Comprehensive Incentives for Reducing Chinook Salmon Bycatch in the Bering Sea Pollock Fleet: Individual Tradable Encounter Credits

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RMA 2010
Helsinki, Finland

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BSAI Pollock Fishery

- Eastern Bering Sea and Aleutian Islands
- Walleye pollock (*Theragra chalcogramma*)
- largest US fishery
  - ~ 1 million metric tons
  - > $300 million ex-vessel revenue
- rationalized in the 1990's
  - subsector allocation of Total Allowable Catch (TAC) similar to individual fishing quota

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BSAI Pollock Fishery

- mid-water trawl
- relatively clean fishery
  - ~ 1% bycatch
  - < 1% discards
- large amount of catch = large amount of bycatch
  - in 2007: 264 mt of Halibut, 338 mt of Herring, 3.8 thousand crabs, 120,000 Chinook salmon, 97,000 Chum salmon

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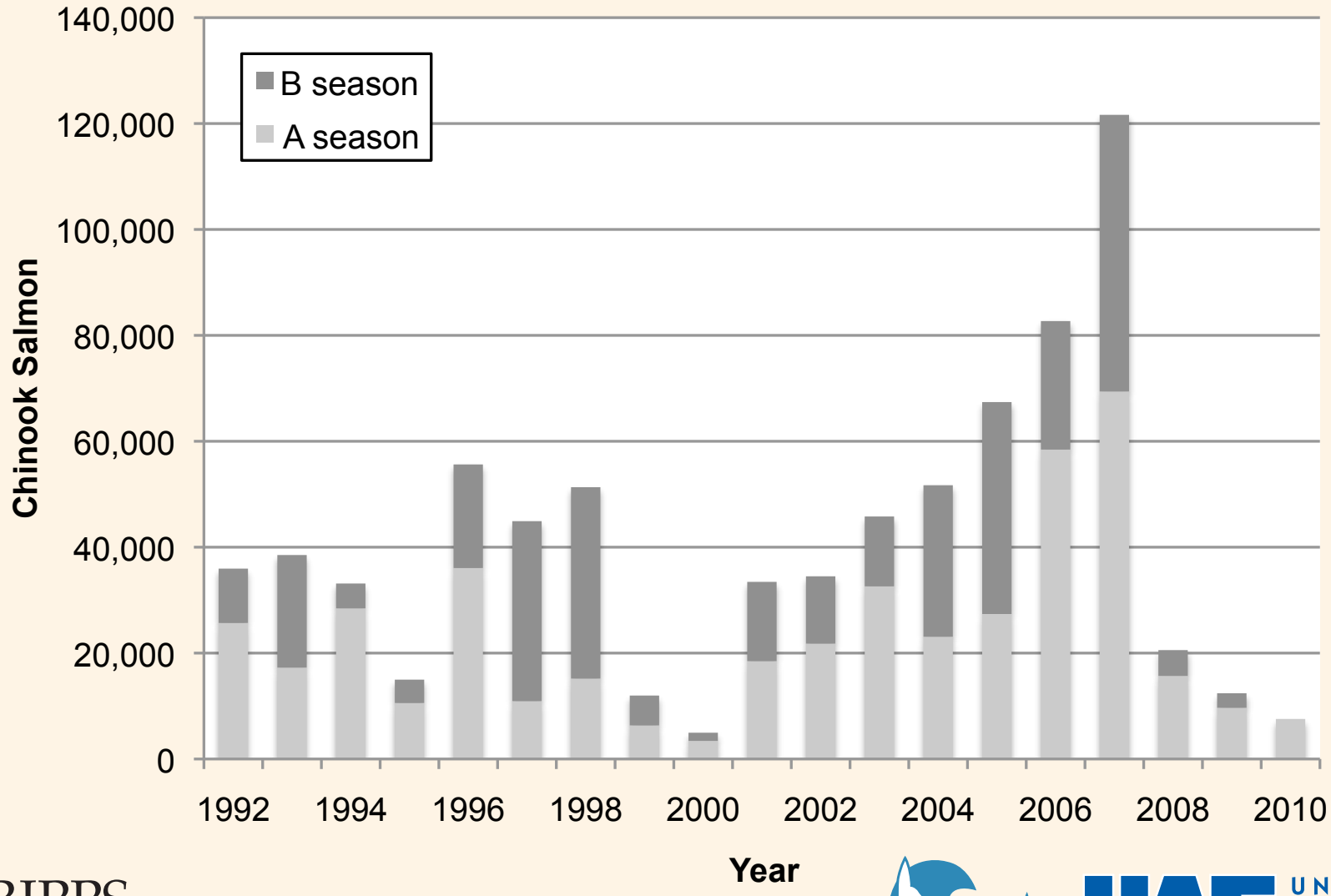
Chinook Salmon Bycatch



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Chinook Salmon Bycatch

- highly variable (across time and space)
- can have a large impact on Chinook Salmon returns in western Alaska
  - average bycatch in 1994-2007 reduces Chinook salmon by 35,706 fish per year
    - 56.3% (20,097) from western Alaska
    - northern Alaska Peninsula, Yukon drainage, Gulf of Alaska, Southeast Alaska, British Columbia, Pacific Northwest

