salmon taken as bycatch, for example, would be extremely expensive for the pollock industry, but would not create a large enough incentive to induce significant behavioral changes by the pollock fleet when Chinook stocks are at low abundance levels.

IV. Explicit Economic Incentive Program for Each Participant to Avoid Chinook Salmon in All Years — ("The Game")

<u>Description of the Proposal</u>

The Council's motion states that incentive measures "*<u>must</u> include <u>rewards for salmon bycatch avoidance</u> and/or <u>penalties for failure to avoid salmon bycatch</u>* at the vessel level." The explicit incentive-based program, which is called "the Game"[viii] in this paper, is designed specifically to provide financial rewards to those vessels that have low Chinook salmon bycatch relative to other vessels in the pollock fleet, while penalizing those vessels with high bycatch.[ix]

Under the Game, each pollock-harvesting vessel has a deficit on its gross stock balance sheet of a certain amount of money per pound for each pound of pollock harvested. For purposes of this paper, we have used a penny per pound of pollock as the "ante" so that the vessel starts the season with the knowledge that one cent will be deducted from the vessel's gross stock per pound of pollock harvested.

At one penny per pound of pollock and a pollock TAC of a million metric tons, the inshore sector will develop a "Fund" just short of $10,000,000 to reward clean fishing practices. The catcher/processor sector will have a fund of about $8,000,000 and the mothership sector will generate a fund of about $2,000,000. That is collectively almost $20,000,000 available to influence fishing behavior.

The Game works as follows: A vessel's bycatch rate is defined as the number of Chinook salmon caught per metric ton of pollock. The vessel with the highest bycatch rate receives nothing from the Fund. Vessels with a bycatch below the highest rate receive money back from the Fund based on the following formula: A vessel's bycatch rate is subtracted from the vessel with the highest bycatch rate to determine the "Chinook Undercatch Rate." The "Undercatch Rate" for each vessel is then multiplied by that vessel's harvest of pollock to determine the actual number of undercaught Chinook relative to the vessel with the worst bycatch rate. The percent of Chinook salmon not caught per metric ton of pollock is then calculated for each vessel relative to the total number of undercaught Chinook salmon in that sector. The percent of Chinook salmon not caught by a vessel is then multiplied by the total amount in the Fund to determine the rebate that vessel will receive.

The Game must be sector-specific, as each sector has inherently different bycatch rates. This Game is not connected with TBA that each vessel might receive. There are no sector allocations to consider nor does the transfer of salmon bycatch allowance to or from a vessel impact the proposal.

Table two, below, is a simple model of the Game as played in a fishery with five vessels at average Chinook salmon abundance levels.

Table 2. Hypothetical model of the Game with five vessels at average bycatch levels.

Vessel/ Player	Tons of pollock harvested	Money put in to the Game	Number of Chinook Caught	Chinook bycatch rate (# per ton of pollock)	Chinook Undercatch rate	Number of Undercaught Chinook relative to Worst Player "Dirty Harry"	Game Payout
Harry	1,000	$22,000	100	0.1	0	0	0
Ana	1,000	$22,000	50	0.05	0.05	50	$19,411.76
Buddy	1,000	$22,000	40	0.04	0.06	60	$23,294.12
Chris	1,000	$22,000	30	0.03	0.07	70	$27,176.47
Julia	2,000	$44,000	40	0.02	0.08	160	$62,117.65
Total	6,000	$132,000	260	0.043		340	$132,000.00

At the end of each fishing season, the money is refunded based on the proportion of undercaught salmon credited to a particular vessel. For example, Julia earns 160 ÷ 340 x 132,000 = $62,117.65. In the table above, Harry has the highest bycatch rate at the end of the fishing season. He is the "Dirty Harry" because he has the highest ratio of Chinook bycatch to pollock harvested. The average value of each salmon avoided in this example is $388. Table three, below, shows the same fleet with *low* Chinook salmon abundance levels.

Table 3. Hypothetical model of the Game with five vessels at low bycatch levels.

Vessel/ Player	Tons of pollock harvested	Money put in to the Game	Number of Chinook Caught	Chinook bycatch rate (# per ton of pollock)	Chinook Undercatch rate	Number of Undercaught Chinook relative to Worst Player "Dirty Harry"	Game Payout
Harry	1,000	$22,000	10	0.01	0	0	0
Ana	1,000	$22,000	5	0.005	0.005	5	$19,411.76
Buddy	1,000	$22,000	4	0.004	0.006	6	$23,294.12
Chris	1,000	$22,000	3	0.003	0.007	7	$27,176.47
Julia	2,000	$44,000	4	0.002	0.008	16	$62,117.65
Total	6,000	$132,000	26	0.004		34	$132,000.00

In this model, the amount of Chinook bycatch drops and the reward for each Chinook that remains uncaught increases. The average value for vessels avoiding a Chinook in this example is $3,882.[x]

The actual marginal value for avoiding a salmon will vary with each participant, depending upon each participant's market share of "undercaught" salmon. The marginal value to Ana for avoiding a single salmon is different from the marginal value received by Julia. To illustrate how the marginal value of avoiding Chinook bycatch is different for each participant depending upon their market share of "uncaught" salmon, Table four shows the marginal value that Ana, a participant with a small market share of "uncaught" salmon, receives by avoiding a single additional salmon.

Table 4. Hypothetical model of the Game with five vessels at low bycatch levels showing marginal value of avoiding a Chinook salmon by a participant with a small market share.

Vessel/ Player	Tons of pollock harvested	Money put in to the Game	Number of Chinook Caught	Chinook bycatch rate (# per ton of pollock)	Chinook Undercatch rate	Number of Undercaught Chinook relative to Worst Player "Dirty Harry"	Game Payout
Harry	1,000	$22,000	10	0.01	0	0	0
Ana	1,000	$22,000	4	0.004	0.006	6	$22,628.57
Buddy	1,000	$22,000	4	0.004	0.006	6	$22,628.57
Chris	1,000	$22,000	3	0.003	0.007	7	$26,400.00
Julia	2,000	$44,000	4	0.002	0.008	16	$60,342.86
Total	6,000	$132,000	25	0.004		35	$132,000.00

By avoiding a single salmon, a small market share participant such as Ana receives $22,628.57 as a refund instead of $19,411.76, or an additional refund of $3,217 from the Game. Ana's marginal value of avoiding Chinook bycatch was therefore $3,217.

If a participant with a large market share of "undercaught" fish, however, avoids another salmon, its marginal value for avoiding that Chinook is lower. In Table five, below, the participant with the largest market share has a marginal value of only $1,997 for avoiding an additional salmon. In this example Julia avoids a single salmon and receives a refund of $64,114.29 instead of $62,117.65.

Table 5. Hypothetical model of the Game with five vessels at low bycatch levels showing marginal value of avoiding a Chinook salmon by a participant with a large market share.

Vessel/ Player	Tons of pollock harvested	Money put in to the Game	Number of Chinook Caught	Chinook bycatch rate (# per ton of pollock)	Chinook Undercatch rate	Number of Undercaught Chinook relative to Worst Player "Dirty Harry"	Game Payout
Harry	1,000	$22,000	10	0.01	0	0	0
Ana	1,000	$22,000	5	0.005	0.005	5	$18,857.14
Buddy	1,000	$22,000	4	0.004	0.006	6	$22,628.57
Chris	1,000	$22,000	3	0.003	0.007	7	$26,400.00
Julia	2,000	$44,000	3	0.0015	0.0085	17	$64,114.29
Total	6,000	$132,000	25	0.004		35	$132,000.00

The problem of relative market shares is a serious issue with any incentive-based program that allocates value from those with relatively high bycatch rates to those with low bycatch rates. It will be discussed more thoroughly in Chapter VIII addressing concerns with the Game.

Brief Analysis of the Game

The Game transfers money from those who have high bycatch rates to those who have low bycatch rates within each sector. Except for inducing the pollock industry to incur cost to avoid Chinook bycatch, the Game itself has no net cost to the industry as a whole.

Using methods detailed in the mathematical appendices, the marginal value of each Chinook avoided has been calculated. The factors that determine the marginal value of each salmon include the amount of money in the Fund, the spread of the bycatch rates of the vessels in each sector, and the number of vessels participating in the sector. The smaller the spread of bycatch rates, the larger the marginal value per Chinook.[xi]

As salmon abundance decreases and bycatch rates fall, the marginal value of each Chinook salmon avoided increases in the Game. This is important for three reasons: As Chinook abundance decreases, reduction of bycatch is increasingly urgent to protect the reproductive capacity of the stock. As Chinook abundance decreases, the marginal value of TBA decreases, and may be near zero, so the Game creates a large marginal value for avoiding Chinook salmon when the impact of the hard cap is minimal. In addition, as salmon abundance decreases and bycatch rates fall, the marginal cost of avoiding each Chinook salmon increases. Consequently the marginal value of avoiding salmon must also increase if the financial incentives to avoid salmon are to be effective.

The Value of Information

Variations in bycatch rates across time and distance constitute opportunities for the fleet to reduce bycatch by altering their location, timing and methods of operations. The extent to which incentives and opportunities are translated into reduced Chinook bycatch will depend upon the quantity, quality and timeliness of the information on bycatch rates available to the fleet. SeaState has been gathering and disseminating information on Chinook bycatch by season and by location for many years. This information will be valuable to vessels seeking to benefit by avoiding Chinook bycatch and is an important component of the RHC program. Real time information, however, would make a large contribution to lowering the cost of avoiding Chinook salmon and thereby helping to reducing bycatch.

The pollock fleet is currently obliged to record for each tow in the log book of the boat its location, catch and bycatch. Catcher vessels empty the net directly into the hold and as a result the entry into the log book is based on estimates of the weight of the catch and bycatch entries are based on inference from what can be observed in the layer closest to the net when the catch in winched aboard. That entry is a rough guess. A second set of books with another preliminary estimate is maintained by the observer. Once the catch is delivered at the onshore processing plant, sorted and weighed, a count of the pollock harvest and Chinook bycatch is taken by an observer stationed at the processing plant. Given the average time between a vessel's harvest and offloading, there is a day or two lag between its rough estimated and a more exact count. On catcher processor vessels, the lag between fishing and processing is shorter and so the information can be verified by the observer in a more timely manner.

The gain to the fleet of providing bycatch information on a timely basis is much greater than the cost of gathering, reporting and processing such bycatch information.[xii] Transmitting the information either from the log or from the observer would cost little, even tow by tow. Soon after each tow each boat should be required to report its best estimate of the time, location, catch and bycatch of that tow to a central data base which would make the information available on the rest of the fleet. For catcher vessels this first report should be explicitly labeled a guesstimate and no liability for its accuracy should be imposed. For catcher processors the information on catch coming from the processing plant would be available within the day. In the case of catcher vessels delivering onshore the more exact information obtained once delivery is made should also be transmitted.[xiii] Corrections could then be applied to the results of each tow. Even if only time, location and bycatch rate (number of Chinook per metric ton of pollock) were reported, actual bycatch rates could decline substantially once vessels have an incentive to avoid Chinook bycatch.[xiv]

The incentive-based program described in this paper will create some motivation to withhold information. One vessel's gain by catching less Chinook will be other vessels' loss. The inter-cooperative agreement should therefore require the sharing of information. In reality, however, it is in the interest of the fleet to share information. Information will be exchanged between captains on a reciprocal basis because the loss to a vessel A transmitting information enabling vessel B to avoid a Chinook is only one hundredth of Vessel B's gain in the case of the catcher vessel fleet. For a catcher processor the loss to the information provider is approximately one eighteenth of the gain to the recipient.[xv] Each pollock vessels' gains from the reports of other pollock fishing vessels would be much larger than the cost of transmitting a few short transmissions each fishing day. Moreover bycatch by one vessel raises the chance of the season for all vessels being cut short by the bycatch hard cap. So each vessel gains not only from the reduction in bycatch enabled by the information it receives, but if there is any danger of exceeding the bycatch hard cap, each vessel also benefits by the reduction in bycatch by other vessels. The fleet is always better off with less bycatch and information exchange is a will help achieve such a bycatch reduction.

A central database could compile the reports and present them in easy to understand format. For example a map showing recent bycatch rates by fishing area for all vessels for the last day, week, and season. The database could also display the cumulative catch of pollock and bycatch of Chinook for the season and the year.

V. The Marginal Value of Avoiding Chinook Induced by TBA and the Game

The marginal values induced by TBA and the Game were estimated using the mathematical model described in Appendices C through F. (Those wanting a copy of the model can email Joe Plesha at joeplesha@tridentseafoods.com.) Using the historical Chinook salmon bycatch rates and pollock TAC from 1998 through 2007, we estimated the expected probability that any given bycatch hard cap would be reached. During this ten-year period the average TAC for pollock was 1,306,324 metric tons. The average number of Chinook taken as bycatch were approximately 50,985 salmon. Using this model it is possible to calculate the expected marginal value of avoiding Chinook bycatch caused by TBA from a hard cap of 47,591, and the combination of TBA from a cap of 68,392 and the Game. The model assumes there is 100% rollover of TBA between the "A" and "B" seasons. The model also assumes that TBA is transferable between sectors; therefore the value of TBA is calculated for the mothership, catcher/processors and the inshore catcher vessel sectors combined.

Figure 3. Marginal value of Chinook salmon at differing expected annual bycatch rates (ABR) with TBA from a hard cap of, 32,482, 47,591 and 68,392.

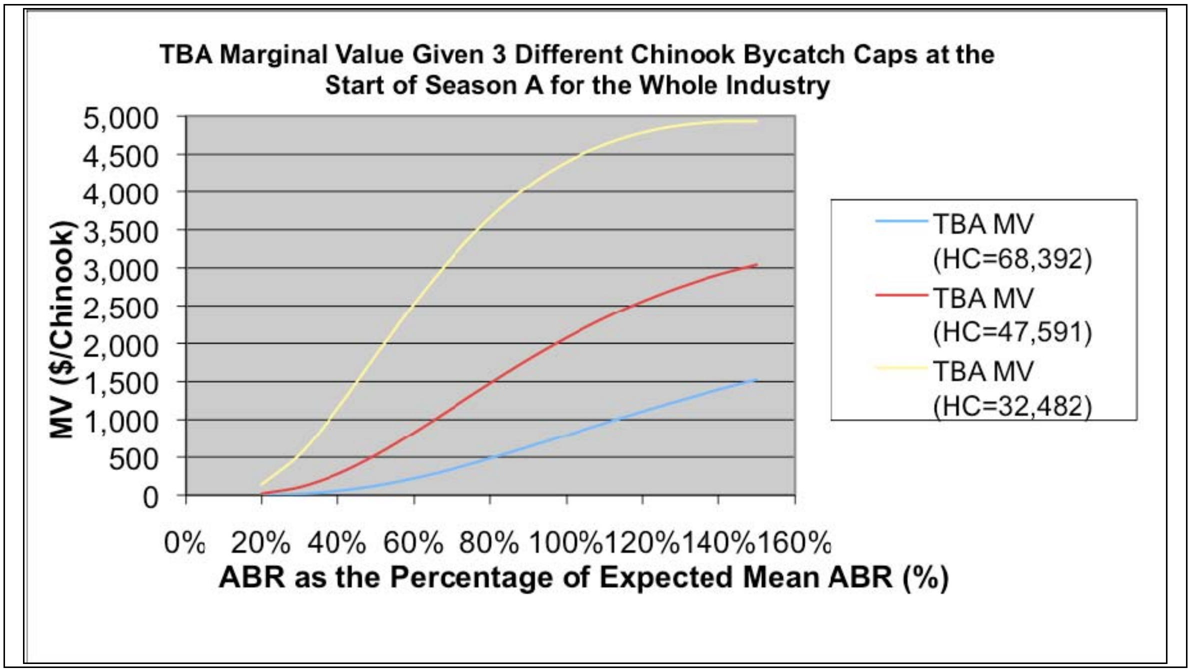
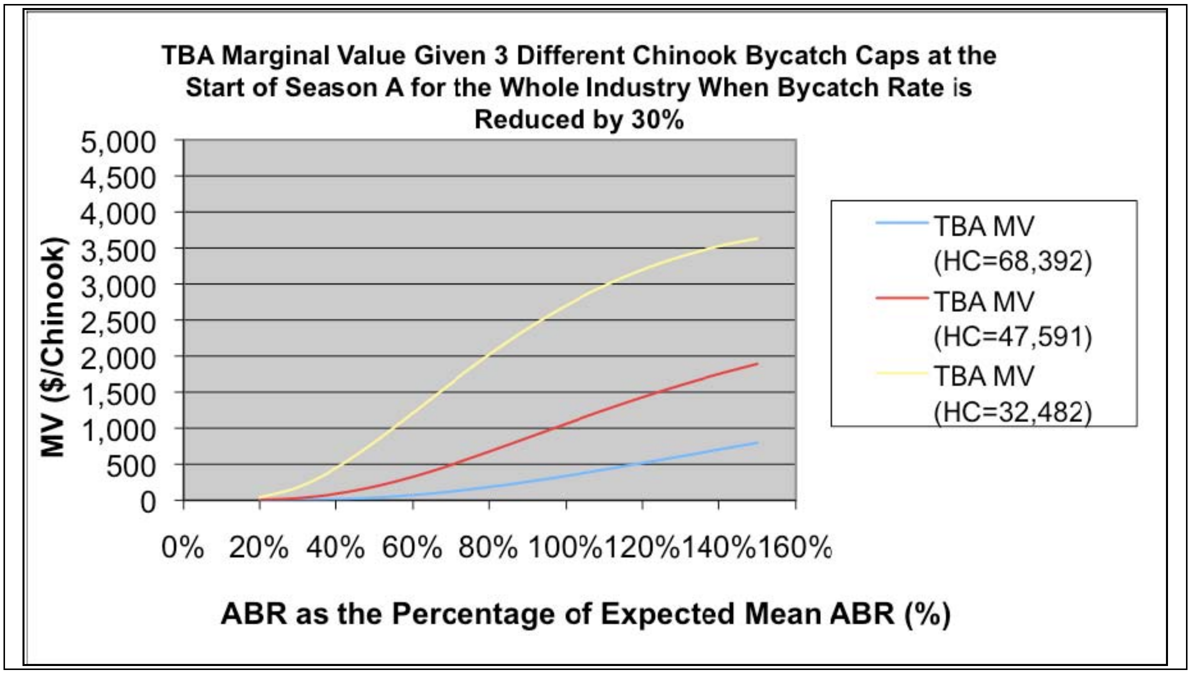


Figure three shows marginal value of Chinook bycatch at various expected bycatch levels for the year. It is based on the historical bycatch rates from the past ten years. The marginal value of TBA falls as bycatch rates are reduced and the probability of the industry reaching the hard cap lessens. If the impact of industry's efforts to avoid salmon is a reduction in Chinook bycatch of thirty percent, then the marginal value of avoiding Chinook bycatch created by TBA is much less.

Figure 4. Marginal value of Chinook salmon at differing expected annual bycatch rates (ABR) with TBA from a hard cap of 32,482, 47,591 and 68,392 with a thirty percent reduction in bycatch rates caused by the incentive-based bycatch avoidance program.

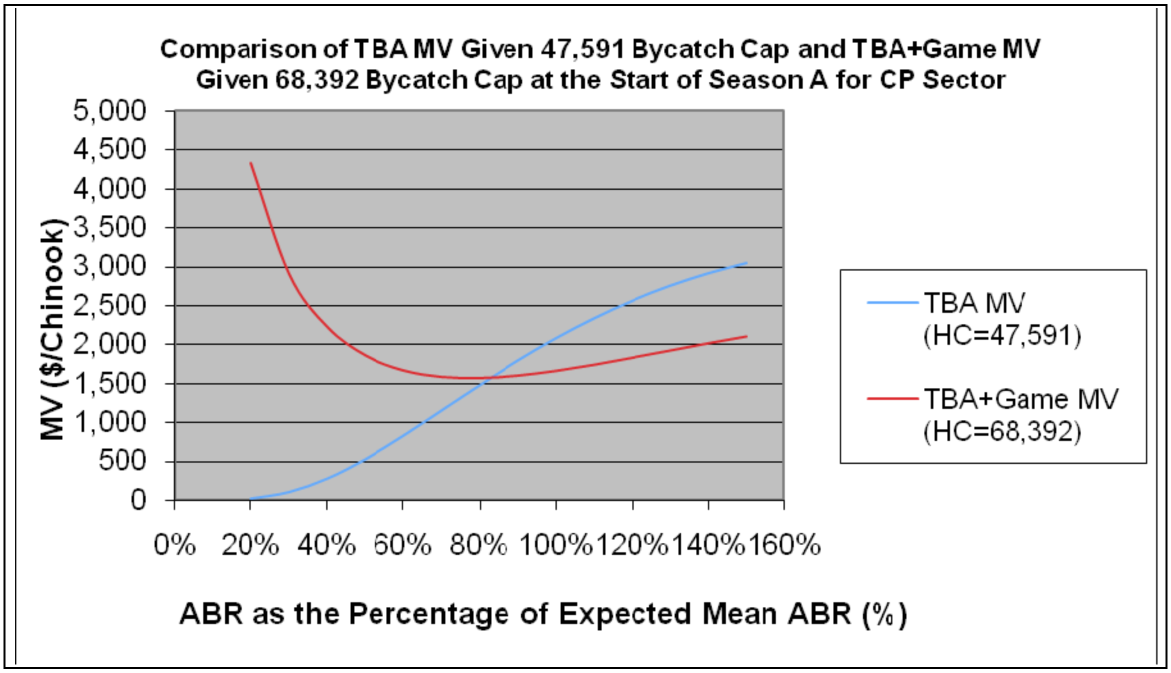


We assume there will be strong incentives to reduce bycatch resulting from the Council's actions. Figure four shows that if the pollock industry starts the season expecting to reduce its overall bycatch rate by just thirty percent, the marginal value induced by TBA is relatively small, especially with a hard cap of 68,392.

Because the marginal *cost* of avoiding salmon will increase as Chinook abundance decreases, there will be little, if any, net economic incentive to avoid catching Chinook salmon with just TBA from a hard cap of 68,392 if Chinook abundance is low. Something more is needed. The Game complements TBA from a hard cap of 68,392 because together the Game and TBA induce significant marginal values for each Chinook avoided at all levels of salmon abundance, but especially during periods of low abundance when a hard cap alone is ineffective.

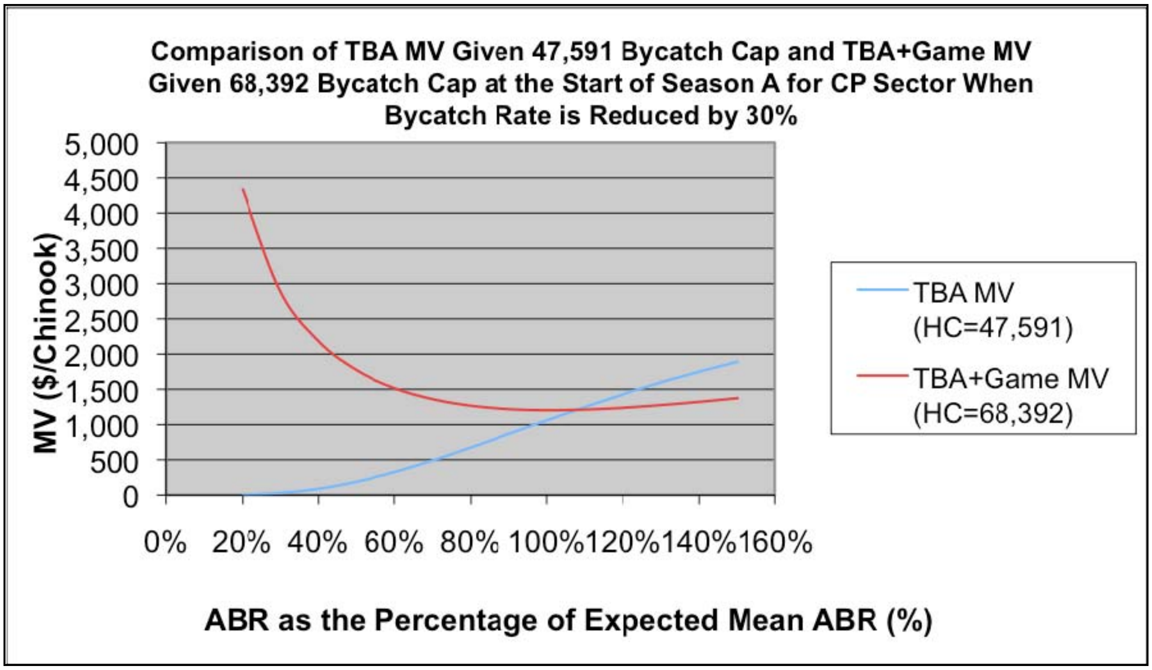
To illustrate this point, figure five below, shows the marginal value of Chinook bycatch induced by a hard cap of 47,591 and a hard cap of 68,392 with the Game.

Figure 5. Marginal value of Chinook salmon at differing expected annual bycatch rates (ABR) with TBA from a hard cap of 47,591 and 68,392 and the Game for the CP Sector.



If the pollock industry expects it will reduce its Chinook bycatch by thirty percent as a result of the incentives resulting from the these bycatch avoidance programs, the marginal value of TBA will decrease, but the marginal value of the Game will increase substantially.

Figure 6. Marginal value of Chinook salmon at differing annual bycatch rates (ABR) with TBA from a hard cap of 47,591, and 68,392 with the Game if the pollock industry expects a thirty percent reduction in bycatch rates caused by the incentive-based bycatch avoidance program.



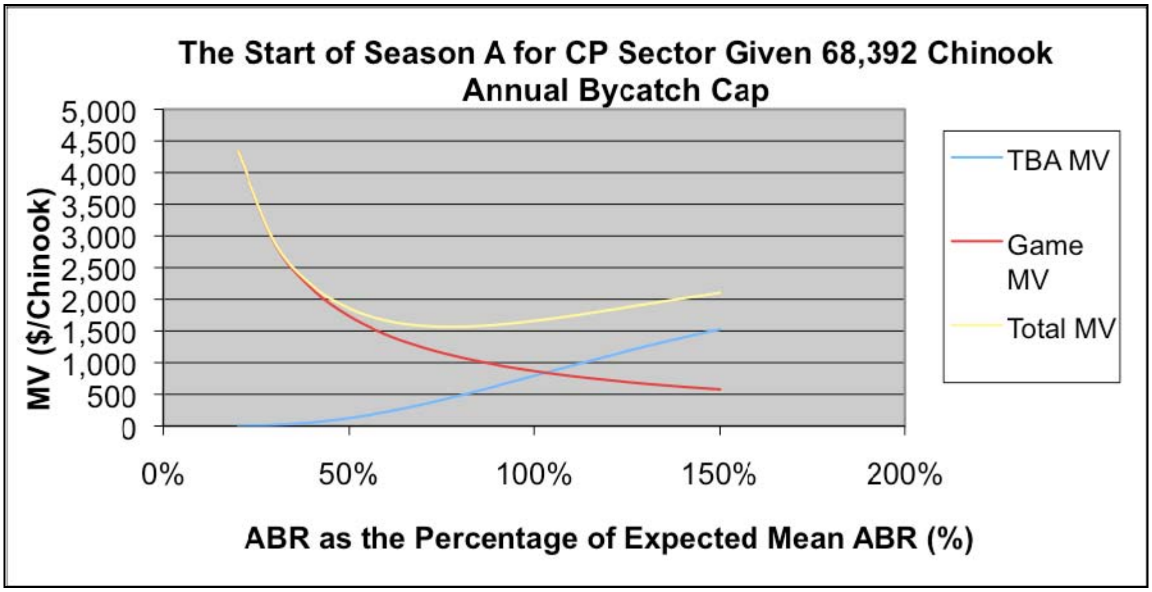
Most participants in the pollock fishery believe Chinook bycatch will sharply decline with the imposition of hard caps and a meaningful incentive-based avoidance program. If the Chinook bycatch rates decline by just thirty percent, the marginal value of avoiding Chinook is modest even with a hard cap of 47,591 in comparison to the marginal value induced by the Game and a hard cap of 68,392.

Figure six illustrates the advantages that a hard cap of 68,392 and the Game have in comparison to a hard cap of 47,591. For those seeking to protect Chinook salmon, a hard cap of 68,392 along with the Game is far preferable to a simple 47,591 hard cap. The Game and a 68,392 hard cap induces significant marginal values for avoiding salmon during all years and at all levels of salmon abundance, especially when Chinook salmon are in low abundance and protection is most needed and avoiding Chinook salmon most costly.

That is the intention of the Council's PPA. If the pollock industry can develop an incentive-based program that induces behavior to protect salmon better than the hard cap of 47,591, the Council may allow the more liberal hard cap of 68,392. The program outlined in this paper strives to achieve the Council's goal.

To illustrate how the marginal value induced by the Game complements the marginal value created by TBA at differing annual bycatch rates, figure seven shows the total marginal value of TBA from a hard cap of 68,392 and the Game.

Figure 7. Marginal value of avoiding a Chinook salmon at differing annual bycatch rates (ABR) with TBA from a hard cap of 68,392 with the Game.



VI. Incentives TBA and the Game Will Have on the Pollock Fleet's Efforts to Avoid Chinook Bycatch

Incentive for a Vessel to Move to Areas of Lower Chinook Bycatch. A substantial marginal value for each Chinook avoided will create incentives for the pollock fleet to move its fishing location to areas of lower bycatch. The examples below provide information on the distances that a vessel will travel to avoid Chinook under the Council's Preferred Preliminary Alternative.

Example 1. The beginning of the A season, catcher/processor under TBA from a 47,591 hard cap with the industry having bycatch at its historically average rate:
Assume that a catcher/processor is fishing in an area of moderately high bycatch rate (Area A) and there is an area of moderately low bycatch (Area B) a distance away. The vessel expects pollock to be available in Area A for an additional twenty-four hours. The vessel also expects pollock to be available in Area B for twenty-four hours after the vessel's arrival. The vessel expects to catch twenty metric tons of pollock per hour at either location. The catcher/processor's cruising speed is ten nautical miles per hour. The total daily cost of traveling is about $54,000 or $2,250 per hour. The cost of traveling one mile is therefore $225.

Assume that the seasonal bycatch rate for the catcher/processor sector is 0.02 Chinook per metric ton of pollock (which is the historical annual bycatch rate observed for the sector over the last ten years). For simplicity of this example, it is also assumed the vessel's processing rate is in excess of twenty metric tons of pollock per hour so that the catcher/processor is unable to gain any advantage by processing during transit.

Area A's Chinook bycatch rate is 150% of the 0.02 average, or 0.03 Chinook per metric ton of pollock. Area B's Chinook bycatch rate is 50% of the 0.02 average, or 0.01 Chinook per metric ton of pollock.

How far will the vessel move to reduce its bycatch of Chinook?

The catcher/processor catches 14.4 Chinook per day while in Area A.
(20 MT per hour x 0.03 x 24 hours = 14.4 Chinook per day.)

The catcher/processor catches 4.8 Chinook per day while in Area B.
(20 MT per hour x 0.01 x 24 hours = 4.8 Chinook per day.)

The marginal value induced by TBA under the model in a year of historically average bycatch rates would be $2,076 per Chinook salmon, with a 47,591 Chinook hard cap for the all sectors combined. We assume that the sectors can freely trade their bycatch allowances. A rational harvester will move if the marginal value of avoiding Chinook is greater than the marginal cost. By moving from Area A to Area B, the catcher/ processor will save 9.6 Chinook per day (14.4 – 4.8 = 9.6) which is worth $19,930 (9.6 x $2,076 = $19,930). The catcher/processor in our example will move a maximum of 88.6 nautical miles to Area B (19,930 ÷ 225 = 88.6) to avoid 9.6 Chinook salmon.

<u>Example 2. Catcher/processor under TBA from a 47,591 hard cap with the industry having bycatch *below* its historically average rate at the beginning of the A season</u>: Now assume a standard bycatch rate is reduced by 30% of the historical average of 0.02 Chinook per metric ton of Pollock due to industry efforts to avoid Chinook, or 0.014 Chinook per metric ton of pollock (0.7 x 0.02 = 0.014). Area A's Chinook bycatch rate is 150% of the 0.014 average, or 0.021 Chinook per metric ton of pollock. Area B's Chinook bycatch rate is 50% of the 0.014 average, or 0.007 Chinook per metric ton of pollock.

How far will the vessel move to reduce its bycatch of Chinook?

The catcher/processor catches 10.08 Chinook per day while in Area A.
(20 MT per hour x 0.021 x 24 hours = 10.08 Chinook per day.)

The catcher/processor catches 3.36 Chinook per day while in Area B.
(20 MT per hour x 0.007 x 24 hours = 3.36 Chinook per day.)

The marginal value of TBA under the model in a year of bycatch rates that are 30% of the historical average would be only $1,060 per Chinook salmon, with a 47,591 Chinook hard cap for all sectors combined. By moving from Area A to Area B, the catcher/processor will save 6.72 Chinook per day (10.08 – 3.36 = 6.72) which is worth $7,123 (6.72 x $1,060 = $7,123). The catcher/processor in this example will move a maximum of 31.7 nautical miles to Area B (7,123 ÷ 225 = 31.7) to avoid 6.72 Chinook salmon.

Example 3. Catcher/processor under the Game and TBA from a 68,392 hard cap with the industry having bycatch *below* its historically average rate:
Now assume that the average bycatch rate is reduced by 30% of its historical average, but the catcher/processor is operating under TBA from a hard cap of 68,392 and the Game. By moving from Area A to Area B, the catcher/processor will still save 6.72 Chinook per day as in the previous example. The marginal value induced by TBA, however, is only $337. The marginal value induced by the Game is $867. The combined marginal value of TBA and the Game is $1,204. The 6.72 Chinook salmon saved by moving to Area B would be worth $8,091 (6.72 x $1,204 = $8,091). The catcher processor in this example will move 36 nautical miles ($8,091 ÷ 225 = 36) to avoid 6.72 Chinook salmon.

Example 4. Catcher/processor under TBA from a 47,591 hard cap with the industry having bycatch *below* its historically average rate:
Now assume a particular year's average bycatch rate is 60% below the projected average bycatch rate, caused by natural conditions, after the industry's efforts have already taken place as shown in example 3. The catcher/processor is operating under TBA from a hard cap of 47,591 and the Game.

Area A's Chinook bycatch rate is 150% of 0.0056 (0.0056 = 0.014 x 0.4), or 0.0084 Chinook per metric ton of pollock. Area B's Chinook bycatch rate is 50% of 0.0056, or 0.0028 Chinook per metric ton of pollock.

How far will the vessel move to reduce its bycatch of Chinook?

The catcher/processor catches 4.03 Chinook per day while in Area A.
(20 MT per hour x 0.0084 x 24 hours = 4.03 Chinook per day.)

The catcher/processor catches 1.34 Chinook per day while in Area B.
(20 MT per hour x 0.0028 x 24 hours = 1.34 Chinook per day.)

By moving from Area A to Area B, the catcher/processor will save 2.69 Chinook per day (4.03 – 1.34 = 2.69). The marginal value induced by TBA is only $89. The 2.69 Chinook salmon saved by moving to Area B would be worth $239 (2.69 x $89 = $239). The catcher processor in this example will move 1.1 nautical miles ($239 ÷ 225 = 1.1) to avoid 2.69 Chinook salmon.

Example 5. Catcher/processor under the Game and TBA from a 68,392 hard cap with the industry having bycatch *below* its historically average rate:

Now assume a particular year's average bycatch rate is 60% below the projected average bycatch rate, caused by natural conditions, after the industry's efforts have already taken place as shown in example 3. The catcher/processor is operating under TBA from a hard cap of 68,392 and the Game.

Area A's Chinook bycatch rate is 150% of 0.0056 (0.0056 = 0.014 x 0.4), or 0.0084 Chinook per metric ton of pollock. Area B's Chinook bycatch rate is 50% of 0.0056, or 0.0028 Chinook per metric ton of pollock.

How far will the vessel move to reduce its bycatch of Chinook?

The catcher/processor catches 4.03 Chinook per day while in Area A.
(20 MT per hour x 0.0084 x 24 hours = 4.03 Chinook per day.)

The catcher/processor catches 1.34 Chinook per day while in Area B.
(20 MT per hour x 0.0028 x 24 hours = 1.34 Chinook per day.)

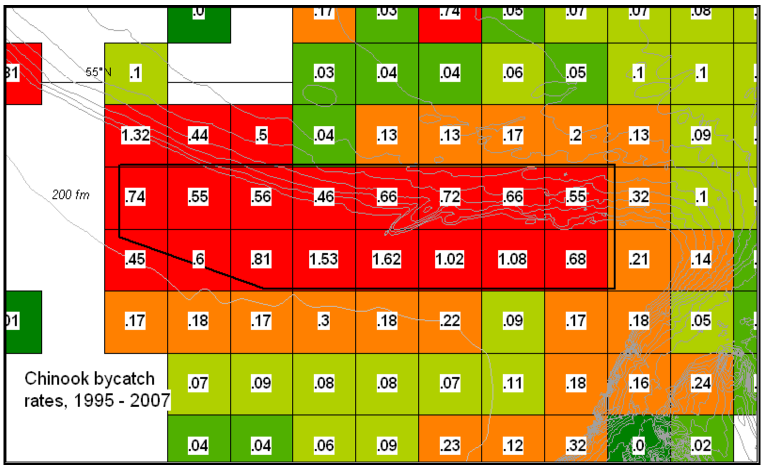
By moving from Area A to Area B, the catcher/processor will save 2.69 Chinook per day (4.03 – 1.34 = 2.69). The marginal value induced by TBA is only $14. The marginal value induced by the Game is $2,168. The combined marginal value of TBA and the Game is $2,182. The 2.69 Chinook salmon saved by moving to Area B would be worth $5,870 (2.69 x $2,182 = $5,870). The catcher processor in this example will move 26.1 nautical miles ($5,870 ÷ 225 = 26.1) to avoid 2.69 Chinook salmon.

Table 3. Distance a catcher/processor will travel to avoid a particular number of Chinook salmon under Examples 1 through 5.

Bycatch Rate (Chinook/ MT of pollock)	Hard Cap (Number of Chinook)	TBA MV ($/Avoided Chinook)	Game MV ($/Avoided Chinook)	Total MV ($/Avoided Chinook)	Bycatch Reduced by Industry Effort	Chinook Abundance	Maximum Distance Traveled to Avoide Chinook (Miles)
0.02	47,591	$2,076	N/A	$2,076	0	100% (Normal)	**88.6**
0.014	47,591	$1,060	N/A	$1,060	-30%	100% (Normal)	**31.7**
0.014	68,392	$337	$867	$1,204	-30%	100% (Normal)	**36**
0.0056	47,591	$89	N/A	$89	-30%	40% (Low)	**1.1**
0.0056	68,392	$14	$2,168	$2,182	-30%	40% (Low)	**26.1**

Figure eight below shows the bycatch rate for the combined years 1995 through 2007 in the pollock A season in the horseshoe area of the Bering Sea. The squares in Figure eight are approximately six miles on each side. It is clear from this Figure that moving twenty five miles can take a vessel from an area of very high Chinook salmon bycatch rates to areas of much lower bycatch rates. The decision to move will not only be motivated by bycatch conditions at that time. Bycatch rates over a shorter period of time will show even more variability than the twelve year averages that are shown in Figure eight.

Figure 8. Chinook bycatch rates during the pollock A season for the combined years 1995-2007 in and around the horseshoe area of the Bering Sea.



Incentive for a Vessel to Change Its Time of Fishing From October to June. Chinook bycatch is far greater after September 15th. The examples below analyze whether the pollock industry will move its production from the fall to summer under the proposed hard caps.

<u>Example 6. Fishing during June or October with TBA from a hard cap of 47,591</u>: Fishing during early October yields recovery of 0.316 pounds of edible product per pound of fish, with a value, at current prices, of $1,111.86 per metric ton. Fishing during the second week of June yields 0.3034 pounds of edible product per pound of fish, with a value of $980.34 per metric ton. This means that for every metric ton of pollock harvested in June rather than in October, the value of the finished products is $131.52 less than if the fish had been harvested in October. If a catcher vessel shifts one trip catching 500 metric tons of pollock from October to June, there is a loss of $65,760.

Consider the situation of a processor-owned catcher vessel where all the economic consequences of fishing timing decisions are reflected in its decisions. If for June, the average bycatch rate for the catcher vessel sector is 0.01 Chinook per metric ton of pollock, and for October the bycatch rate is 0.2 Chinook metric ton of pollock (see Figure two), the number of Chinook expected to be caught in one trip of June fishing is 0.01 x 500 = 5 Chinook; and in one trip in October fishing is 0.2 x 500 = 100 Chinook. The number of Chinook saved by shifting one trip from October to June is 95 salmon. The loss of revenue as a result of this change and the reduced Pollock recovery that results from this change is $65,760. The marginal cost of avoidance is equal to $692.21 (65,760 ÷ 95 = $692.21).

The marginal value of TBA at the end of "A" season in an average year with the overall hard cap of 47,591 Chinook is expected to be $1,789. Therefore, a rational fisherman would be incentivized to shift one trip from October to June.

At the expected annual bycatch rate of 60% of the average, however, TBA would be worth only $75. In this case of a low Chinook abundance, the average bycatch rate for June for the catcher vessel sector would be 0.01 x 0.6 = 0.006 Chinook per metric ton of pollock and for October would be 0.2 x 0.6 = 0.12 Chinook per metric ton of pollock. The number of Chinook expected to be caught in one trip of June fishing is 0.006 x 500 = 3 Chinook and in one trip in October fishing is 0.12 x 500 = 60 Chinook. The number of Chinook saved by shifting one trip from October to June is 57 Chinook. The marginal cost of avoidance is equal to $1,153.68 (65,760 ÷ 57 = $1,153.68). We can see that in a year of a low Chinook abundance, with TBA from a hard cap of 47,591 Chinook, it would be profitable to move fishing effort from the low bycatch in June to the high bycatch in October.

<u>Example 7. Fishing during June or October with TBA from a hard cap of 68,392 with the Game in place</u>:
Again, every metric ton of pollock harvested in June rather than in October, the value of the finished products is $131.52 less than if the fish had been harvested in October. If a catcher vessel shifts one trip catching 500 metric tons of pollock from September to June, there is a loss of $65,760.

Consider again the situation of a processor-owned catcher vessel where all the economic consequences of fishing timing decisions are reflected in its decisions. If for June, the average bycatch rate for the catcher vessel sector is 0.01 Chinook per metric ton of pollock, and for October is 0.2 Chinook per metric ton of pollock (see Figure 5), the number of Chinook expected to be caught in one trip of June fishing is 0.01 x 500 = 5 Chinook and in one trip in October fishing is 0.2 x 500 = 100 Chinook. The number of Chinook saved by shifting one trip from October to June is 95 Chinook. The loss of revenue as a result of this change and the reduced pollock recovery that results from this change is $65,760. The marginal cost of avoidance is equal to $692.21 (65,760 ÷ 95). The marginal value of TBA at the end of "A" season in an average year with the overall hard cap of 68,392 Chinook is expected to be $167. The marginal value of the Game at the end of "A" season in an average year with the overall hard cap of 68,392 Chinook is expected to be $867, so the total marginal value of avoiding a Chinook is expected to be $1,034. Therefore, a rational harvester would still be incentivized to shift one trip from October to June.

In fact, at the expected annual bycatch rate of 60% of the average, TBA would be worth only $1. In this case of low Chinook abundance, the average bycatch rate for June for the catcher vessel sector would be 0.01 x 0.6 = 0.006 Chinook per of pollock and for October would be 0.2 x 0.6 = 0.12 Chinook per metric ton of pollock. The number of Chinook expected to be caught in one trip of June fishing is 0.006 x 500 = 3 Chinook. In one trip in October fishing the number of Chinook expected to caught is 0.12 x 500 = 60. The number of Chinook saved by shifting one trip from October to June is 57 Chinook. The marginal cost of avoidance is equal to $1,153.68 (65,760 ÷ 57 = $1,153.68). The marginal value of Chinook avoidance under the Game, however, increases to $1,445. Because the marginal value is greater than the marginal cost, even in a year of a low Chinook abundance, having TBA at the hard cap of 68,392 and the Game would make it profitable to move fishing effort from October to June.

Incentive for a Vessel to Use an Excluder Device with its Trawl Gear. The pollock industry is working to develop an effective salmon excluder device to use with pollock trawl gear. This excluder device is being designed to allow a significant percentage of Chinook salmon to escape from being caught in the trawl net's cod end.

Tests of salmon excluder devices suggest that when properly operated they can reduce the bycatch of Chinook by twenty percent. Some pollock that would otherwise be caught in the trawl net also escapes are a result of the Salmon excluded device. Early tests show about five percent of the pollock that would otherwise be harvested escapes as a result of operating salmon excluder gear. The operation of a salmon excluder requires skill on the part of the captain. Simply ordering the salmon excluder be on the vessel would probably not result in a significant reduction of salmon bycatch.

The cost to purchase a salmon excluder is only about $6,000. Although salmon excluders reduce Chinook bycatch by twenty percent, they result in increased fishing costs. Pollock vessels will therefore not likely use an excluder without incentives.

<u>Example 8. Catcher/processor during the "A" season</u>:
If the catch rate of a catcher/processor, as limited by its processing capacity, is about twenty metric tons per hour, the vessel will harvest 400 metric tons of pollock in a twenty-hour period. Using a salmon excluder device, however, the catcher/processor will now take twenty-one hours to harvest the same 400 metric tons.

Assume the average bycatch rate during the "A" season is .05 Chinook per metric ton of pollock. At that rate, the catcher/processor would expect to have twenty Chinook salmon as bycatch in its harvest of its 400 metric tons of pollock. (400 x .05 = 20) Using the excluder will reduce the vessel's bycatch by twenty percent and therefore reduce the bycatch from twenty to sixteen salmon (20 x .20 = 16), thus saving four Chinook salmon.

Using the excluder would require the catcher/processor to fish one additional hour in order to harvest the same amount of pollock as it would without the device. The cost of the catcher/processor fishing is about $2,500 per hour. The marginal cost of using the salmon excluder is $625. ($2,500 divided by the four salmon avoided.) The marginal values induced by the Game and TBA from a hard cap of 68,392 would provide the incentive necessary to cause this catcher/processor to use and properly operate a salmon excluder device during the "A" season. Just TBA from a hard cap of 47,591, however, would not create marginal values required to induce the vessel to use a salmon excluder during the "A" season in periods of even moderately low Chinook abundance.

Example 9. Catcher/processor during the "B" season:

During the summer months of the pollock "B" season, salmon bycatch rates are extremely low, perhaps ten percent of the "A" season rates. If we assume that the Chinook bycatch rate while fishing pollock in July is .005, the catcher/processor in the above example will take only two salmon as bycatch in its harvest of 400 metric tons of pollock without using an excluder (400 x .005 = 2). Using the excluder will reduce the vessel's expected bycatch of Chinook to 1.6 salmon (2 x .20 = .16), thus reducing its bycatch by .4 Chinook salmon; however, the cost of using the excluder device will still be $2,500 for the extra hour it takes to harvest 400 metric tons of pollock. The expected marginal cost of using the excluder is therefore $6,250. ($2,500 divided by the .4 salmon avoided.) Under the typical conditions of fishing pollock in the early summer, therefore, it is unlikely that the pollock fleet will effectively use a salmon excluder because the marginal cost of using the device significantly exceeds the marginal value of the salmon that would be avoided.[xvi]

Example 10. Catcher vessel delivering onshore during the "A" season:

A catcher vessel delivering onshore has different financial considerations to make. A catcher boat's fishing during "A" season is not limited by the vessel's processing capacity and a catcher vessel's harvest rate can exceed twenty metric tons per hour. Twenty metric tons per hour is a general approximation, however, of the average hourly production during "A" season for a catcher vessel. The catcher vessel would then take 400 metric tons of pollock in twenty hours, assuming it had the hold capacity.

Assuming the "A" season Chinook bycatch rate is of .05, the catcher vessel would expect to have twenty Chinook salmon as bycatch in its harvest of its 400 metric tons of pollock (400 x .05 = 20). Using the excluder would reduce the vessel's bycatch by twenty percent and therefore reduce the bycatch from twenty to sixteen salmon (20 x .20 = 16), thus saving four Chinook salmon.

The cost of pollock fishing for a catcher vessel is about $600 per hour. Using the excluder would require the vessel to fish for an additional hour to harvest the same amount of pollock it would take without the excluder device. The marginal cost of using the salmon excluder would be $150. ($600 divided by the four salmon avoided.) There would be an economic incentive for the catcher vessel to use the excluder device during the "A" season with a hard cap of 68,392 together with the Game, and with just a hard cap of 47,591 (except under conditions of very low Chinook abundance).

Example 11. Catcher vessel during the "B" season:

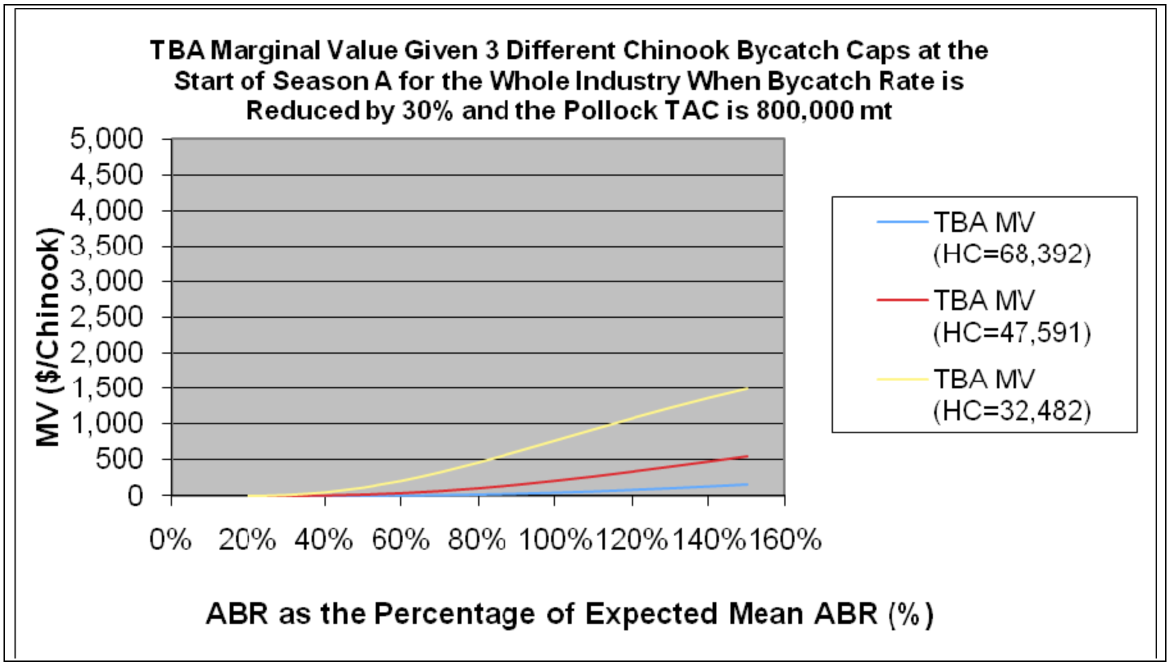
During the summer of the "B" season harvest rates can fall to approximately ten to fifteen metric tons per hour. Assume the vessel is harvesting ten metric tons an hour for twenty hours, for purposes of this example. If the bycatch drops to .005 Chinook salmon per metric ton during the summer of the "B" season, the catcher vessel would expect to have only 1 Chinook salmon as bycatch in its harvest of 200 metric tons of pollock (200 x .005 = 1). Using the excluder would reduce the vessel's bycatch by twenty percent and therefore reduce the expected bycatch from 1 by .8 salmon (1 x .20 = .8), thus saving .2 Chinook salmon.

The cost of pollock fishing for a catcher vessel is still about $600 per hour. Using the excluder would require the vessel to fish for an additional hour to harvest the same amount of pollock it would take in twenty hours without the excluder device. The marginal cost of using the salmon excluder would now be $3,000 ($600 divided by the .2 salmon expected to be avoided). Both TBA from a hard cap of 68,392 with the Game, and TBA from a hard cap of 47,591 would be unlikely to create a marginal value greater than $3,000.

VII. Pollock Abundance

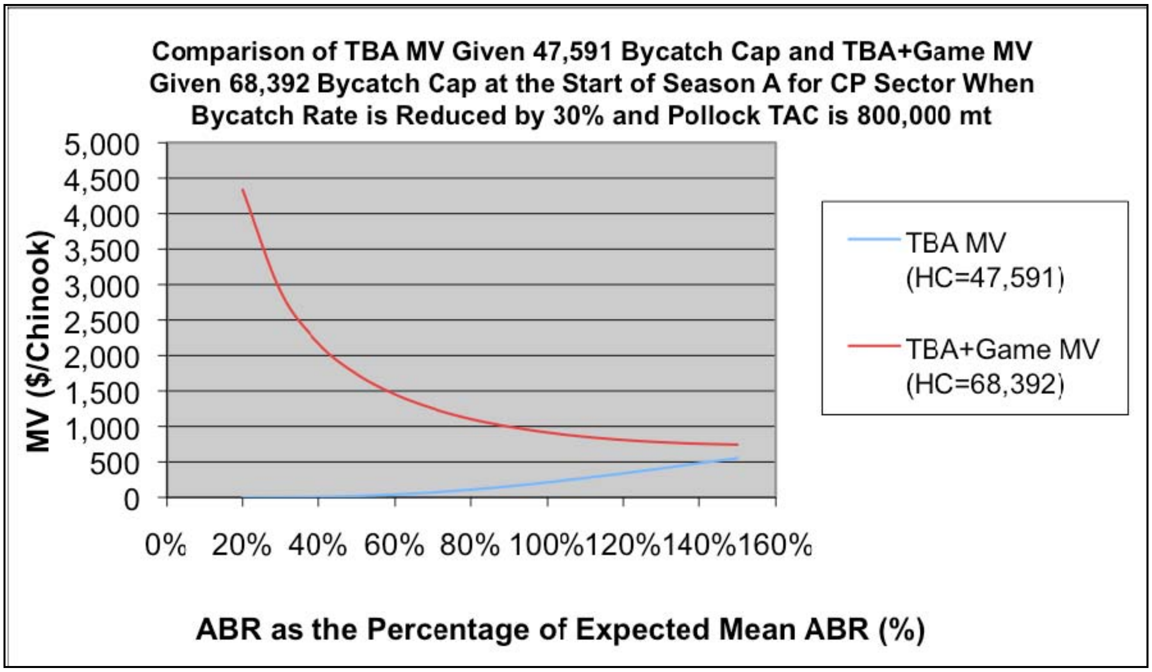
The Council's PPA specifically notes that the incentive-based bycatch avoidance program "must provide incentive(s) for each vessel to avoid salmon bycatch under any condition of *pollock* and salmon abundance in all years." An important assumption upon which the proceeding models and examples were all based is the average pollock TAC from 1998 through 2007. During this ten-year period the average TAC for pollock was 1,306,000 metric tons. This is a historically high pollock TAC for a ten-year period of time.[xvii] If pollock abundance declines, and the TAC falls from this historically high level, the probability of reaching the bycatch caps in the PPA is reduced and the marginal value created by TBA declines. The marginal value of avoiding Chinook bycatch can become small at a pollock TAC of 800,000 metric tons.[xviii]

Figure 9. Marginal value of Chinook salmon at differing expected annual bycatch rates (ABR) with TBA from a hard cap of 47,591 and 68,392 with a thirty percent reduction in bycatch rates caused by the incentive-based bycatch avoidance program and a Pollock TAC of 800,000 metric tons.



As shown by Figure nine, the marginal value induced by TBA from even a hard cap of 47,591 is minimal. The marginal value of avoiding Chinook bycatch induced by TBA with a hard cap of 68,391 is even less. In periods of lower pollock abundance, Figure nine shows how the Game will complement TBA by providing strong financial incentives to avoid Chinook bycatch when there is little change of reaching the hard cap. Even in cases of chronically low pollock abundance, the Game will create a large marginal value for avoiding Chinook bycatch.

Figure 10. Marginal value of Chinook salmon at differing expected annual bycatch rates (ABR) with TBA from a hard cap of 68,392 and the Game with a thirty percent reduction in bycatch rates caused by the incentive-based bycatch avoidance program and a Pollock TAC of 800,000 metric tons.



VIII. Concerns About the Game

Conspiracy to fish with similar bycatch rates

It has been suggested that a vessel with a small amount of pollock quota could be paid by the rest of the pollock fleet to “fish dirty” while all other vessels conspire with each other fish with similar bycatch rates, causing the net gains and losses for each vessel to also be similar. By fishing dirty, an artificially high “undercatch” would be established in the Game. By increasing the spread between the vessel with the worst bycatch and the rest of the fleet, the marginal value of avoiding Chinook is reduced. If all the other vessels in the fleet then fished pollock with nearly identical Chinook bycatch rates, the actual wins and losses for each vessel under the Game would be modest.

Paying a vessel to “fish dirty” for the purpose of intentionally reducing the marginal value of avoiding Chinook bycatch and then the fleet conspiring to harvest pollock with similar Chinook bycatch rates would be a federal crime, unless it had been previously disclosed in the Inter-Cooperative Agreement application process.[xix]

It is highly unlikely this conspiracy could be successfully implemented. Even within the catcher/processor sector, which typically uses only sixteen to eighteen vessels during the season, the number of individuals who would have to be involved would include the chief executives and fleet managers of all five of the offshore companies, as well as the captains and relief captains on each vessel. For the conspiracy to work in the catcher/processor sector, at least fifty individuals would have to be aware of, and participate in, the agreement. For the onshore sector such a conspiracy would require the active participation of well over a hundred people to be effective. Given each vessel's unique operational characteristics, it would also be difficult and costly for the entire fleet to fish pollock with similar Chinook bycatch rates.

If all vessels just fished with similar bycatch rates the wins and losses from the Game for each vessel would be extremely large. There would be huge financial incentives for vessels to "cheat" on any agreement by avoiding a few additional salmon. A hypothetical example is provided in Table six, below. The example assumes that the catcher/processor fleet purposely fished pollock so as to achieve similar Chinook bycatch rates. In this example, the Game provided a marginal value of over $21,000 for each Chinook avoided! The profit or loss for each vessel under the Game is extremely large, even though the all had similar bycatch rates.

Table 6. Hypothetical example of the catcher/processor fleet conspiring to fish pollock with similar Chinook bycatch rates.

Offshore CP Vessels	Percent of CP Harvest	Actual Pollock Harvest (MT)	Contribution to SBCF	Chinook Bycatch Number	Chinook Bycatch Rate/MT	Chinook Undercatch" Rate	Total "Undercatch" of Chinook	Percent of Undercatch	SBCF Rebate	SBCF Profit/ Loss
Alaska Ocean	7.47%	38,829	$856,024	771	0.01985629	0.00237578	92	17.09982	$1,958,749	$1,102,725
Dynasty	2.90%	15,088	$332,630	325	0.0215403	0.00069178	10	1.9347605	$221,623	-$111,007
Triumpth	8.33%	43,257	$953,644	934	0.02159188	0.00064019	28	5.1333004	$588,009	-$365,635
Eagle	8.36%	43,452	$957,943	932	0.02144896	0.00078312	34	6.3076376	$722,527	-$235,416
Hawk	8.06%	41,879	$923,264	898	0.02144273	0.00078935	33	6.1276377	$701,908	-$221,356
Jaeger	8.14%	42,311	$932,788	904	0.0213656	0.00086647	37	6.7957423	$778,438	-$154,350
Rover	7.70%	40,033	$882,568	865	0.02160717	0.0006249	25	4.6372236	$531,184	-$351,383
Fjord	6.65%	34,575	$762,240	727	0.02102675	0.00120532	42	7.7249176	$884,873	$122,633
Storm	6.15%	31,932	$703,973	691	0.02163973	0.00059234	19	3.5061164	$401,618	-$302,354
Northern Glacier	3.04%	15,788	$348,062	351	0.02223207	0	0	0	$0	-$348,062
Pacific Glacier	5.05%	26,215	$577,936	557	0.02124738	0.0009847	26	4.7849947	$548,111	-$29,825
Highland Light	5.79%	30,084	$663,232	636	0.02114081	0.00109127	33	6.0854996	$697,081	$33,850
Starbound	5.03%	26,160	$576,723	557	0.02129205	0.00094003	25	4.5583365	$522,148	-$54,575
Island Enterprise	5.45%	28,315	$624,232	603	0.02129613	0.00093594	27	4.912407	$562,706	-$61,526
Kodiak Enterprise	5.50%	28,581	$630,097	613	0.02144781	0.00078426	22	4.1549541	$475,941	-$154,155
Seattle Enterprise	6.37%	33,087	$729,436	648	0.01958473	0.00264734	88	16.236652	$1,859,875	$1,130,439
Katie Ann	0.00%	0	$0	0	#DIV/0!	#DIV/0!	0	0	$0	$0
	100.00%	519,586	$11,454,793	11,012	0.0211938	0.05142345	539	100	$11,454,793	$0

To achieve small marginal values for each Chinook avoided, it is necessary to have a vessel with extraordinarily high bycatch rate relative to the rest of the fleet. A hypothetical example of this concern is provided in Table seven, below. The example assumes that one catcher/processor vessel harvesting a small amount of pollock was paid to have a Chinook bycatch rate over three times the average, and that the rest of the catcher/processor fleet purposely fished pollock so as to achieve similar Chinook bycatch rates. In this example, the Game provided a marginal value of $429 for each Chinook avoided. The profit or loss for each vessel under the Game was minimal.

Table 7. Hypothetical example of the catcher/processor fleet hiring one vessel to fish pollock with a high Chinook bycatch rate and then conspiring to fish pollock with similar Chinook bycatch rates.

Offshore CP Vessels	Percent of CP Harvest	Actual Pollock Harvest (MT)	Contribution to SBCF	Chinook Bycatch Number	Chinook Bycatch Rate/MT	Chinook Undercatch" Rate	Total "Undercatch" of Chinook	Percent of Undercatch	SBCF Rebate	SBCF Profit/ Loss
Alaska Ocean	7.47%	38,829	$856,024	771	0.01985629	0.05276095	2,049	7.6674366	$878,289	$22,265
Dynasty	2.90%	15,088	$332,630	325	0.0215403	0.05107695	771	2.8842837	$330,389	-$2,241
Triumpth	8.33%	43,257	$953,644	934	0.02159188	0.05102537	2,207	8.2608335	$946,261	-$7,382
Eagle	8.36%	43,452	$957,943	932	0.02144896	0.05116829	2,223	8.3213164	$953,190	-$4,753
Hawk	8.06%	41,879	$923,264	898	0.02144273	0.05117452	2,143	8.0210536	$918,795	-$4,469
Jaeger	8.14%	42,311	$932,788	858	0.02027841	0.05233883	2,215	8.2881703	$949,393	$16,604
Rover	7.70%	40,033	$882,568	815	0.0203582	0.05225904	2,092	7.829985	$896,909	$14,341
Fjord	6.65%	34,575	$762,240	727	0.02102675	0.05159049	1,784	6.6759522	$764,717	$2,476
Storm	6.15%	31,932	$703,973	691	0.02163973	0.05097751	1,628	6.0923677	$697,868	-$6,105
Northern Glacier	3.04%	15,788	$348,062	351	0.02223207	0.05038517	795	2.9772219	$341,035	-$7,028
Pacific Glacier	5.05%	26,215	$577,936	557	0.02124738	0.05136987	1,347	5.040106	$577,334	-$602
Highland Light	5.79%	30,084	$663,232	636	0.02114081	0.05147644	1,549	5.7959608	$663,915	$683
Starbound	5.03%	26,160	$576,723	557	0.02129205	0.0513252	1,343	5.025158	$575,621	-$1,102
Island Enterprise	5.45%	28,315	$624,232	603	0.02129613	0.05132111	1,453	5.438686	$622,990	-$1,242
Kodiak Enterprise	5.50%	28,581	$630,097	613	0.02144781	0.05116943	1,462	5.4735534	$626,984	-$3,113
Seattle Enterprise	6.11%	31,765	$700,291	648	0.02039981	0.05221744	1,659	6.2079148	$711,104	$10,813
Katie Ann	0.25%	1,322	$29,145	96	0.07261725	0	0	0	$0	-$29,145
	100.00%	519,586	$11,454,793	11,012	0.0211938	0.05142345	26,719	100	$11,454,793	$0

The catcher/processor sector has agreed in principal that as part of the rules of the Game, any vessel that harvested less than one and one-half percent of the sector's pollock quota *and* was "Dirty Harry" because the vessel had the worst bycatch rate, would not be used to determine refunds under the Game. Instead, the vessel with the second-worst Chinook bycatch rate would be used. This creates two "Dirty Harrys."

Table 8. Hypothetical example of the catcher/processor fleet conspiring to fish pollock with similar Chinook bycatch rates with two Dirty Harrys.

Offshore CP Vessels	Percent of CP Harvest	Actual Pollock Harvest (MT)	Contribution to SBCF	Chinook Bycatch Number	Chinook Bycatch Rate/MT	Chinook Undercatch" Rate	Total "Undercatch" of Chinook	Percent of Undercatch	SBCF Rebate	SBCF Profit/ Loss
Alaska Ocean	7.47%	38,829	$856,024	771	0.01985629	0.00237578	92	15.220534	$1,743,481	$887,457
Dynasty	2.90%	15,088	$332,630	325	0.0215403	0.00069178	10	1.7221285	$197,266	-$135,364
Triumpth	8.33%	43,257	$953,644	934	0.02159188	0.00064019	28	4.569146	$523,386	-$430,258
Eagle	8.36%	43,452	$957,943	932	0.02144896	0.00078312	34	5.6144225	$643,120	-$314,822
Hawk	8.06%	41,879	$923,264	898	0.02144273	0.00078935	33	5.4542048	$624,768	-$298,497
Jaeger	8.14%	42,311	$932,788	858	0.02027841	0.00195366	83	13.63859	$1,562,272	$629,484
Rover	7.70%	40,033	$882,568	815	0.0203582	0.00187387	75	12.377269	$1,417,790	$535,223
Fjord	6.65%	34,575	$762,240	727	0.02102675	0.00120532	42	6.8759421	$787,625	$25,384
Storm	6.15%	31,932	$703,973	691	0.02163973	0.00059234	19	3.120791	$357,480	-$346,493
Northern Glacier	3.04%	15,788	$348,062	351	0.02223207	0	0	0	$0	-$348,062
Pacific Glacier	5.05%	26,215	$577,936	557	0.02124738	0.0009847	26	4.2591194	$487,873	-$90,063
Highland Light	5.79%	30,084	$663,232	636	0.02114081	0.00109127	33	5.4166977	$620,472	-$42,760
Starbound	5.03%	26,160	$576,723	557	0.02129205	0.00094003	25	4.0573711	$464,763	-$111,960
Island Enterprise	5.45%	28,315	$624,232	603	0.02129613	0.00093594	27	4.372529	$500,864	-$123,368
Kodiak Enterprise	5.50%	28,581	$630,097	613	0.02144781	0.00078426	22	3.6983209	$423,635	-$206,462
Seattle Enterprise	6.11%	31,765	$700,291	648	0.02039981	0.00183226	58	9.6029348	$1,099,996	$399,705
Katie Ann	0.25%	1,322	$29,145	96	0.07261725	-0.0503852	0	0	$0	-$29,145
	100.00%	519,586	$11,454,793	11,012	0.0211938	0.05142345	606	100	$11,454,793	$0

Table eight shows the same hypothetical as Table seven, but by the rules of the Game, there are now two "Dirty Harrys." Even if were possible for the catcher/processor sector to fish pollock with similar bycatch rates, each vessel would now have significant profits and losses from the Game. Because the spread between the bycatch rates of each vessel is narrow, the marginal value of each Chinook avoided in this example is now $18,900. There would be tremendous financial pressure on vessels to avoid Chinook bycatch.

Spread between the vessel with the worst Chinook bycatch rate and the rest of the fleet

A more realistic problem with the spread in Chinook bycatch rates under the Game can occur in the inshore harvesting sector. Because of the large number of inshore harvesting vessels and the relatively small amount of pollock harvested by many vessels in the inshore fleet, it can happen that one or two inshore harvesting vessels will have abnormally high bycatch rates. Similar to if a vessel had been paid to "fish dirty," the marginal value of avoiding a Chinook salmon is thereby deflated. When the inshore fleet is modeled under the Game for the years 2000 through 2007, the marginal value of avoiding Chinook salmon is typically lower than it is for the catcher/processor fleet for this reason.

If the inshore sector is interested in pursuing the incentive-based plan described in this paper, in order to consistently achieve the high marginal values for avoiding Chinook bycatch, it will have to consider modifying the rules of the Game to include multiple Dirty Harrys or arithmetically narrowing the spread between the vessels with worst bycatch rate and the fleet average.[xx]

The effect of large market shares

The problem of differing marginal values depending upon the market share of "uncaught" salmon for each company is a serious issue for any incentive-based program that is a "zero sum" game such as the one proposed in this paper. If a vessel is one of a number owned by a single company, then some of the gains going to that vessel's account from the Game will be coming from the accounts of other vessels in the company's fleet. Therefore the gain from avoiding one Chinook will likely be smaller to a company owning many vessels then to a company owning only one vessel. This reduces the marginal value to the company of avoiding a Chinook since, for this company, the total additional gain from avoiding the Chinook is the gain to the company as a whole. This consideration is of substantial importance in both the catcher/processor sector and the inshore sector, where some companies have large market shares of the sector's pollock quota and are therefore more likely to have a larger number of "uncaught" salmon. For those companies the marginal value of avoiding a Chinook under the Game is far less than the marginal value of avoiding a Chinook to a company owning only one vessel with an infinitesimal share of the pollock quota, since much of the Game's gains of avoiding a salmon to any vessel in this large fleet are losses to other vessels in that company's fleet.

Paradoxically because a company with a large share of the uncaught salmon in its sector has less incentive to avoid Chinook bycatch then do smaller companies, we would expect that other things equal a company with a large share of the pollock quota in its sector would tend to lose at the Game. Its losses on the Game would, however, be smaller than its saving on Chinook avoidance costs. The lower marginal value of avoiding Chinook by one company compared with another would make the cost of avoidance higher than if the same number of Chinook had been avoided by firms with equal incentives.

The Game should be modified to better equalize marginal value of avoiding a Chinook for all participants in the pollock fishery. With these modifications to the Game we would expect that large and small firms would be equally likely to win or lose at the Game as their incentive to avoid Chinook bycatch would be largely the same.

Firms owning multiple vessels purposely fishing with high bycatch rates

It is possible for a firm owning multiple vessels to allow one of its vessels to fish pollock in disregard to Chinook bycatch, knowing that a single vessel could not lose more than a penny per pound of pollock. If the firm's other vessels also had relatively high bycatch rates (such that they were net losers in the Game) the firm could benefit from one of its vessels having an extremely high bycatch rate. As an example, a company owning multiple vessels all of which had a relatively high bycatch could take its worst performing vessel and decided, since that vessel was already going to lose a penny per pound under the Game, it would have that "Dirty Harry" vessel fish pollock in late September and October, when Chinook bycatch extremely high.

IX. Issues Raised by the Department of Commerce to the Council's Motion

The "Opt Out" Fishery

The Council's motion provides that if an incentive-based program[xxi] is developed by the industry that "provides explicit incentives for each participant to avoid salmon bycatch in all years" then the Council may establish a hard cap of 68,392. Those pollock harvesters that do not participate in the incentive-based program (i.e., "opt out") will fish against a backstop cap of 32,482 Chinook salmon. Once a total of 32,482 Chinook salmon is taken as bycatch in the pollock fishery, any pollock vessel in the "opt out" fishery must stop fishing.

In an August 18, 2008, letter to the North Pacific Council, the Department of Commerce noted that the "opt out" fishery could potentially allow the 68,392 hard cap to be exceeded because the Chinook salmon in the 32,482 "opt out" category would not be deducted from the 68,392 hard cap.[xxii] If vessels fishing under the incentive-based program have Chinook bycatch approaching the 68,392 hard cap, total bycatch could exceed the hard cap because vessels fishing in the "opt out" fishery would also have some level of Chinook bycatch. For example, if the vessels in the incentive-based program had a total bycatch of 55,000 Chinook and the vessels in the "opt out" fishery had a bycatch of 15,000 Chinook, the total bycatch would be 70,000 and thus exceed the 68,392 hard cap.

The letter from Commerce also provides an option to eliminate the possibility of exceeding the hard cap. The "opt out" fishery could be allocated a portion of the 32,482 cap based on the opting out participants' respective pollock catch histories. Chinook salmon from vessels that opted out would be subtracted from the 68,392 hard cap. This would result in two separate bycatch limits: one cap for those who participate in an incentive-based program who receive a portion of the 68,352 hard cap; another for those who opt out of the incentive-based program who have allocated to the "opt out" fishery their percentage of the pollock catch history multiplied by their sector's Chinook bycatch allocation and the 32,482 "opt out" cap.

The alternative of separately managing the hard cap of 68,393 and the "opt out" cap of 32,482 is not in the Council's motion, nor currently in the analysis being undertaken as part of the Environmental Impact Statement (EIS). It is a reasonable alternative that meets the intent of the Council's motion by assuring that the 68,352 hard cap is not exceeded, regardless of the number of participants who "opt out" of any incentive-based bycatch avoidance program. This alternative does not require a Supplemental EIS because the proposal does not contain additional changes in the environment that are not already being analyzed. As a result of the Council's PPA, the 68,392 hard cap is already being fully analyzed in the EIS as a cap that is not intended to be exceed by the pollock fleet. The EIS will examine the 68,392 hard cap's impact on Chinook salmon, pollock and other species of fish, as well as those reliant upon those resources. The EIS also examines how the pollock fleet and other impacted parties will be affected by the 68,392 hard cap. In summary, this proposal does not create changes to the environment that are not already being analyzed in the EIS so it would not require a Supplemental EIS.

For the inshore and mothership harvesting vessels, it is easy to calculate the portion of the 32,482 Chinook that should be allocated to the "opt out" pool, based on the opting out participants' respective pollock catch histories as defined by the AFA. The AFA already allocates a percentage of the pollock TAC to each vessel in a cooperative based on that vessel's catch history. Assuming the inshore sector receives 65% of the total Chinook hard cap, for example, if an inshore catcher vessel with 2.5% of the inshore pollock TAC opted out of an incentive-based program, it would bring into the "opt out" fishery 2.5% of the inshore sector's percentage allocation of Chinook bycatch hard cap (65%) multiplied by 30,046 (the Non-CDQ "opt out" cap). That boat would therefore bring to the "opt out" fishery approximately the following amount of Chinook bycatch allowance:

2.5% x 65% = 1.625% x 30,046 = 488 Chinook salmon.

These 488 salmon would be available for all vessels in the "opt out" fishery to take as bycatch in the pollock fishery and would be deducted from the 68,392 hard cap. There would therefore be two separate bycatch limits and the 68,392 hard cap could not be exceeded.

It is not as simple to determine the number of Chinook bycatch allowance a catcher/processor or catcher vessel delivering to a catcher/processor would bring into the "opt out" fishery. Under the terms of the Pollock Conservation Cooperation (PCC), membership agreement pollock are not allocated to specific catcher/processor vessels, but instead to specific companies.

The PCC Board of Directors formally took the position of recommending that any catcher/processor which opted out of an incentive-based program have Chinook bycatch allocated to the opt out category based on the catch history of the catcher/processor fleet for 2006. This follows the basic approach of allocating Chinook bycatch allowance to each vessel based on that vessel's pollock catch history. The year 2006 was used because it was one of the few years the American Dynasty fished pollock during both the "A" and "B" seasons; therefore the year is a good approximation of the relative harvesting capacity of each vessel in the catcher/processor fleet. The catch history of the catcher/processor fleet in 2006 (or any other year) does not match the pollock allocated to PCC members because many PCC member companies harvest pollock allocated to High Seas Catcher's Cooperative (HSCC) vessels. Therefore the 2006 history has to be adjusted so that the catcher/processor fleet pollock harvest equals the percentage of pollock allocated to each company under the PCC membership agreement.

The PCC-recommended percentage of Chinook bycatch allowance to each vessel, in the event that vessel opts out of the incentive-based program, is shown in the last column of the table below. (See Table ten, below.)

Table 10. Percentage of offshore catcher/processor sector's Chinook allocation that each vessel would take into the opt out fishery if it opted out of the incentive-based bycatch avoidance program (right hand column).

	Company	Vessel	Percent of Non-CDQ TAC	Percent of C/P Sector's Pollock Allocation	2006 Harvest History of C/Ps	Adjusted History to Conform to PCC Pollock Allocation	Factoring in the Ocean Peace 1/2 of 1% Allowance
AFA C/P's PCC Agreement	American	Dynasty			5.33%	4.9569%	4.932%
		Triumph			7.83%	7.2818%	7.245%
		Eagle			6.56%	6.1005%	6.070%
		Hawk			9.13%	8.4910%	8.449%
		Jaeger			7.98%	7.4214%	7.384%
		Rover			6.91%	6.4263%	6.394%
		Highland Light			5.55%	5.1615%	5.136%
		Total =	18.336%	45.8400%	49.29%	45.8400%	
	Trident	Island			5.62%	5.6233%	5.595%
		Seattle			5.50%	5.5032%	5.476%
		Kodiak			5.93%	5.9135%	5.884%
		Total =	6.824%	17.0600%	17.05%	17.0600%	
	Glacier	Pacific Glacier			5.19%	5.0970%	5.072%
		Northern Glacier			3.20%	3.1365%	3.121%
		Alaska Ocean			7.48%	7.3315%	7.295%
		Total =	6.222%	15.5550%	15.87%	15.5550%	
	Arctic Storm	Storm	1.841%	4.6025%	6.65%	4.6025%	4.579%
	Arctic Fjord	Fjord	1.792%	4.4800%	6.10%	4.4800%	4.458%
	Starbound	Starbound	1.585%	3.9625%	5.04%	3.9625%	3.943%
		Subtotal =	36.600%		100.00%	91.5000%	
High Seas Coop Agreement	American	Challenger	0.5590%	1.3975%			1.391%
		Harvester Ent.	0.4325%	1.0813%			1.076%
		Tracy Anne	0.4642%	1.1605%			1.155%
	Aleutian Spray	Muir Milach	0.4538%	1.1345%			1.129%
	Neahkahnie	Neahkahnie	0.6679%	1.6698%			1.661%
	Sea Storm	Sea Storm	0.8226%	2.0565%			2.046%
		Subtotal =	3.4000%	8.5000%		8.5000%	
		Total Offshore =	40.0000%			100.0000%	
AFA Maximum	Ocean Peace	Ocean Peace	0.500%				0.500%
	(No more than 1/2 of 1% of Offshore)					Total =	100.000%
AFA Eligible Not Fishing Pollock	Trident	U.S. Enterprise	0.000%				0.000%
		American Ent.	0.000%				0.000%
	American	Kato Anne	0.000%				0.000%
Not Eligible	(Foreign)	Endurance	0.000%				Not Eligible

The first column of the spreadsheet shows the percentage of pollock that each company receives under the PCC agreement, and the percentage of pollock that each vessel receives under the HSCC agreement.[xxiii]

Because Chinook salmon bycatch will be allocated by sector, each vessel eligible to harvest pollock in the offshore catcher/processor sector must have its Chinook salmon opt out percentage expressed as a percentage of the entire sector. Under the AFA, the offshore catcher/processor sector receives forty percent of the non-CDQ pollock TAC.[xxiv] Eight and a half percent of that forty percent, however, is reserved for catcher vessels harvesting pollock for processing by catcher/processors (i.e., vessels in the HSCC).[xxv] The second column of the spreadsheet divides each vessel's percent of the pollock allocation by forty percent, determining each PCC company's and each HSCC vessel's percentage of the total offshore catcher/processor pollock allocation.

The third column shows the catch history of each catcher/processor vessel using the fleet's catch history in 2006.

PCC members have agreed that each company's total Chinook bycatch allowance percentage will equal that company's percentage of pollock allocated under the PCC agreement. The fourth column adjusts the 2006 history so it equals each company's pollock allocation under the PCC agreement.

To take the one-half of one percent allocation reserved in the AFA for the Ocean Peace[xxvi] into account, the fifth column allocated to that vessel is one-half of one percent, which is then adjusted for all of the other vessels in the offshore catcher/processors sector accordingly.

To determine the actual number of Chinook salmon that each catcher/processor would take into the "opt out" fishery, the vessel's percentage in the right hand column would be multiplied by the offshore catcher/processor sector's Chinook allocation and then multiplied by the non-CDQ portion of the "opt out" cap.

If the Island Enterprise opted out of the incentive-based program, for example, it would bring the following amount of Chinook salmon into the "opt out" fishery:

5.595% x 28% (the assumed catcher/processor sector's percentage of the Chinook bycatch hard cap) = 1.566% x 30,046 = 471 Chinook salmon.

There are three AFA-eligible catcher/processor vessels that currently do not harvest pollock. These vessels are the Katie Ann, owned by American Seafoods; and the U.S. Enterprise and the American Enterprise, owned by Trident Seafoods. The PCC has recommended that these three vessels not receive a salmon bycatch allowance and be prohibited from opting out of the incentive-based bycatch avoidance program.

The Endurance is also a catcher/processor vessel listed as eligible to fish pollock in the AFA. The Endurance, however, is no longer documented as a vessel of the United States; therefore, the Endurance is not eligible to fish in the United States Exclusive Economic Zone.

Required Level of Participation in the Incentive-Based Program

The second issue raised by the Department of Commerce's letter to the Council is whether there are minimum levels of participation or sector composition required for the incentive-based program to be acceptable. The Department's letter notes that absent additional clarification from the Council, it is assumed that there are no minimum participation or composition requirements because none were specified in the Council's motion.

This issue seems to be a question of policy, not law. Prior to a final vote by the Council on the Chinook bycatch issue, it is the pollock industry's responsibility to develop an incentive-based program that the Council believes is sufficient to warrant recommendation of a hard cap of 68,392 with the backstop cap of 32,484. If the Council is not convinced the industry has developed a strong incentive-based program it can simply recommend a hard cap of 47,591. The Council will make this recommendation based on the proposed incentive-based program's ability to create strong incentives to avoid Chinook salmon bycatch at all levels of salmon abundance. As part of the Council's consideration, it may be appropriate to consider the level of participation in the program.

A compelling argument can be made that regardless of the level of industry participation in the program, an incentive-based program as outlined in this paper would justify the Council approving a hard cap of 68,392 if the backstop cap of 32,484 is managed separately.

The Purpose and Need Statement for the EIS notes "the purpose of Chinook salmon bycatch management in the Bering Sea pollock fishery is to minimize Chinook salmon bycatch to the extent practicable while achieving optimum yield from the pollock fishery." An incentive-based program such as the Game and TBA from a 68,392 hard cap is clearly better than a simple hard cap of 47,591 at achieving optimum yield (by providing a greater likelihood that entire pollock TAC is harvested) while reducing bycatch at low levels of Chinook abundance to the extent practicable, as required by the MSA's National Standards and described in the Purpose and Need Statement.

Is the Incentive-Based Proposal "Practical" for the Pollock Fleet?

Claims that it is not practical for the pollock industry to participate in the Game have been raised, based on the Game's potential cost to vessels with relatively high Chinook bycatch rates. When vessel owners express concern over the cost of the Game, they cite a penny per pound of pollock as an excessive cost for vessels that have the highest bycatch rates.

The Game will create incentives for the pollock fleet to take practical measures to avoid Chinook salmon. In that sense there is a cost to the industry. The average cost to the pollock industry of the Game itself, however, is zero. Assuming a vessel takes practical measures to avoid salmon, the wins and losses from the Game quickly even out.

Hind casting the pollock industry's gains and losses under the Game from the years 2000 through 2007 shows how small the average cost of the Game is per vessel. This is especially true when the gains and losses are expressed in terms of the pounds of pollock harvested by each vessel. Over this eight-year period, the Game results in gains and losses to each vessel in both the catcher/processor and the inshore fleet measured in tenths of a cent to thousands of a cent for each pound of pollock harvested.

Table 11. Hind cast of gains and losses to each vessel in the pollock catcher/processor fleet under the Game, 2000-2007.

Vessel Name	Total Gains/Losses 2000-2007	Gains/Losses /lb. pollock
Alaska Ocean	$1,034,221	$0.001591
Dynasty	-$1,859,648	-$0.008285
Triumph	-$944,631	-$0.001316
Eagle	$641,596	$0.000933
Hawk	$189,926	$0.000260
Jaeger	$834,131	$0.001177
Rover	$2,360,549	$0.003567
Fjord	$287,283	$0.000246
Storm	$308,827	$0.000531
Northern Glacier	-$537,858	-$0.001989
Pacific Glacier	$616,433	$0.001421
Highland Light	$2,362,468	$0.004935
Starbound	-$566,699	-$0.001287
Island Enterprise	-$2,076,952	-$0.004084
Kodiak Enterprise	-$1,557,396	-$0.002998
Seattle Enterprise	-$1,063,106	-$0.002613

Table 12. Hind cast of gains and losses to each vessel in the inshore pollock fleet under the Game, 2000-2007.

Vessel Name	Total Gains/Losses 2000-2007	Gains/Losses /lb. pollock
Alaska Rose	-$66,612	-$0.000334
Alaska Command	-$228,491	-$0.000871
[illegible]	-$97,462	-$0.000610
Alsea	$32,469	$0.000100
Alyeska	-$26,361	-$0.001610
Amber Dawn	-$4,262	-$0.001162
American Beauty	$91,469	$0.001734
American Eagle	$19,029	$0.000160
Anita J	-$40,394	-$0.000646
Arctic Explorer	$134,276	$0.000062

Arctic Wind	[illegible]	[illegible]
Arcturus	-$212,222	-$0.001281
Argosy	$53,760	[illegible]
Auriga	$134,241	[illegible]
Aurora	$219,876	[illegible]
Bering Rose	-$428,222	-$0.002096
Blue Fox	$31,047	[illegible]
Bristol Explorer	-$41,877	-$0.000239
Cailin Anne	$170,344	$0.001363
Cape Kiwanda	[illegible]	[illegible]
Chelsea K	$17,630	[illegible]
Collier Brothers	[illegible]	[illegible]
Columbia	-$294,727	-$0.001767
Commodore	-$147,467	-$0.001120
Defender	$237,640	[illegible]
Destination	-$302,210	-$0.001224
Dominator	$9,324	[illegible]
Dona Martita	-$108,611	-$0.002121
Elizabeth F	$87,060	[illegible]
Excalibur II	$95,604	$0.001067
Exodus	[illegible]	[illegible]
Fierce Allegiance	$124,111	$0.000762
Gladiator	-$20,400	-$0.000120
Gold Rush	$95,341	$0.002137
Golden Dawn	-$41,166	-$0.000169
Golden Pisces	$129,032	[illegible]
Great Pacific	-$278,039	-$0.002071
Gun-Mar	$173,004	$0.001760
Half Moon Bay	$17,408	[illegible]
Hazel Lorraine	$23,002	$0.000773
Hickory Wind	$38,002	$0.001480
Intrepid Explorer	$30,827	$0.000711
Leslie Lee	[illegible]	$0.001714
Lisa Melinda	-$2,008	-$0.000149
Majesty	$84,817	$0.001167
Marcy J	[illegible]	$0.002124
Margaret Lyn	-$6,260	-$0.001662
Mar Gun	$11,820	$0.001464
Mark I	$10,437	[illegible]
Miss Berdie	$4,061	$0.000140
Morning Star	-$541,456	-$0.002840
Nordic Explorer	$7,848	$0.000346
Nordic Fury	-$1,615	-$0.000124
Nordic Star	$86,490	$0.000743
Northern Patroit	-$249,213	-$0.000871
Northwest Explorer	-$118,747	-$0.000793
Ocean Explorer	$60,072	$0.000358
Ocean Hope 3	-$14,328	-$0.000353
Ocean Leader	$48,451	$0.001859
Oceanic	$97,107	$0.002595

Pacific Challenger	-$45,118	-$0.002979
Pacific Explorer	$234,346	$0.001482
Pacific Fury	$491	$0.000855
Pacific Knight	-$26,813	-$0.001139
Pacific Monarch	$2,247	$0.003632
Pacific Prince	$56,512	$0.000189
Pacific Ram	-$13,320	-$0.000911
Pacific Viking	-$109,602	-$0.000927
Pegasus	$20,790	$0.000350
Peggy Jo	-$12,432	-$0.000431
[illegible]	[illegible]	[illegible]
Poseidon	[illegible]	[illegible]
Predator	[illegible]	[illegible]
Progress	[illegible]	[illegible]
Raven	[illegible]	[illegible]
Royal American	[illegible]	[illegible]
Royal Atlantic	[illegible]	[illegible]
Sea Wolf	[illegible]	[illegible]
Seadawn	$129,621	[illegible]
Seeker	[illegible]	[illegible]
Sovereignty	[illegible]	[illegible]
Starfish	[illegible]	[illegible]
Starlite	[illegible]	[illegible]
Starward	[illegible]	[illegible]
Storm Petrel	[illegible]	[illegible]
Sunset Bay	[illegible]	[illegible]
Topaz	$4,121	[illegible]
Traveler	[illegible]	[illegible]
Vanguard	[illegible]	[illegible]
Viking	[illegible]	[illegible]
Viking Explorer	[illegible]	[illegible]
Walter N	[illegible]	[illegible]
Western Dawn	[illegible]	[illegible]
Westward I	[illegible]	[illegible]

The Game along with TBA from a hard cap of 68,392 will create incentives for the pollock fleet to take measures to avoid Chinook salmon bycatch. Given the value of the pollock fishery, it would seem that the program outline in this paper to reduce Chinook is practical in that it does not create excessive cost on the industry.

X. Conclusion

The Council's PPA has two alternatives: A hard cap on Chinook salmon of 47,591; and, if the pollock industry develops a program that "provides explicit incentives for each participant to avoid salmon bycatch," then the Council will consider a Chinook salmon hard cap of 68,392, a level much less likely to be constraining on the pollock fishery. The Council will consider the more liberal hard cap of 68,392 if the pollock industry can document that its incentive-based program will reduce Chinook bycatch better than a hard cap of 47,591. The industry's proposal must also provide these incentives during all years and at all levels of salmon abundance.

The incentive-based proposal outlined in this paper meets those objectives. It includes continuation of the Rolling Hotspot Closure program, a hard cap of 68,392 which will be allocated through the pollock cooperatives to each vessel and is transferable, and a Game that transfers money from those vessels with the highest relative Chinook bycatch rates to those with the lowest bycatch rates within each sector.

The analysis in this paper is based on a model that is detailed in the mathematical Appendices. The model uses historical bycatch data to project likely marginal values of avoiding Chinook salmon at differing annual bycatch rates.

We have shown how the incentives provided by TBA and the Game will induce the pollock industry to move vessels to avoid areas of high Chinook bycatch, shift fishing effort from times of high bycatch to times of low bycatch, and to use newly developed salmon excluder devices with their trawl gear. In combination, the Game and TBA complement each other. Together they effectively create a large marginal value for avoiding Chinook salmon bycatch during all years and at all levels of salmon abundance.

The proposal of TBA under a hard cap of 68,392 along with the Game is more effective at reducing Chinook bycatch, especially at low levels of Chinook salmon abundance when Chinook are particularly valuable, than a hard cap of 47,591 by itself, while providing the pollock industry a greater chance of achieving optimum yield from the pollock fishery.

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[*] Associate Professor of Economics, University of Washington. Ph.D., University of Chicago, 1975. Principal, Financial Kochin Consultants. Consultant to Trident Seafoods Corporation.

[**] B.A., Economics, University of Washington, 1988. Director of Research and Development, Trident Seafoods Corporation.

[***] B.S., Economics, University of Washington 2008. Consultant to Trident Seafoods Corporation.

[#] J.D., Seattle University. Chief Legal Officer, Trident Seafoods Corporation.

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[i] Initial Draft EIS for the Bering Sea/Aleutian Islands Chinook Salmon Bycatch Management, May 15, 2008. p. 155.

[ii] Because elements of the industry developed incentive-based program will not be incorporated in regulation, the Council will have to trust industry to follow through with its promise to implement the incentive-based program it presents to the Council.

[iii] This example assumes that the bycatach rate results in both the hard cap and pollock TAC are reached at *precisely the same time*. In other words, the very last tow captures the final pound of the pollock TAC and the final Chinook salmon allowed under the hard cap. In this one instance, the total value of the pollock fishery is captured by TBA. *The actual marginal value of bycatch allowance has nothing to do, per se, with the value of stranded pollock*. As an example, if the pollock TAC was 1.5 million metric tons, but bycatch rates were 1,000 Chinook salmon per metric ton of pollock and the hard cap was 50,000 Chinook salmon, the marginal value of bycatch allowance for a single Chinook salmon would be very low. The pollock fishery would be shut down after 50 metric tons of the pollock were caught. Each salmon would be worth the value of pollock you could catch with it. In this case, that would be 1/1000 of a metric ton of pollock. Assuming lease rate for pollock was $300 a metric ton, the marginal value of a salmon would be only one-third of a cent because that would be the value of pollock you could harvest with the additional salmon ($300 x .0001 = $0.003).

[iv] Nathan J. Mantua, Steven R. Hare, Yuan Zhang, John M. Wallace, and Robert C. Francis, A Pacific interdecadal climate oscillation with impacts on salmon production, Bulletin of the American Meteorological Society, Vol. 78, Issue 6, p.1076.

[v] Memo from SeaState to IC Representatives, August 7, 2007.

[vi] During 2006 Chinook bycatch in the pollock fishery was 81,341 salmon.

[vii] The Pacific Fishery Management Council voted on November 7, 2008, to rationalize the Pacific Whiting fishery through an Individual Fishing Quota system. This plan amendment is scheduled to go into effect in 2011.

[viii] The authors apologize to those who are troubled by use of the word "game." We do not mean to diminish the importance of the Chinook salmon bycatch issue nor the Game's ability to create powerful economic incentives for the pollock industry to avoid Chinook salmon. From the time it was first conceived, however, and throughout the many hours of discussing and writing this analysis, we have referred to the individual vessel Chinook bycatch avoidance incentive program as "the Game." For the sake of simplicity we continue to call it the Game in this paper. And, truth be told, it is a game in that each player antes money to play and then wins or loses based on how well that player performs.

[ix] The Game is a response to the problems of fixed quotas when there is little information on fish stocks as discussed by Weitzman, *Landing Fess vs. Harvest Quotas with Uncertain Fish Stocks*, 2001.

[x] Except for the worst performer in this example, Dirty Harry, who would not receive a refund in the model if he avoided a Chinook.

[xi] The spread between bycatch rates of inshore catcher vessels is considerably larger than the spread between the catcher/processor sector. Therefore the Game provides greater marginal value at a one cent ante for the offshore sector than for the inshore fleet.

[xii] Information on pollock roe yields and quality has been exchanged on a real time basis for the last several years between all catcher vessels belonged to each of the onshore cooperatives. There are about twenty-five catcher vessels belonging to each cooperative.

[xiii] Corrections could then be applied to the results of each tow. For example, if the preliminary guess on all the tows showed 500 tons of pollock and 50 Chinook for .1 Chinook per ton, but the more exact count the processing plant showed only 400 tons of Pollock and 60 Chinook. The simplest linear correction would be to reduce each of the tow's catch of pollock by 20% and increase the count of salmon bycatch by 20% on each tow. If one tow at a particular location had a guess of 50 tons of pollock and 5 Chinook then that tow's results would be corrected to 40 tons of Pollock and 6 Chinook for .15 Chinook per ton of pollock. The average delay between hauling in the net and delivery onshore is three to four days so the more exact information on pollock catch as well as Chinook bycatch on each tow would be available with a delay of one to two days on average.

[xiv] Information without incentives is useless. We are aware of one case in the last two years of a pollock vessel that caught five hundred Chinook in one tow. After the catch had been emptied and catalogued the vessel make a second tow in essentially the same place and had another Chinook bycatch of essentially the same size. The Chinook cost him nothing and the value of the pollock was substantial. With the incentive-based proposals described in this paper, the lost revenue (at $500 per Chinook) from catching 500 Chinook would be at least $250,000. Even a 100 metric ton tow of the pollock with extremely high roe content would have a value net of the lease cost of the pollock quota of less than $70,000. So that second tow by that vessel would never have been made with the incentives programs described in this paper.

[xv] This example assumes there are 101 Catcher Vessels and 19 Catcher Processors. But since the incentive-based proposal presented in this paper is sector specific, a catcher vessel would not have any reason to avoid providing information to the catcher processor.

[xvi] Given that other measures to reduce Chinook bycatch are cheaper, there is no reason to order the industry to take this ineffective measure.

[xvii] Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions, Nov. 2007, Eastern Bering Sea Walleye Pollock, p. 69.

[xviii] This model assumes the Chinook bycatch rates are the same regardless of the pollock TAC. Although Catch Per Unit of Effort (CPUE) of pollock during the "A" season may be similar with a lower pollock TAC because pollock a schooled , it is possible that a lower pollock TAC in the "B" season would also result in a lower CPUE. A lower CPUE may result in higher Chinook bycatch rates than are represented in these examples.

[xix] 18 U.S.C. 1001 makes it a crime to knowingly falsify, conceal or cover up or otherwise make any materially false or fraudulent statements or representations to the federal government.

[xx] In the mathematical appendices we assume four Dirty Harrys for the inshore fleet. Alternatively the same result could be accomplished by having one Dirty Harry and distributing proceeds from the Game, not on the basis of the sum of the undercaught Chinook, but rather sum of a vessel's total undercaught Chinook raised to a power between zero and one.

[xxi] This paper uses the term "incentive-based program" instead of ICA. Council's motion notes that an "ICA" must provide "explicit incentive(s) for each participant to avoid salmon bycatch in all years." But the ICA contemplated by the Council's motion is not the type of Inter-Cooperative Agreement currently in existence. The existing RHC program ICA includes all pollock harvesting vessels (except for the vessel Ocean Peace) in every cooperative, and all of the CDQ groups. The regulations implementing the existing ICA require that the parties to the ICA be "AFA cooperatives or CDQ groups." (50 CFR §679.21(g)(g).) The ICA contemplated by the Council's motion, however, clearly provides that not all pollock participants need participate in the program that "provides explicit incentive(s) for each participant to avoid salmon bycatch in all years." For that reason, it is perhaps preferable to refer to the program that allows the Council to recommend a hard cap of 68,392 as the "incentive-based" bycatch avoidance program instead of the ICA.

[xxii] Letter from Robert D. Mecum, Acting Regional Administrator, NOAA, to Mr. Eric Olson, Chairman, North Pacific Fishery Management Council, August 18, 2008.

[xxiii] The High Seas Catchers' Cooperative (HSCC) includes seven catcher vessels that have a total of 3.4% of pollock catch history that is eligible to be harvested by the catcher/processor fleet. Similar to the PCC agreement, these seven vessels formed a private cooperative to divide the available pollock allocation among themselves. Unlike the PCC agreement, however, each of the seven vessels in the HSCC is allocated a specific percentage of pollock. Therefore, each of the vessels has a specific pollock allocation.

[xxiv] Section 206(b)(2) of the AFA.

[xxv] Section 210(c) of the AFA.

[xxvi] Section 208(e)(21) of the AFA.

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Appendix A

North Pacific Fishery Management Council's June 2008 Motion

D-1(a) Bering Sea AFA pollock trawl fishery salmon bycatch

MOTION

The Council directs staff to provide analysis on the preliminary preferred alternative specified below in addition to those in the existing analysis and release the resulting EIS/RIR/IRFA for public review. For a complete description of alternatives in the existing analysis, see Chapter 2 of the BSAI Salmon Bycatch EIS Initial Review Draft (dated May 15, 2008).

Alternative 4: Preliminary preferred alternative

Alternative 4 would establish a Chinook salmon bycatch cap for each pollock fishery season which, when reached, would require all directed pollock fishing to cease for that season. Components 2-4 specify the allocation and transferability provisions associated with the cap.

Component 1: Hard cap with option for ICA regulated incentive system

Annual scenario 1: Hard cap with an ICA that provides explicit incentive(s) to promote salmon avoidance in all years

Hard cap if an ICA is in place that provides explicit incentive(s) for each participant to avoid salmon bycatch in all years:

Overall cap: 68,392, allocated by season and under Components 2-4 as described below

For those operations that opt out of such an ICA, the hard cap will be established as follows:

Overall cap: 32,482
CDQ allocation: 2,436
Non-CDQ cap: 30,046

All salmon bycatch attributed to the AFA pollock trawl fleet will accumulate against this lower cap, but only those operations not in the ICA will be required to stop fishing when the CDQ or non-CDQ cap has been reached. This backstop cap of 32,482 will not be allocated by sector, so all other components in Alterative 4 are not relevant to this backstop cap. (In absence of a sector allocation for this backstop cap a 7.5% allocation applies to the CDQ sector by default, and the remaining 92.5% is set as the non-CDQ cap.)

ICA requirements:

- An ICA must provide incentive(s) for each vessel to avoid salmon bycatch under any condition of pollock and salmon abundance in all years.
- Incentive measures must include rewards for salmon bycatch avoidance and/or penalties for failure to avoid salmon bycatch at the vessel level.
- The ICA must specify how those incentives are expected to promote reductions in actual individual vessel bycatch rates relative to what would have occurred in absence of the incentive program. Incentive measures must promote salmon savings in any condition of pollock and salmon abundance, such that they are expected to influence operational decisions at bycatch levels below the hard cap.

Annual reporting:

- The ICA must be made available for Council and public review.

- An annual report to the Council will be required and must include:
  1) a comprehensive explanation of incentive measures in effect in the previous year,
  2) how incentive measures affected individual vessels, and
  3) evaluation of whether incentive measures were effective in achieving salmon savings beyond levels that would have been achieved in absence of the measures.

Annual scenario 2: Hard cap in absence of an ICA with explicit incentive(s) to promote salmon avoidance
Hard cap in absence of an ICA that provides explicit incentive(s) to all participants to avoid salmon bycatch in all years:

Overall cap: 47,591, allocated by season and under Components 2-4 as described below

Seasonal distribution of caps
Any hard cap would be apportioned between the pollock A and B seasons. The seasonal distribution is 58/42, based on the average distributional ratio of salmon bycatch between A and B seasons in the 2000-2007 period.

Seasonal rollover of caps
Unused salmon from the A season would be made available to the recipient of the salmon bycatch hard cap in the B season within each management year at an amount up to 80% of the recipient's unused A season bycatch cap.

Component 2: Sector allocation
Separate sector level caps will be distributed within each season for the CDQ sector and the three remaining AFA sectors, the inshore catcher vessel (CV) sector, the mothership sector, and the offshore catcher processor (CP) sector, as follows:

A season: CDQ 9.3%; inshore CV fleet 49.8%; mothership fleet 8.0%; offshore CP fleet 32.9%
B season: CDQ 5.5%; inshore CV fleet 69.3%; mothership fleet 7.3%; offshore CP fleet 17.9%

This distribution is based on the 5-year (2002-2006) historical average of the annual proportion of salmon bycatch by sector within each season, adjusted by blending the bycatch rate for CDQ and non-CDQ partner sectors. It is also weighted by the AFA pollock allocation for each sector; in each season, the proportional allocation by sector comprises the adjusted 5-year historical average by sector weighted by 0.75 for the salmon bycatch history and the AFA pollock allocation by sector weighted by 0.25.

Component 3: Sector transfers
Allocate salmon bycatch caps to each sector and allow the entity representing each non-CDQ sector and the CDQ groups to transfer salmon bycatch trigger caps among the sectors and CDQ groups. (NMFS does not actively manage the salmon bycatch allocations).

Component 4: Cooperative provisions
Each inshore cooperative and the inshore open access fishery (if the inshore open access fishery existed in a particular year) shall receive a salmon allocation managed at the cooperative level. If the cooperative or open access fishery salmon cap is reached, the cooperative or open access fishery must stop fishing for pollock.

The initial allocation of salmon by cooperative within the shore-based CV fleet or to the open access fishery would be based upon the proportion of total sector pollock catch associated with the vessels in the cooperative or open access fishery.

Cooperative transfers

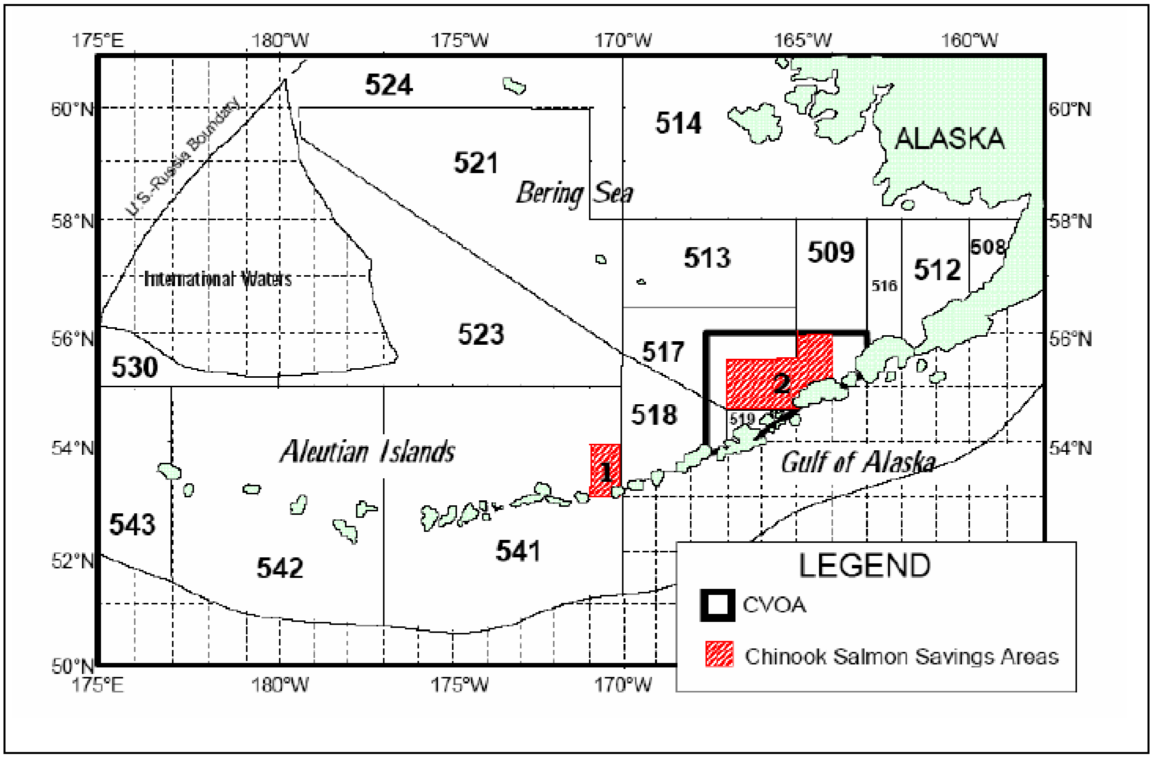
When a salmon cooperative cap is reached, the cooperative must stop fishing for pollock and may transfer salmon bycatch from other inshore cooperatives, CDQ groups, or entities representing non-CDQ groups (industry initiated).

Appendix B

Rolling Hotspot Closure Program

In 1995 the Council established triggered Chinook Salmon Savings Areas that were closed to all pollock fishing if 29,000 Chinook salmon were taken.[1] The Chinook Salmon Savings Area closed approximately 5,000 square miles, a substantial portion of the Catcher Vessel Operation Area, making the closure very restrictive if the threshold of 29,000 Chinook was exceeded. Below is a chart showing the triggered closure area.

Figure 1. Chinook Salmon Savings Area and the CVOA.



[1] BSAI Amendment 21b as revised by BSAI Amendment 58. The timing of the closure depended upon when the limit was reached. If the limited was reached prior to April 15, the areas closed immediately through April 15. After April 15 the areas reopened, but were closed from September 1 through December 31. If the limit was reached after April 15 but before September 1, the areas closed on September 1 through the end of the year. If the limit was reached after September 1, the areas closed immediately through the end of the year.

The Council was concerned, however, that "salmon bycatch may be higher outside the savings areas than inside."[2] Although AFA cooperatives had been operating under an inter-cooperative agreement that included rolling hot spot closures for Chinook salmon since 2003, the Council formally authorized the RHC program to replace the large triggered closure area when it passed Amendment 84 in October of 2006. The Council's decision was strongly supported by the inshore pollock fleet, which had much of its best fishing grounds closed when the 29,000 Chinook threshold was reached. The analysis before the Council stated, "salmon bycatch is expected to *decrease* under this alternative [the RHC program], given the flexible system provided by dynamic hot spot management of the pollock fleet."[3]

To understand its strengths and weaknesses it is important to know how the RHC program actually works. As detailed below, the RHC program temporarily limits fishing access for some vessels to areas of the Bering Sea where Chinook salmon bycatch is greater than a specified "Base Rate" of bycatch.

<u>"A" Season Base Rate Calculation</u>
The initial "A" season Base Rate is equal to the prior year's "A" season Chinook bycatch rate, except that the initial base rate cannot be greater than 0.06 nor less than 0.04. The Base Rate is adjusted during the "A" season in response to the actual Chinook bycatch experienced during the season. Starting on February 14, and continuing weekly thereafter, the three-week average bycatch rate is calculated and the lower of initial Base Rate or the recalculated Base Rate is used.

<u>Tier Structure</u>

* Cooperatives with Chinook bycatch rates of 75% or less of the Base Rate are in Tier 1.

* Cooperatives with Chinook bycatch rates greater than 75% but less than or equal to 125% of the Base Rate are in Tier 2.

* Cooperatives with Chinook bycatch rates of greater than 125% of the Base Rate are in Tier 3.[4]

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[2] Initial Review Draft EA/RIR/IRFA for Modifying existing Chinook and chum salmon savings areas, NPFMC, May 23.2005. p. ii.

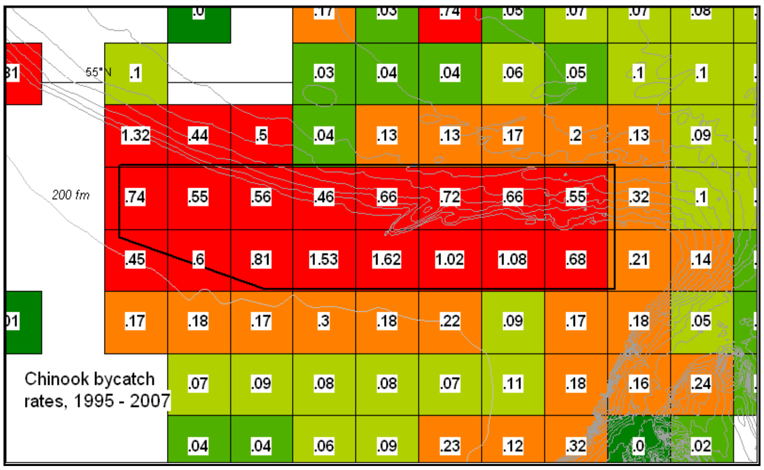
[3] Initial Review Draft EA/RIR/IRFA for Modifying existing Chinook and chum salmon savings areas, NPFMC, May 23.2005. p. ii.

[4] The RHC program does not include a tier assignment for Chinook salmon during the "B" season. Instead all Chinook Savings Area closures that were instituted applied to all cooperatives (and thus all pollock vessels). It was deemed appropriate to close areas for all pollock fishing because: "1) Chinook bycatch tends to increase by week in the 'B' season and thus the 'backward looking' system of imposing tier assignments and closures based on previous week's bycatch rates is not adequately responsive to changing

Establishment of Chinook Savings Areas
On January 30 and each Monday and Thursday thereafter, one or more Chinook Savings Areas are established. Chinook Savings Areas are established "as SeaState determines appropriate to address Chinook bycatch."

In addition to these Chinook Savings Areas, the industry agreed to modify the RHC program to close for the entire "A" season an area of the so-called horseshoe region. This area was closed to all pollock fishing starting in 2008.

Figure 2. Chinook bycatch rates for the combined years 1995-2007 in and around area closed to pollock fishing in 2008 under the modified RHC program.



Limitations on Establishment of Chinook Savings Areas
To qualify as a potential Chinook Savings Area, it must be an area where (1) a substantial amount of pollock is harvested (roughly defined as two percent or more of that week's pollock catch), and (2) Chinook salmon bycatch exceeds the Base Rate. Chinook Savings Areas, furthermore, cannot exceed 500 square miles West of 168 degrees West longitude. The total area of all Chinook Savings areas cannot exceed 1,500 square miles. No more than two Chinook Savings Areas West of 168 degrees West longitude and two East of 168 degrees West longitude are allowed.

Publication of Savings Areas and Tier Status
Closures are announced on Thursdays (effective at 6:00 PM on Friday) and Mondays (effective at 6:00 PM on Tuesday). Chinook Savings Areas work as follows: The Chinook Savings Areas announced on Thursday, and as updated by Monday, are closed to pollock fishing by Tier 3 Coop vessels for seven days beginning Friday at 6:00 PM.

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conditions in the fishery, and 2) the fishery is spread out over a larger area in the 'B' season and conditions tend to change more rapidly than in the 'A' season." Initial Review Draft EA/RIR/IRFA for Modifying existing Chinook and Chum Salmon Savings Areas, NPFMC, May 23, 2005. p. 45.

Chinook Savings Areas announced on Thursday are closed to fishing by Tier 2 Coop vessels from Friday at 6:00 PM through 6:00 PM the following Tuesday. Tier 1 Coop vessels may fish in all Chinook Savings Areas.

Distribution of Information to the Fleet

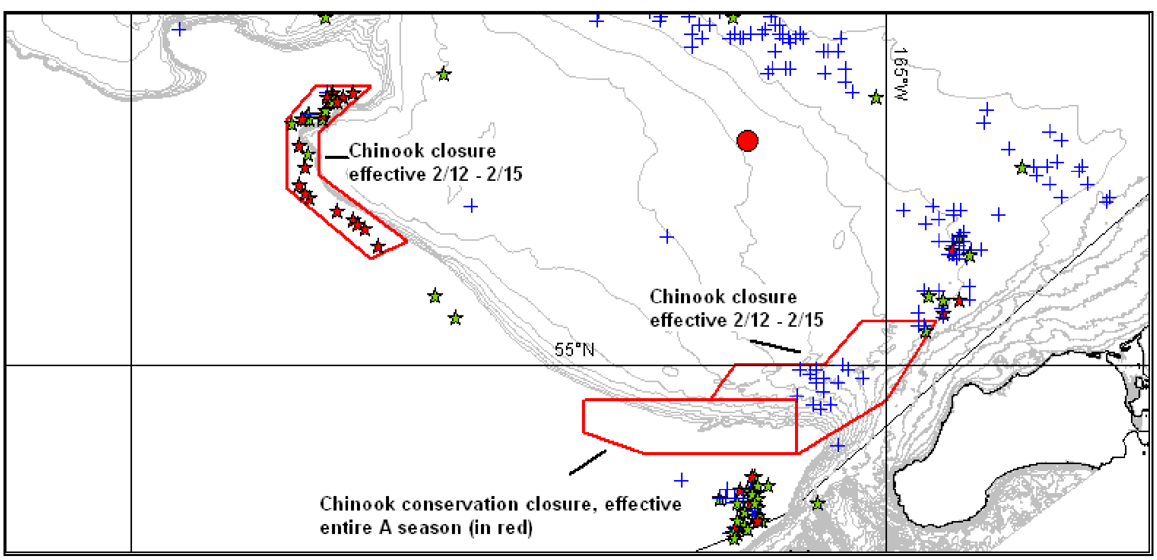
Each Monday and Thursday announcement includes an update on pollock harvest and Chinook bycatch by sector and in total, each Coop's rolling two week bycatch rate and associated Tier status (Thursday's announcement only). The announcement also gives chart coordinates describing each Chinook Savings Area, Chinook bycatch rates for each ADF&G statistical area where there has been directed pollock fishing in the previous week, and a vessel performance list (Thursday's announcement only).

"B" Season Base Rate Calculation

For the entire 2008 "B" season, the Chinook salmon Base Rate is 0.05.[5] (Because Chinook bycatch this year is below the 0.05 Base Rate, there will be no Chinook Savings Areas implemented until late in this year's "B" season.) For 2009 and beyond, the Chinook salmon Base Rate will be determined by using the prior year's Chinook bycatch rate for the same period of time.

For illustrative purposes, figure three is a chart of Chinook Savings Areas under the RHC program during February of 2008.

Figure 3. Chinook Savings Areas during the week of February 12, 2008.



Brief Analysis of the RHC Program

The RHC program provides the pollock fleet with extremely useful information on areas of high Chinook bycatch on a timely basis. Modification of the RHC program in 2008 to

[5] 50 C.F.R. §679.21.

close for the entire "A" season an area of the horseshoe will significantly reduce Chinook bycatch from levels seen in previous years. The RHC program also reduces pollock fishing effort in areas with the highest bycatch rates outside of this permanently closed area. If there is an area with high Chinook bycatch and also an exceptionally high percentage of pollock roe, for example, the RHC program can limit access to this area.

A simple model will show how the RHC program can limit access to areas of high pollock roe value when a substantial marginal value per salmon may not:

The average roe recovery for the catcher/processor sector was approximately 5.5% in 2008. It is not unusual, however, for roe recovery in the deeper waters of the "mushroom" area of the Bering Sea to be 7%. The average value of pollock roe for the catcher processor sector in 2008 was approximately $5.80 per pound. The additional value per metric ton of pollock fishing in the mushroom, as opposed to other areas, can be calculated as follows:

Average roe recovery rate =	5.5%
Average price of pollock roe per pound =	$5.80
Value of roe per MT of pollock harvest =	$703
Roe recovery rate in mushroom =	7%
Average price of pollock roe per pound =	$5.80
Value of roe per MT of pollock harvest in mushroom =	$895
Difference between mushroom and average roe value per MT =	$192

It is important to understand that fishable quantities of pollock do not always appear in the deep of the mushroom area. When there are pollock in the mushroom, however, there is typically Chinook bycatch at rates three to five times higher than average bycatch rates elsewhere.

If the average Chinook bycatch rate for the catcher/processor fleet is .03 Chinook salmon per metric ton of pollock, the bycatch rate in the mushroom area could be .12 (at four times the average rate elsewhere). The difference between the average bycatch rate and the bycatch rate in the mushroom area is therefore .09 in this example.

Given that the value of roe pollock is $192 greater per metric ton in the mushroom and the bycatch rate .09 per metric ton higher, it would take a marginal value of $2,131 ($192 divided by .09) for each Chinook salmon to provide an economic incentive large enough for a vessel to choose to fish pollock outside of the mushroom.

Under the RHC program, with bycatch rates three to five times greater in the mushroom, vessels that fish in the mushroom area would likely cause their coop to be in Tier 1 or Tier 2, and therefore be precluded from fishing for pollock in that area for a week or four days respectively.

But the RHC program has obvious limitations. The Base Rate for the "A" season is initially based on the bycatch rate of the previous year, which may or may not reflect bycatch in the current year. Chinook bycatch typically declines as the "A" season progresses, which may allow vessels to harvest salmon below the adjusted Base Rate while avoiding costly measures to avoid salmon bycatch. The RHC program is not sector-specific yet each pollock sector has inherently different bycatch rates due to operational distinctions.

The RHC program, moreover, does not provide "explicit incentives for *each participant* to avoid salmon bycatch in all years." Under the RHC program, once a cooperative is likely to be operating in Tier 3, vessels within that cooperative have no incentive to avoid Chinook bycatch. Vessels in such a cooperative will target the best pollock fishing within the areas open to fishing, and Chinook bycatch will be a secondary consideration. (In fact, these vessels would have a perverse incentive to increase salmon harvests, as more bycatch would ultimately increase the Base Rate.) The areas immediately outside of the Chinook Savings Areas often have relatively high salmon bycatch rates. Vessels in Tier 3 cooperatives can fish immediately outside of the Chinook Savings Areas without restrictions. Additionally, the RHC program is coop specific, so vessels within a cooperative can fish in high bycatch areas if they know that their cooperative, as a whole, has lower than average bycatch.

The effectiveness of the RHC program would be improved, obviously, if the Chinook Savings Area size were increased substantially beyond its current restrictions. But regardless of the size of the Chinook Savings Area, vessels fishing outside of the closed grounds can fish pollock without concern for Chinook bycatch.

Although the RHC program helps to reduce Chinook bycatch, it is an example of a "command-and-control" regulation. The only way to achieve "explicit incentives for each participant to avoid salmon bycatch in all years" and to create incentives for "each vessel to avoid salmon under any condition of salmon abundance" is the use of a market-based approach.

Appendix C

Glossary of Symbols

ABR	Chinook annual bycatch rate (Chinook/mt of pollock)
BCR	Chinook bycatch cutoff rate (Chinook/mt of pollock)
E(ABR)	Expected Chinook annual bycatch rate (Chinook/mt of pollock)
$E(Q_P)$	Expected pollock harvest (mt)
E(SPL)	Expected stranded pollock loss ($)
G	The Game
HC	Chinook bycatch hard cap under TBA (Number of Chinook)
LBR	Limiting bycatch rate under TBA (Chinook/mt of pollock)
ln	The Natural logarithm
M	Money in at the beginning of the game ($/lb of pollock)
MV	Marginal value ($/Chinook)
n	Sample size
$P_{\%}$	Percentile
P(X)	The probability density function of the X variable
P_P	Lease value of the pollock quota ($/mt of pollock)
Q_C	Quantity of Chinook caught in a year (Number of Chinook)
Q_P	Quantity of pollock caught in a year (mt)
q_P	Pollock quota in a given year (mt)
R	Rebate
s	Sample standard deviation
SBR	Seasonal bycatch rate (Chinook/mt of pollock)
TBA	Transferable bycatch allowance
U	Quantity of uncaught Chinook (Number of Chinook)
UR	Chinook undercatch rate (Chinook/mt of pollock)
Σ	The Greek letter *Sigma*, which means “the sum of”
μ	Sample arithmetic mean

Appendix D

Mathematical Model of TBA

1. Chinook annual bycatch rate:

$$ABR = \frac{Q_C}{Q_P}$$

where Q_C is a quantity of Chinook caught in a year and Q_P is a quantity of pollock caught in a year.

2. Limiting bycatch rate:

$$LBR = \frac{HC}{q_p}$$

where HC is a Chinook bycatch hard cap and q_P is the pollock quota for a given year.

$$BR = \frac{Q_C}{Q_P}$$

3. The natural logarithm of the ABR variable:

$$\ln(ABR) = \ln(Q_c) - \ln(Q_p)$$

$$TBA\ MV = \frac{1}{BR} P_p$$

4. Arithmetic mean of the ln(ABR) variable:

$$\mu = \frac{\sum[\ln(ABR)]}{n}$$

$$\mu = \frac{\sum \ln(BR)}{n}$$

5. Standard deviation of the ln(ABR) variable:

$$s = \sqrt{\frac{\sum[\ln(ABR) - \mu]^2}{(n-1)}}$$

6. Expected value of $\ln(ABR_t)$ variable at the start of the fishing season (the start of A Season):

$$E\left[\ln\left(ABR_t\right)\right] = a + b\left[\ln\left(SBR_{A_{t-1}}\right)\right] + e_{t,A(t-1)}$$

where $e_{t,A(t-1)}$ is the error in expectations of $\ln(ABR_t)$ using last years $\ln(SBR_{A(t-1)})$.

7. Expected value of $\ln(ABR_t)$ variable after the first four weeks of fishing:

$$E_4\left[\ln\left(ABR_t\right)\right] = a + b\left[\ln\left(SBR_4\right)\right] + e_{t,4}$$

where $e_{t,4}$ is the error in expectations of $\ln(ABR_t)$ using the $\ln(SBR_4)$ in the first 4 weeks of fishing.

8. Expected value of $\ln(ABR_t)$ variable after A Season:

$$E_A\left[\ln\left(ABR_t\right)\right] = a + b\left[\ln\left(SBR_A\right)\right] + e_{t,A}$$

where $e_{t,A}$ is the error in expectations of $\ln(ABR_t)$ using the $\ln(SBR_A)$ in Season A.

9. The probability density function of the $E(ABR_t)$ variable for the log normal distribution:

$$P\left[E\left(ABR_t\right)\right] = F\left[E\left(ABR_t\right), \mu, s\right] = \frac{1}{s\sqrt{2\pi}E\left(ABR_t\right)} e^{-\frac{\left\{E\left[\ln\left(ABR_t\right)\right] - \mu\right\}^2}{2s^2}}$$

for $E(ABR_t) > 0$, where $\boldsymbol{\mu}$ is the mean of the log normal distribution of $E(ABR_t)$ and $\boldsymbol{s}$ is the standard deviation of the error term in expectations of $\ln(ABR_t)$.

10. The probability density function of the $E_4(ABR_t)$ variable for the log normal distribution:

$$P\left[E_4\left(ABR_t\right)\right] = F\left[E_4\left(ABR_t\right), \mu, s\right] = \frac{1}{s\sqrt{2\pi}\,E_4\left(ABR_t\right)} e^{-\frac{\left\{E_4\left[\ln\left(ABR_t\right)\right] - \mu\right\}^2}{2s^2}}$$

for $E_4(ABR_t) > 0$, where $\boldsymbol{\mu}$ is the mean of the log normal distribution of $E_4(ABR_t)$ and $\boldsymbol{s}$ is the standard deviation of the error term in expectations of $\ln(ABR_t)$.

11. The probability density function of the $E_A(ABR_t)$ variable for the log normal distribution:

$$P[E_A(ABR_t)] = F[E_A(ABR_t), \mu, s] = \frac{1}{s\sqrt{2\pi}\, E_A(ABR_t)} e^{-\frac{\{E_A[\ln(ABR_t)] - \mu\}^2}{2s^2}}$$

for $E_A(ABR_t) > 0$, where $\boldsymbol{\mu}$ is the mean of the log normal distribution of $E_A(ABR_t)$ and $\boldsymbol{s}$ is the standard deviation of the error term in expectations of $\ln(ABR_t)$.

12. The area under the $P[E(ABR_t)]$ curve:

$$\int_0^{+\infty} P[E(ABR_t)]\, d[E(ABR_t)] = \frac{1}{s\sqrt{2\pi}} \int_{-\infty}^{+\infty} e^{-\frac{\{E[\ln(ABR_t)] - \mu\}^2}{2s^2}} = 1$$

13. The area under the $P[E_4(ABR_t)]$ curve:

$$\int_0^{+\infty} P[E_4(ABR_t)]\, d[E_4(ABR_t)] = \frac{1}{s\sqrt{2\pi}} \int_{-\infty}^{+\infty} e^{-\frac{\{E_4[\ln(ABR_t)] - \mu\}^2}{2s^2}} = 1$$

14. The area under the $P[E_A(ABR_t)]$ curve:

$$\int_0^{+\infty} P[E_A(ABR_t)]\, d[E_A(ABR_t)] = \frac{1}{s\sqrt{2\pi}} \int_{-\infty}^{+\infty} e^{-\frac{\{E_A[\ln(ABR_t)] - \mu\}^2}{2s^2}} = 1$$

15. The probability that the $E(ABR_t)$ variable is less than or equal to LBR (the probability of reaching the pollock quota given the LBR constraint):

$$P\left[E\left(ABR_t\right) \le LBR\right] = \int_0^{LBR} P\left[E\left(ABR_t\right)\right] d\left[E\left(ABR_t\right)\right]$$

16. The probability that the $E_4(ABR_t)$ variable is less than or equal to LBR:

$$P\left[E_4\left(ABR_t\right) \le LBR\right] = \int_0^{LBR} P\left[E_4\left(ABR_t\right)\right] d\left[E_4\left(ABR_t\right)\right]$$

17. The probability that the $E_A(ABR_t)$ variable is less than or equal to LBR:

$$P\left[E_A\left(ABR_t\right) \le LBR\right] = \int_0^{LBR} P\left[E_A\left(ABR_t\right)\right] d\left[E_A\left(ABR_t\right)\right]$$

18. The probability that the $E(ABR_t)$ variable is greater than LBR (the probability of not reaching the pollock quota given the LBR constraint):

$$P\left[E\left(ABR_t\right) > LBR\right] = 1 - P\left[E\left(ABR_t\right) \le LBR\right]$$

19. The probability that the $E_4(ABR_t)$ variable is greater than LBR:

$$P\left[E_4\left(ABR_t\right) > LBR\right] = 1 - P\left[E_4\left(ABR_t\right) \le LBR\right]$$

20. The probability that the $E_A(ABR_t)$ variable is greater than LBR:

$$P\left[E_A\left(ABR_t\right) > LBR\right] = 1 - P\left[E_A\left(ABR_t\right) \le LBR\right]$$

21. The average $E(ABR_t)$ variable that is greater than LBR:

$$E\left(ABR_t\right) = F^{-1}\left\{P\left[E\left(ABR_t\right) \le LBR\right] + \frac{1 - P\left[E\left(ABR_t\right) \le LBR\right]}{2}, \mu, s\right\}$$

for $E(ABR_t) > 0$, where F^{-1} is the inverse of the log normal cumulative distribution function of the $E(ABR_t)$ variable, $\boldsymbol{\mu}$ is the mean of the log normal distribution of $E(ABR_t)$, and $\boldsymbol{s}$ is the standard deviation of the error term in expectations of $\ln(ABR_t)$.

$E(ABR_t)$ is approximated by the midpoint of the log normal probability distribution of $E(ABR_t)$ for values greater than LBR.

22. The average $E_4(ABR_t)$ variable that is greater than LBR:

$$E_4(ABR_t) = F^{-1}\left\{ P\left[E_4(ABR_t) \leq LBR\right] + \frac{1 - P\left[E_4(ABR_t) \leq LBR\right]}{2}, \mu, s \right\}$$

for $E_4(ABR_t) > 0$, where F^{-1} is the inverse of the log normal cumulative distribution function of the $E_4(ABR_t)$ variable, $\boldsymbol{\mu}$ is the mean of the log normal distribution of $E_4(ABR_t)$, and $\boldsymbol{s}$ is the standard deviation of the error term in expectations of $\ln(ABR_t)$.

$E_4(ABR_t)$ is approximated by the midpoint of the log normal probability distribution of $E_4(ABR_t)$ for values greater than LBR.

23. The average $E_A(ABR_t)$ variable that is greater than LBR:

$$E_A(ABR_t) = F^{-1}\left\{ P\left[E_A(ABR_t) \leq LBR\right] + \frac{1 - P\left[E_A(ABR_t) \leq LBR\right]}{2}, \mu, s \right\}$$

for $E_A(ABR_t) > 0$, where F^{-1} is the inverse of the log normal cumulative distribution function of the $E_A(ABR_t)$ variable, $\boldsymbol{\mu}$ is the mean of the log normal distribution of $E_A(ABR_t)$, and $\boldsymbol{s}$ is the standard deviation of the error term in expectations of $\ln(ABR_t)$.

$E_A(ABR_t)$ is approximated by the midpoint of the log normal probability distribution of $E_A(ABR_t)$ for values greater than LBR.

24. Marginal value of a transferable bycatch allowance at the start of the fishing season (the start of A Season):

$$TBAMV = \frac{P\left[E(ABR_t) > LBR\right]}{E(ABR_t)} P_p$$

where P_P is the lease value of the pollock quota.

25. Marginal value of a transferable bycatch allowance after the first four weeks of fishing:

$$TBAMV = \frac{P\left[E_4(ABR_t) > LBR\right]}{E_4(ABR_t)} P_p$$

26. Marginal value of a transferable bycatch allowance after A Season:

$$TBAMV = \frac{P\left[E_A(ABR_t) > LBR\right]}{E_A(ABR_t)} P_p$$

27. Marginal value of a transferable bycatch allowance at the end of the fishing season (the end of B Season):

$$TBAMV = \frac{1}{ABR} P_p \quad \text{if ABR > LBR}$$

$$TBAMV = 0 \quad \text{if ABR < LBR}$$

28. Expected pollock harvest at the start of the fishing season (the start of A Season):

$$E(Q_p) = P\left[E(ABR_t) \le LBR\right] q_p + P\left[E(ABR_t) > LBR\right] q_p \left\lfloor \frac{LBR}{E(ABR_t)} \right\rfloor$$

where q_P is the pollock quota for a given year and $E(ABR_t)$ is approximated by the midpoint of the log normal probability distribution of $E(ABR_t)$ for values greater than LBR.

29. Expected pollock harvest after the first four weeks of fishing:

$$E_4(Q_p) = P\left[E_4(ABR_t) \le LBR\right] q_p + P\left[E_4(ABR_t) > LBR\right] q_p \left\lfloor \frac{LBR}{E_4(ABR_t)} \right\rfloor$$

where $E_4(ABR_t)$ is approximated by the midpoint of the log normal probability distribution of $E_4(ABR_t)$ for values greater than LBR.

30. Expected pollock harvest after A Season:

$$E_A(Q_p) = P[E_A(ABR_t) \leq LBR]q_p + P[E_A(ABR_t) > LBR]q_p \left\lfloor \frac{LBR}{E_A(ABR_t)} \right\rfloor$$

where $E_A(ABR_t)$ is approximated by the midpoint of the log normal probability distribution of $E_A(ABR_t)$ for values greater than LBR.

31. Expected stranded pollock loss at the start of the fishing season (the start of A Season):

$$E(SPL) = \left[q_p - E(Q_p)\right](P_p)$$

where q_P is the pollock quota for a given year and P_P is the lease value of the pollock quota.

32. Expected stranded pollock loss after the first four weeks of fishing:

$$E_4(SPL) = \left[q_p - E_4(Q_p)\right](P_p)$$

33. Expected stranded pollock loss after A Season:

$$E_A(SPL) = \left[q_p - E_A(Q_p)\right](P_p)$$

Mathematical Model of the Game

34. Money in (ante) at the beginning of the Game (the start of A Season):

$$M = \$0.01(2204.6q_p)$$

where \$0.01 is ante per pound of pollock quota and q_P is the pollock quota for a given year in metric tons.

35. Bycatch cutoff rate (96^{th} percentile of the ABR variables for individual vessels):

$$BCR = P_{96}$$

36. Chinook undercatch rate at the end of the fishing season (the end of B Season):

$UR = BCR - ABR$ if BCR > ABR

$UR = 0$ if BCR < ABR

37. Quantity of uncaught Chinook at the end of the fishing season (the end of B Season):

$$U_i = Q_p(UR_i)$$

where Q_P is a quantity of pollock caught in a year.

38. The amount of money (rebate) a vessel gets back at the end of the fishing season (the end of B Season):

$$R = M\left(\frac{U_i}{U}\right)$$

for U > 0, where M is the total amount of money in the fund, U_i is an individual vessel's quantity of uncaught Chinook, and U is the total quantity of uncaught Chinook for CP/CV sector.

39. Marginal value of a Chinook under the Game at the end of the fishing season (the end of B Season):

$$GMV = \frac{M}{U_i}$$

for $U_i > 0$.

TBA AND THE GAME COMBINED

40. Total marginal value of TBA and the Game:

$$TMV = TBAMV + GMV$$

Appendix E

Frequency Distributions and Graphs

Calculations used in the mathematical model of Transferable Bycatch Allowance (TBA) are derived from the data on Chinook bycatch (in numbers of Chinook), pollock harvest (in metric tons) and TAC (in metric tons) for the EBS pollock fleet for 1998-2007 time period (Appendix D, Table 1, 2 and 3). Our model of TBA assumes the bycatch quota is fully transferable between Season A and Season B as well as between the sectors.

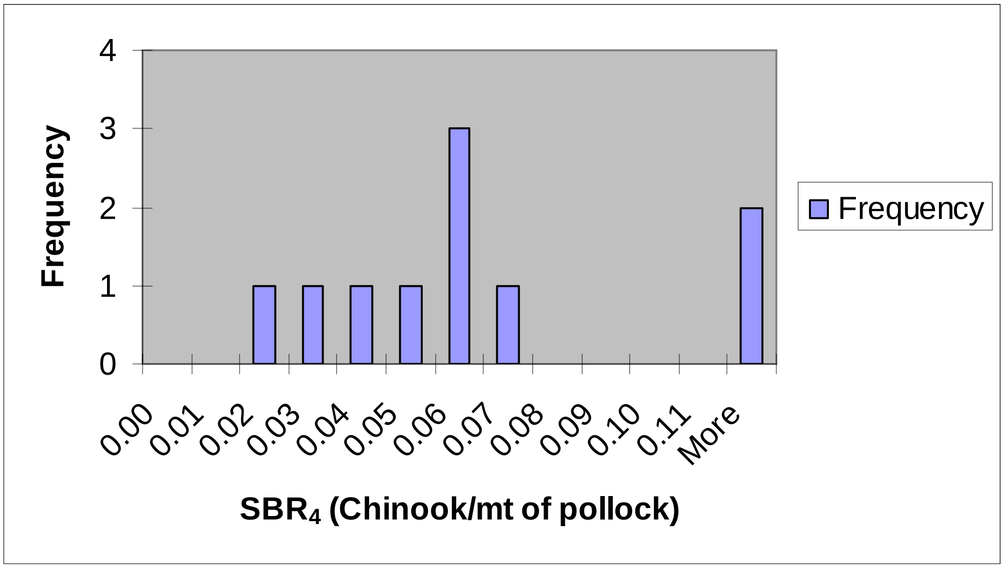
The first step in developing our model of TBA was to calculate the Seasonal Bycatch Rate (SBR) and the Annual Bycatch Rate (ABR) over the past ten years for the whole industry. SBR is the ratio of the total number of Chinook caught in a given season and total seasonal pollock harvest (Appendix F, Table 4, and 5). ABR is the ratio of the total number of Chinook caught in a given year and total annual pollock harvest (Appendix F, Table 6). Both SBR and ABR are expressed in units of Chinook/mt of pollock.

Since our model depends on normality assumptions, we had to make sure that SBR and ABR data were normally distributed.[6] As indicated by histograms in Figures 1, 2 and 3, as well as the numerical measures of skewness and kurtosis,[7] it turned out that our data sets were not normally distributed. There are many different approaches and useful techniques to deal with an asymmetric distribution. We chose to transform our data to make it more normal by taking the natural logarithm of SBR and ABR values as shown in Figures 4, 5 and 6. The motivation for using the log normal distribution comes from the fact our data sets are skewed to the right and are bounded bellow by zero, the lowest possible value of SBR and ABR variables.

Figure 1. Histogram for SBR values for the first four weeks of fishing for the whole industry.

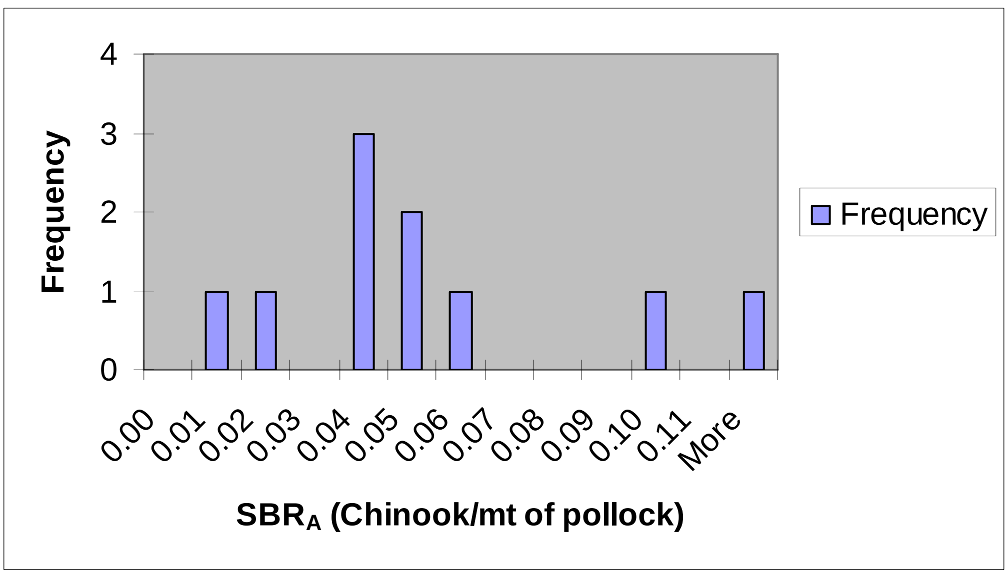
[6] Normal distribution, also known as *Gaussian distribution*, is a frequency distribution that is bell-shaped and symmetrical about the mean. It is the most widely used probability distribution that is applicable in many fields.

[7] Skewness (*Sk*) refers to the asymmetry of a distribution, while kurtosis (*Kur*) refers to its peakedness or flatness. If a distribution is symmetrical, $Sk = 0$ and $Kur = 0$. If a distribution is asymmetrical, $Sk \neq 0$ and $Kur \neq 0$.



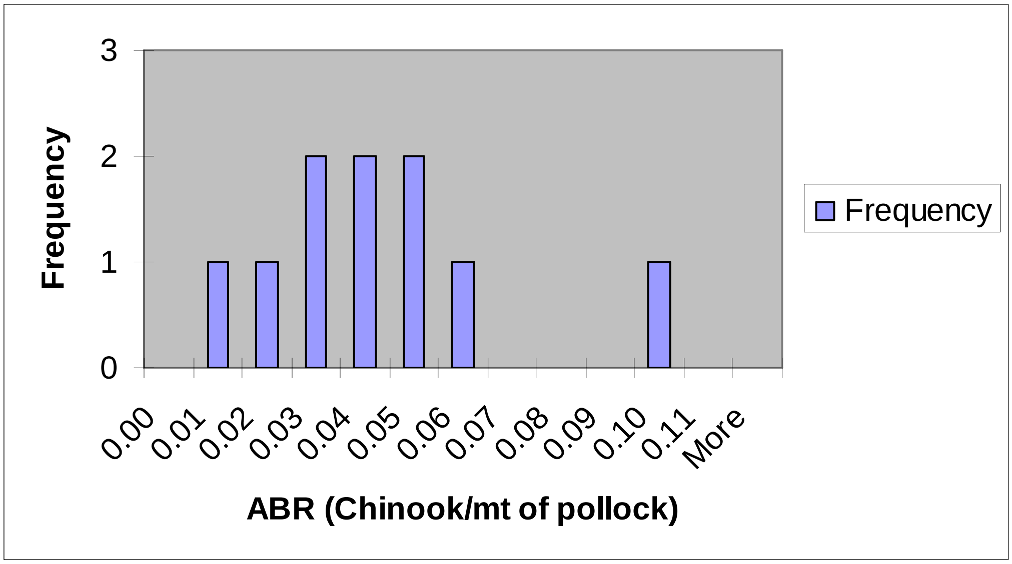
n = 10, μ = 0.07, s = 0.06, Sk = 1.83, Kur = 3.57. (Data from Appendix D, Table 10)

Figure 2. Histogram for SBR values for A Season for the whole industry.



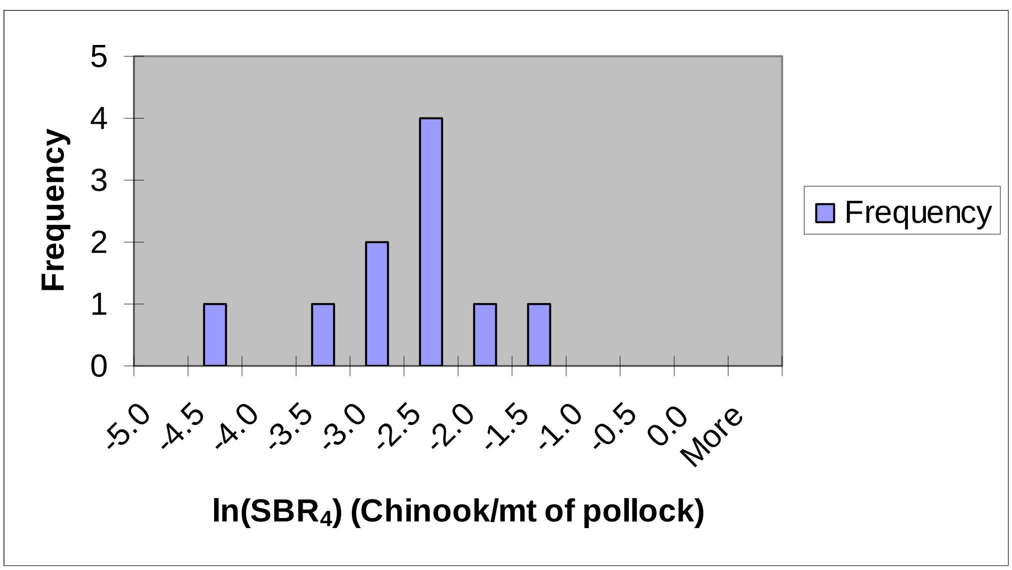
n = 10, μ = 0.05, s = 0.04, Sk = 1.22, Kur = 0.94. (Data from Appendix D, Table 11)

Figure 3. Histogram for ABR values for the whole industry.



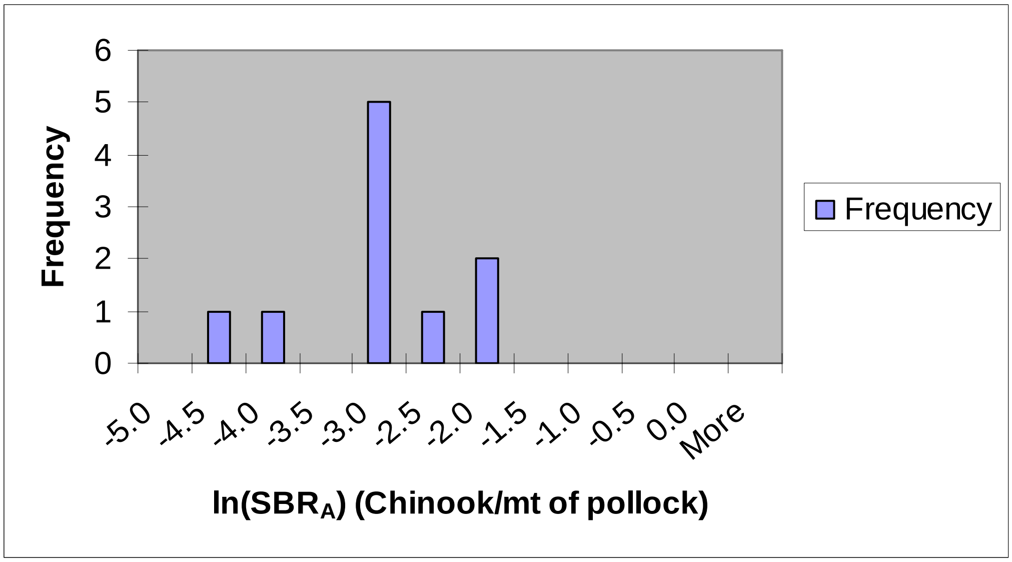
n = 10, μ = 0.04, s = 0.02, Sk = 0.95, Kur = 1.48. (Data from Appendix D, Table 12)

Figure 4. Histogram for ln(SBR) values for the first four weeks of fishing for the whole industry.



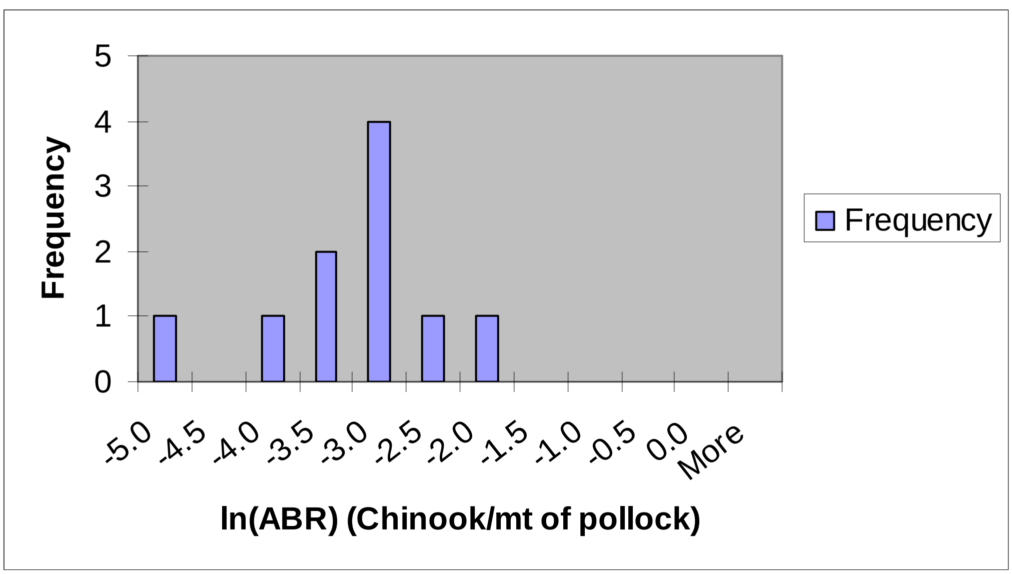
n = 10, μ = -3.02, s = 0.82, Sk = -0.14, Kur = 0.61. (Data from Appendix D, Table 13)

Figure 5. Histogram for ln(SBR) values for A Season for the whole industry.



n = 10, μ = -3.26, s = 0.80, Sk = -0.56, Kur = 0.78. (Data from Appendix D, Table 14)

Figure 6. Histogram for ln(ABR) values for the whole industry.



n = 10, μ = -3.54, s = 0.84, Sk = -1.16, Kur = 1.79. (Data from Appendix D, Table 15)

Expectations

The expected value of this year's ABR at the beginning of Season A is different year by year because there is a sizable correlation between this year's ABR and last year's SBR_A. For the period after the American Fisheries Act (AFA), the correlation of $\ln(SBR_A)$ of one year with ln(ABR) of the next year is 0.64 so fishers at the beginning of Season A have reason to expect bycatch to be low in the current year if bycatch was low in Season A of the previous year. The correlation of ln(ABR) for the year with the $\ln(SBR_4)$ observed in the first four weeks of fishing is considerably tighter at 0.88. The correlation of ln(ABR) for the year with the $\ln(SBR_A)$ observed in Season A is 0.93.

Given the correlation of ln(ABR) for the year with the $\ln(SBR_A)$ of the previous year, the $\ln(SBR_4)$ observed in the first four weeks of fishing and $\ln(SBR_A)$ observed in A Season, we can predict this year's ln(ABR) using regression analysis.

The expected value of this year's ln(ABR) at the start of A Season:

$$E\left[\ln\left(ABR_t\right)\right] = a + b\left[\ln\left(SBR_{A_{t-1}}\right)\right] + e_{t,A(t-1)}$$ (See Appendix F, Table 16, Graph 1)

where $e_{t,A(t-1)}$ is the error in expectations of $\ln(ABR_t)$ using last years $\ln(SBR_{A(t-1)})$.

The expected value of this year's ln(ABR) after the first four weeks of fishing:

$$E_4\left[\ln\left(ABR_t\right)\right] = a + b\left[\ln\left(SBR_4\right)\right] + e_{t,4}$$ (See Appendix F, Table 17, Graph 2)

where $e_{t,4}$ is the error in expectations of $\ln(ABR_t)$ using the $\ln(SBR_4)$ in the first four weeks of fishing.

The expected value of this year's ln(ABR) at the end of A Season:

$$E_A\left[\ln\left(ABR_t\right)\right] = a + b\left[\ln\left(SBR_A\right)\right] + e_{t,A}$$ (See Appendix F, Table 18, Graph 3)

where $e_{t,A}$ is the error in expectations of $\ln(ABR_t)$ using the $\ln(SBR_A)$ in Season A.

Probability

Fishers' expectations of ABR throughout a year play an important role in determining the probability of reaching the Limiting Bycatch Rate (LBR). LBR is the ratio of Chinook bycatch hard cap and the pollock quota for a given year. It is expressed in Chinook/mt of pollock. At the beginning of A Season, fishers face a certain pollock quota and Chinook bycatch hard cap for that year. Fishers have assertions concerning reaching the entire pollock quota given the Chinook bycatch hard cap constraint.

What is the likelihood that fishers will reach their pollock quota given the bycatch hard cap constraint? In order to answer this question, we need to calculate the probability of the occurrence of an event.[8] We can find the probability that a data point will fall within a certain range of values by using a set of cumulative normal distribution tables or by calculating the area under the probability density curve in the form of a definite integral.

The area under the P[E(ABR_t)] curve:

$$\int_0^{+\infty} P\left[E\left(ABR_t\right)\right] d\left[E\left(ABR_t\right)\right] = \frac{1}{s\sqrt{2\pi}} \int_{-\infty}^{+\infty} e^{-\frac{\left\{E\left[\ln\left(ABR_t\right)\right]-\mu\right\}^2}{2s^2}} = 1$$

for E(ABR_t) > 0, where $\boldsymbol{\mu}$ is the mean of the log normal distribution of E(ABR_t) and $\boldsymbol{s}$ is the standard deviation of the error term in expectations of ln(ABR_t).

The area under the P[E_4(ABR_t)] curve:

$$\int_0^{+\infty} P\left[E_4\left(ABR_t\right)\right] d\left[E_4\left(ABR_t\right)\right] = \frac{1}{s\sqrt{2\pi}} \int_{-\infty}^{+\infty} e^{-\frac{\left\{E_4\left[\ln\left(ABR_t\right)\right]-\mu\right\}^2}{2s^2}} = 1$$

for E_4(ABR_t) > 0, where $\boldsymbol{\mu}$ is the mean of the log normal distribution of E_4(ABR_t) and $\boldsymbol{s}$ is the standard deviation of the error term in expectations of ln(ABR_t).

The area under the P[E_A(ABR_t)] curve:

$$\int_0^{+\infty} P\left[E_A\left(ABR_t\right)\right] d\left[E_A\left(ABR_t\right)\right] = \frac{1}{s\sqrt{2\pi}} \int_{-\infty}^{+\infty} e^{-\frac{\left\{E_A\left[\ln\left(ABR_t\right)\right]-\mu\right\}^2}{2s^2}} = 1$$

for E_A(ABR_t) > 0, where $\boldsymbol{\mu}$ is the mean of the log normal distribution of E_A(ABR_t) and $\boldsymbol{s}$ is the standard deviation of the error term in expectations of ln(ABR_t).

The probability of fishers reaching their pollock quota given the bycatch hard cap constraint at the start of A Season is the probability of E(ABR_t) variable being less than or equal to LBR:

$$P\left[E\left(ABR_t\right) \leq LBR\right] = \int_0^{LBR} P\left[E\left(ABR_t\right)\right] d\left[E\left(ABR_t\right)\right]$$

The probability of fishers reaching their pollock quota given the bycatch hard cap constraint after the first four weeks of fishing is the probability of E_4(ABR_t) variable being less than or equal to LBR:

$$P\left[E_4\left(ABR_t\right) \leq LBR\right] = \int_0^{LBR} P\left[E_4\left(ABR_t\right)\right] d\left[E_4\left(ABR_t\right)\right]$$

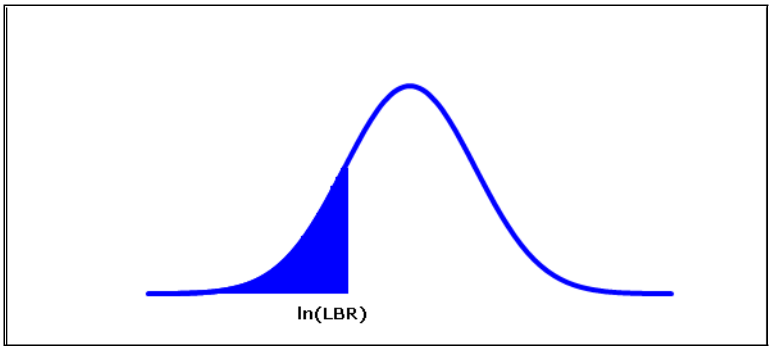
[8] *Event* in this case is fishers reaching their pollock quota. The probability of the occurrence of an event is a decimal number between 0 and 1. Events that are unlikely to happen will have probabilities near 0, and events that are likely to happen will have probabilities near 1.

The probability of fishers reaching their pollock quota given the bycatch hard cap constraint after A Season is the probability of $E_A(ABR_t)$ variable being less than or equal to LBR:

$$P[E_A(ABR_t) \leq LBR] = \int_0^{LBR} P[E_A(ABR_t)]d[E_A(ABR_t)]$$

The probability of fishers reaching the pollock quota given the bycatch constraint during the fishing season is illustrated in Figure 7.

<u>Figure 7. The probability of fishers reaching/not reaching the pollock quota given the bycatch hard cap constraint.</u>



The shaded area is the probability of fishers reaching the pollock quota given ln(LBR) constraint. The area to the right of ln(LBR) is the probability of fishers not reaching the pollock quota.

The probability of fishers not reaching their pollock quota given the bycatch hard cap constraint at the start of A Season is the probability of $E(ABR_t)$ variable being greater than LBR:

$$P[E(ABR_t) > LBR] = 1 - P[E(ABR_t) \leq LBR]$$

The probability of fishers not reaching their pollock quota given the bycatch hard cap constraint after the first four weeks of fishing is the probability of $E_4(ABR_t)$ variable being greater than LBR:

$$P[E_4(ABR_t) > LBR] = 1 - P[E_4(ABR_t) \leq LBR]$$

The probability of fisher not reaching their pollock quota given the bycatch hard cap constraint after A Season is the probability of $E_A(ABR_t)$ variable being greater than LBR:

$$P[E_A(ABR_t) > LBR] = 1 - P[E_A(ABR_t) \leq LBR]$$

The probability of fishers not reaching the pollock quota given the bycatch constraint during the fishing season is illustrated in Figure 7.

Marginal Value of TBA

In order to facilitate comparison between the gain to avoiding Chinook induced by TBA and the gain to avoiding Chinook induced by the Game, we have put both in terms of their Marginal Value (MV). The aim of our mathematical model is to produce an estimate of MV obtained by a fisher by avoiding a Chinook under TBA and the Game.

MV of TBA is the value of an additional Chinook bycatch allowance given the fact we already reached our individual bycatch allowance. In other words, we ask the following question: In the event of reaching our bycatch allowance, how much would an additional bycatch allowance be worth? We could sell extra bycatch allowances at this price or if we need them we could buy extra allowances at this price. Each additional bycatch allowance gives the right to catch more pollock when bycatch limits pollock harvest. TBA has value only when bycatch limits pollock catch.

MV of TBA at the start of A Season:

$$TBAMV = \frac{P[E(ABR_t) > LBR]}{E(ABR_t)} P_p$$

where P_P is the lease value of the pollock quota and $E(ABR_t)$ is approximated by the midpoint of the log normal probability distribution of $E(ABR_t)$ for values greater than LBR (See Appendix D, Equation 21).

MV of TBA after the first four weeks of fishing:

$$TBAMV = \frac{P[E_4(ABR_t) > LBR]}{E_4(ABR_t)} P_p$$

where $E_4(ABR_t)$ is approximated by the midpoint of the log normal probability distribution of $E_4(ABR_t)$ for values greater than LBR (See Appendix B, Equation 22).

MV of TBA after A Season:

$$TBAMV = \frac{P[E_A(ABR_t) > LBR]}{E_A(ABR_t)} P_p$$

where $E_A(ABR_t)$ is approximated by the midpoint of the log normal probability distribution of $E_A(ABR_t)$ for values greater than LBR (See Appendix B, Equation 23).

MV of TBA after B Season:

$$TBAMV = \frac{1}{ABR} P_p \qquad \text{if ABR > LBR}$$

$$TBAMV = 0 \qquad \text{if ABR < LBR}$$

Fishers' expectations of ABR and assertions concerning their chances of harvesting the entire pollock quota when facing a fixed Chinook bycatch hard cap determine the value of avoiding an additional Chinook. For example, after a year in which ABR was low, the value of TBA at the beginning of an A Season will be lower than usual as the chance that ABR will exceed the LBR is lower than usual. After the first four weeks of fishing in which the SBR_4 was low, the value of TBA will further decline as the chance that ABR will exceed the LBR decreases. After an A Season in which the SBR_A was low, the value of TBA will be much lower than usual as the chance that the LBR will be reached is much lower than during an average year.

Expected Pollock Harvest

Fishers can estimate their pollock harvest given their expectations of ABR and chances of reaching the pollock quota when facing the bycatch hard cap constraint.

Expected pollock harvest at the start of A Season:

$$E(Q_p) = P\left[E(ABR_t) \le LBR\right] q_p + P\left[E(ABR_t) > LBR\right] q_p \left|\frac{LBR}{E(ABR_t)}\right|$$

where q_P is the pollock quota for a given year and $E(ABR_t)$ is approximated by the midpoint of the log normal probability distribution of $E(ABR_t)$ for values greater than LBR.

Expected pollock harvest after the first four weeks of fishing:

$$E_4(Q_p) = P\left[E_4(ABR_t) \le LBR\right] q_p + P\left[E_4(ABR_t) > LBR\right] q_p \left|\frac{LBR}{E_4(ABR_t)}\right|$$

where $E_4(ABR_t)$ is approximated by the midpoint of the log normal probability distribution of $E_4(ABR_t)$ for values greater than LBR.

Expected pollock harvest after A Season:

$$E_A(Q_p) = P\left[E_A(ABR_t) \le LBR\right] q_p + P\left[E_A(ABR_t) > LBR\right] q_p \left|\frac{LBR}{E_A(ABR_t)}\right|$$

where $E_A(ABR_t)$ is approximated by the midpoint of the log normal probability distribution of $E_A(ABR_t)$ for values greater than LBR.

Expected Stranded Pollock Loss

Fishers can estimate their stranded pollock loss given their expectations of pollock harvest when facing the bycatch hard cap constraint.

Expected stranded pollock loss at the start of A Season:

$$E(SPL) = \left[q_p - E(Q_p)\right](P_p)$$

where q_P is the pollock quota for a given year and P_P is the lease value of the pollock quota.

Expected stranded pollock loss after the first four weeks of fishing:

$$E_4(SPL) = \left[q_p - E_4(Q_p)\right](P_p)$$

Expected stranded pollock loss after A Season:

$$E_A(SPL) = \left[q_p - E_A(Q_p)\right](P_p)$$

Marginal Value of the Game

Calculations used in the mathematical model of the Game are derived from the data on pollock harvest (in metric tons) and Chinook bycatch (in numbers of Chinook) for individual vessels in CP and CV sector for 2000-2007 time period. We estimated only MV of the Game at the end of B Season due to insufficient weekly and seasonal data on pollock harvest and Chinook bycatch for individual vessels.

The Game is played separately by each sector. Every vessel that participates in the Game invests one penny per pound of its pollock quota at the start of A Season. The Chinook Bycatch Cutoff Rate (BCR) is the 96th percentile of the ABR values for individual vessels. This means that 4% of the vessels with the highest ABR, labeled as "Dirty Harry", get none of their initial investment back at the end of B Season. The other participating vessels with ABR below the 96th percentile share among themselves the fund in proportion to the Chinook they did not catch relative to "Dirty Harry". The better the vessel is compared to "Dirty Harry", the vessel gets more money back from the fund.

In the CP sector there are on average 14 vessels of which one is "Dirty Harry", while in the CV sector there are on average 80 vessels of which four are "Dirty Harry". Chinook undercatch rate for individual vessels is the difference between their ABR and the BCR:

$UR = BCR - ABR$ if BCR > ABR

$UR = 0$ if BCR < ABR

Quantity of uncaught Chinook is the product of a Chinook undercatch rate and the quantity of pollock caught in a year:

$$U_i = Q_p(UR_i)$$

The amount of money a vessel gets back from the fund depends on its quantity of uncaught Chinook relative to the total quantity of uncaught Chinook for CP/CV sector at the end of the fishing season:

$$R = M\left(\frac{U_i}{U}\right)$$

for U > 0, where M is the total amount of money in the fund, U_i is an individual vessel's quantity of uncaught Chinook, and U is the total quantity of uncaught Chinook for CP/CV sector.

MV of the Game is the value of an additional Chinook a fisher does not catch relative to "Dirty Harry":

$$GMV = \frac{M}{U_i}$$

for $U_i > 0$.

Appendix F

Data Used For Deriving the Mathematical Model of TBA

Table 1. Chinook bycatch by sector for the EBS pollock fleet, 1998-2008 as of [May 5, 2008] in numbers of Chinook.

	A Season				B Season				Annual
YEAR	CP	CV	M	A Total	CP	CV	M	B Total	Total
1998	6,500	4,334	4,284	15,118	2,547	27,218	6,361	36,126	51,244
1999	2,694	3,103	554	6,351	2,590	2,662	374	5,626	11,977
2000	2,525	878	19	3,422	568	717	253	1,538	4,960
2001	8,264	8,555	1,664	18,483	9,863	3,779	1,319	14,961	33,444
2002	9,481	10,336	1,976	21,793	1,386	9,560	1,755	12,701	34,494
2003	14,428	16,488	2,892	33,808	4,044	7,202	1,940	13,186	46,994
2004	9,492	12,376	2,092	23,960	4,289	23,701	2,076	30,066	54,026
2005	11,421	14,097	2,111	27,629	4,343	34,986	888	40,217	67,846
2006	17,306	36,039	5,408	58,753	1,551	22,654	200	24,405	83,158
2007	27,943	35,458	5,860	69,261	7,148	41,751	3,544	52,443	121,704
2008	3,990	10,033	1,102	15,125					

Source: BSAI Salmon Bycatch EIS. Initial Review Draft – May 15, 2008. Table 5-4.

Table 2. Catch of pollock by sector and season for the EBS pollock fleet, 1998-2007 in metric tons.

	A Season				B Season				Annual
YEAR	CP	CV	M	A Total	CP	CV	M	B Total	Total
1998	271,472	159,575	65,058	496,104	331,799	195,036	79,516	606,350	1,102,454
1999	169,851	169,744	40,191	379,786	254,777	254,617	60,286	569,680	949,466
2000	196,310	194,789	45,639	436,739	294,465	292,184	68,459	655,108	1,091,847
2001	241,563	241,311	56,310	539,184	362,344	361,967	84,465	808,775	1,347,959
2002	257,755	257,618	59,968	575,342	386,633	386,428	89,952	863,013	1,438,355
2003	280,505	260,212	51,811	592,528	413,512	393,550	80,817	887,879	1,480,407
2004	275,625	262,570	60,222	598,417	401,570	378,855	90,736	871,161	1,469,578
2005	273,977	259,002	57,802	590,781	403,537	386,473	89,225	879,235	1,470,016
2006	274,279	262,997	58,134	595,410	405,586	381,981	89,303	876,870	1,472,280
2007	257,647	250,726	56,526	564,899	372,737	327,962	84,978	785,677	1,350,576

1998-2002 data source: NMFS/AKR Fish Management. Weekly Production and Observer Reports.
2003-2007 data source: BSAI Salmon Bycatch EIS. Initial Review Draft – May 15, 2008. Table 5-5.
Note: 1998 data for CP and M sector is an estimate. We estimated 80% of 664,594 catch is CP sector and 20% of 664,594 catch is M sector.
For 1998, we allocated 45% of total catch to A Season and 55% to B Season. 1999-2002, we allocated 40% of total catch to A Season and 60% to B Season.

Table 3. TAC by sector for the EBS pollock fleet, 1998-2008 in metric tons.

YEAR	CP	CV	M	Total
1998	481,740	482,850	112,110	1,076,700
1999	430,528	431,520	100,192	962,240
2000	494,326	495,465	115,039	1,104,830
2001	607,600	609,000	141,400	1,358,000
2002	644,490	645,975	149,985	1,440,450
2003	647,424	648,916	150,668	1,447,007
2004	647,528	649,020	150,692	1,447,240
2005	641,669	643,148	149,329	1,434,145
2006	644,490	645,975	149,985	1,440,450
2007	604,996	606,390	140,794	1,352,180
2008	434,000	435,000	101,000	970,000

Table 4. Bycatch rate for the first four weeks of the fishing season for the whole industry, 1998-2007 in Chinook/mt of pollock.

YEAR	SBR_4
1998	0.031546
1999	0.021462
2000	0.010934
2001	0.055005
2002	0.051847
2003	0.064003
2004	0.044641
2005	0.055846
2006	0.119274
2007	0.198853

Table 5. Seasonal bycatch rate by sector for the EBS pollock fleet, 1998-2007 in Chinook/mt of pollock.

	A Season				B Season			
YEAR	CP	CV	M	A Total	CP	CV	M	B Total
1998	0.023944	0.027160	0.065849	0.030473	0.007676	0.139554	0.079997	0.059579
1999	0.015861	0.018280	0.013784	0.016723	0.010166	0.010455	0.006204	0.009876
2000	0.012862	0.004507	0.000416	0.007835	0.001929	0.002454	0.003696	0.002348
2001	0.034211	0.035452	0.029551	0.034280	0.027220	0.010440	0.015616	0.018498
2002	0.036783	0.040121	0.032951	0.037878	0.003585	0.024739	0.019510	0.014717
2003	0.051436	0.063364	0.055818	0.057057	0.009780	0.018300	0.024005	0.014851
2004	0.034438	0.047134	0.034738	0.040039	0.010681	0.062560	0.022880	0.034513
2005	0.041686	0.054428	0.036521	0.046767	0.010762	0.090526	0.009952	0.045741
2006	0.063096	0.137032	0.093026	0.098677	0.003824	0.059307	0.002240	0.027832
2007	0.108455	0.141421	0.103669	0.122608	0.019177	0.127304	0.041705	0.066749

Table 6. Annual bycatch rate by sector for the EBS pollock fleet, 1998-2007 in Chinook/mt of pollock.

YEAR	CP	CV	M	Total
1998	0.014997	0.088977	0.073630	0.046482
1999	0.012444	0.013585	0.009236	0.012614
2000	0.006302	0.003275	0.002384	0.004543
2001	0.030016	0.020445	0.021190	0.024811
2002	0.016864	0.030892	0.024886	0.023982
2003	0.026616	0.036236	0.036433	0.031744
2004	0.020350	0.056245	0.027610	0.036763
2005	0.023267	0.076042	0.020398	0.046153
2006	0.027736	0.091000	0.038037	0.056482
2007	0.055666	0.133421	0.066457	0.090113

Table 7. The natural logarithm of the bycatch rate variables for the first four weeks of fishing from Table 4.

YEAR	$\ln(SBR_4)$
1998	-3.456308
1999	-3.841471
2000	-4.515878
2001	-2.900331
2002	-2.959458
2003	-2.748825
2004	-3.109103
2005	-2.885157
2006	-2.126332
2007	-1.615189

Table 8. The natural logarithm of A Season Total bycatch rate variables from Table 5.

YEAR	$\ln(SBR_A)$
1998	-3.490900
1999	-4.090997
2000	-4.849110
2001	-3.373205
2002	-3.273376
2003	-2.863701
2004	-3.217902
2005	-3.062579
2006	-2.315908
2007	-2.098765

Table 9. The natural logarithm of the annual bycatch rate Total variables from Table 6.

YEAR	ln(ABR)
1998	-3.068695
1999	-4.372912
2000	-5.394220
2001	-3.696474
2002	-3.730470
2003	-3.450052
2004	-3.303265
2005	-3.075788
2006	-2.873825
2007	-2.406695

Table 10. Frequency distribution for SBR_4 variables from Table 4.

Bin	*Frequency*
0.00	0
0.01	0
0.02	1
0.03	1
0.04	1
0.05	1
0.06	3
0.07	1
0.08	0
0.09	0
0.10	0
0.11	0
More	2
	*n** = 10
* *n* denotes the total number of variables in the frequency distribution.	

Table 11. Frequency distribution for SBR_A variables for the whole industry from Table 5.

Bin	*Frequency*
0.00	0
0.01	1
0.02	1
0.03	0
0.04	3
0.05	2
0.06	1
0.07	0
0.08	0
0.09	0
0.10	1
0.11	0
More	1
	*n** = 10
* *n* denotes the total number of variables in the frequency distribution.	

Table 12. Frequency distribution for ABR variables for the whole industry from Table 6.

Bin	*Frequency*
0.00	0
0.01	1
0.02	1
0.03	2
0.04	2
0.05	2
0.06	1
0.07	0
0.08	0
0.09	0
0.10	1
0.11	0
More	0
	*n** = 10

* *n* denotes the total number of variables in the frequency distribution.

Table 13. Frequency distribution for ln(SBR_4) variables from Table 7.

Bin	*Frequency*
-5.0	0
-4.5	1
-4.0	0
-3.5	1
-3.0	2
-2.5	4
-2.0	1
-1.5	1
-1.0	0
-0.5	0
0.0	0
More	0
	*n** = 10

* *n* denotes the total number of variables in the frequency distribution.

Table 14. Frequency distribution for ln(SBR_A) variables from Table 8.

Bin	*Frequency*
-5.0	0
-4.5	1
-4.0	1
-3.5	0
-3.0	5
-2.5	1
-2.0	2
-1.5	0
-1.0	0
-0.5	0
0.0	0
More	0
	*n** = 10

* *n* denotes the total number of variables in the frequency distribution.

Table 15. Frequency distribution for ln(ABR) variables from Table 9.

Bin	*Frequency*
-5.0	1
-4.5	0
-4.0	1
-3.5	2
-3.0	4
-2.5	1
-2.0	1
-1.5	0
-1.0	0
-0.5	0
0.0	0
More	0
	*n** = 10

* *n* denotes the total number of variables in the frequency distribution.

Table 16. Regression analysis: $\ln(ABR_t) = a + b \ln(SBR_{A(t-1)}) + e_{t,A(t-1)}$.

Observation	Predicted Y	Residuals	Actual Y= $\ln(ABR_t)$	X= $\ln(SBR_{A(t-1)})$
1998				-3.490900
1999	-3.664970	-0.707942	-4.372912	-4.090997
2000	-4.129156	-1.265064	-5.394220	-4.849110
2001	-4.715572	1.019097	-3.696474	-3.373205
2002	-3.573930	-0.156540	-3.730470	-3.273376
2003	-3.496710	0.046658	-3.450052	-2.863701
2004	-3.179818	-0.123447	-3.303265	-3.217902
2005	-3.453800	0.378012	-3.075788	-3.062579
2006	-3.333655	0.459830	-2.873825	-2.315908
2007	-2.756090	0.349395	-2.406695	

Regression Statistics	
Multiple R	0.638653
R Square	0.407878
Adjusted R Square	0.323289
Standard Error	0.722937
Observations	9

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	-0.964689	1.219295	-0.791186	0.454803	-3.847863	1.918484
X Variable 1	0.773520	0.352260	2.195878	0.064120	-0.059442	1.606482

Graph 1. $\ln(ABR_t) = a + b \ln(SBR_{A(t-1)}) + e_{t,A(t-1)}$.

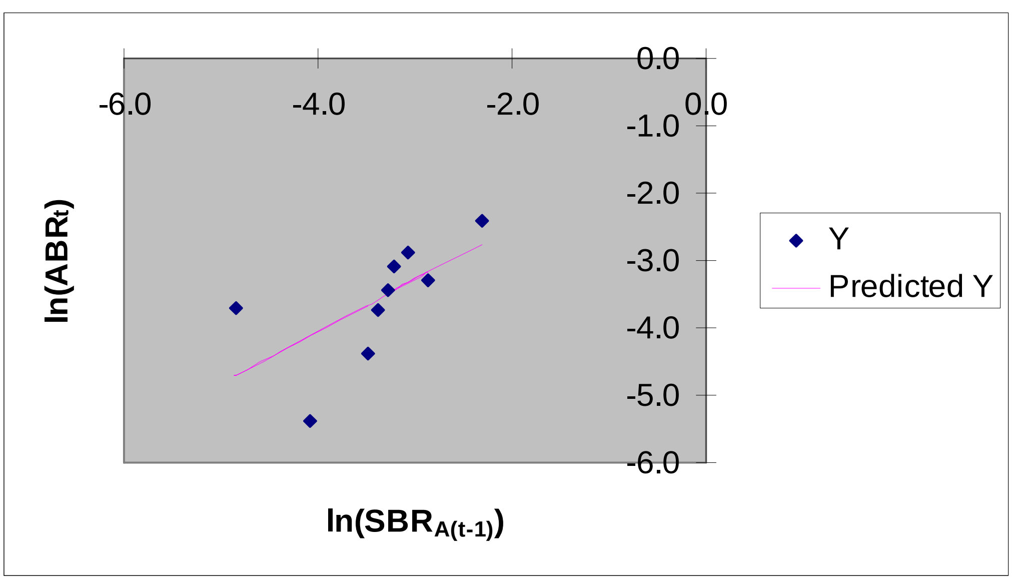


Table 17. Regression analysis: $\ln(ABR_t) = a + b \ln(SBR_4) + e_{t,4.}$

Observation	Predicted Y	Residuals	Actual Y= $\ln(ABR_t)$	X= $\ln(SBR_4)$
1998	-3.939721	0.871026	-3.068695	-3.456308
1999	-4.291639	-0.081272	-4.372912	-3.841471
2000	-4.907836	-0.486385	-5.394220	-4.515878
2001	-3.431732	-0.264742	-3.696474	-2.900331
2002	-3.485756	-0.244714	-3.730470	-2.959458
2003	-3.293304	-0.156749	-3.450052	-2.748825
2004	-3.622484	0.319219	-3.303265	-3.109103
2005	-3.417868	0.342080	-3.075788	-2.885157
2006	-2.724540	-0.149285	-2.873825	-2.126332
2007	-2.257516	-0.149179	-2.406695	-1.615189

Regression Statistics	
Multiple R	0.882566
R Square	0.778923
Adjusted R Square	0.751288
Standard Error	0.421287
Observations	10

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	-0.781739	0.535841	-1.458902	0.182709	-2.017390	0.453912
X Variable 1	0.913686	0.172098	5.309093	0.000720	0.516827	1.310546

Graph 2. $\ln(ABR_t) = a + b \ln(SBR_4) + e_{t,4.}$

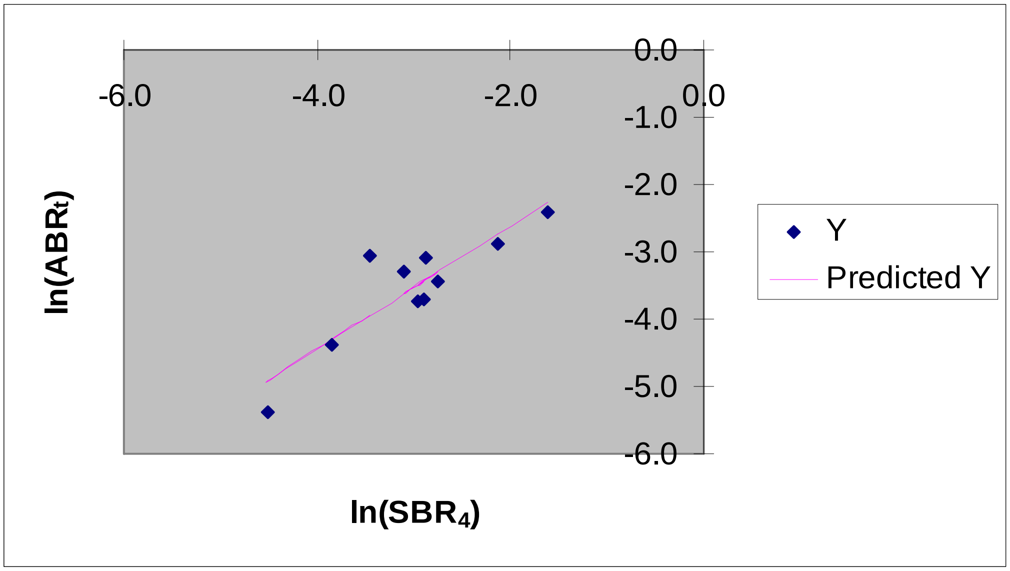


Table 18. Regression analysis: $\ln(ABR_t) = a + b \ln(SBR_A) + e_{t,A.}$

Observation	Predicted Y	Residuals	Actual Y= $\ln(ABR_t)$	X= $\ln(SBR_A)$
1998	-3.761034	0.692339	-3.068695	-3.490900
1999	-4.351991	-0.020921	-4.372912	-4.090997
2000	-5.098558	-0.295663	-5.394220	-4.849110
2001	-3.645132	-0.051343	-3.696474	-3.373205
2002	-3.546823	-0.183647	-3.730470	-3.273376
2003	-3.143388	-0.306665	-3.450052	-2.863701
2004	-3.492194	0.188929	-3.303265	-3.217902
2005	-3.339237	0.263449	-3.075788	-3.062579
2006	-2.603938	-0.269887	-2.873825	-2.315908
2007	-2.390102	-0.016592	-2.406695	-2.098765

Regression Statistics	
Multiple R	0.929319
R Square	0.863634
Adjusted R Square	0.846589
Standard Error	0.330871
Observations	10

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	-0.323303	0.463487	-0.697544	0.505226	-1.392107	0.745501
X Variable 1	0.984769	0.138349	7.117991	0.000100	0.665735	1.303803

Graph 3. $\ln(ABR_t) = a + b \ln(SBR_A) + e_{t,A}$.