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Management Measures

- fixed and variable spatial closures
  - fixed closure areas
  - variable closure areas (rolling hotspots)
    - determined by three-week running average of bycatch rate
    - vessels are given 1-2 days notice of closures
    - can potentially fish out an area before closure is in effect

Proposed Measures

- NPFMC adopts Preliminary Preferred Alternative (PPA) to manage Chinook bycatch
- 2 options
  - simple hardcap of 47,591 Chinook salmon per year (with fixed percentages for different sectors and different seasons)
  - hardcap of 60,000 Chinook salmon per year with an intercooperative agreement (ICA) to create individual vessel incentives

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Simple Hardcaps

- without individual allocation of hardcap quota, race to ~~fish~~ bycatch!
- obvious solution: individually allocate fractions of hardcap *pro rata* to pollock TAC fractions
  - high variability in bycatch (year to year)
  - high variability in bycatch (vessel to vessel)
  - no trading scheme
    - REVENUE LOSS!!

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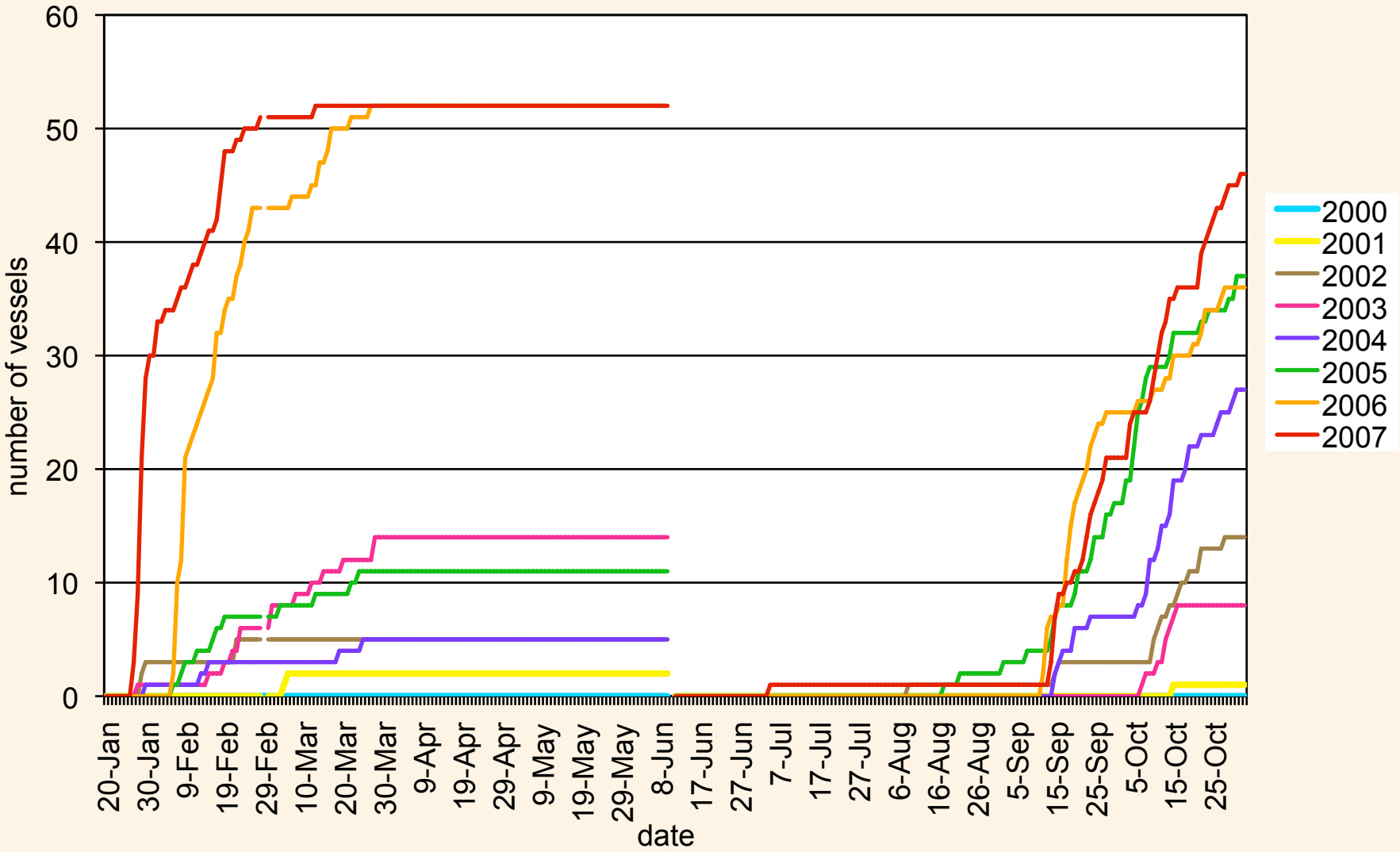
Vessels Exceeding Hardcap



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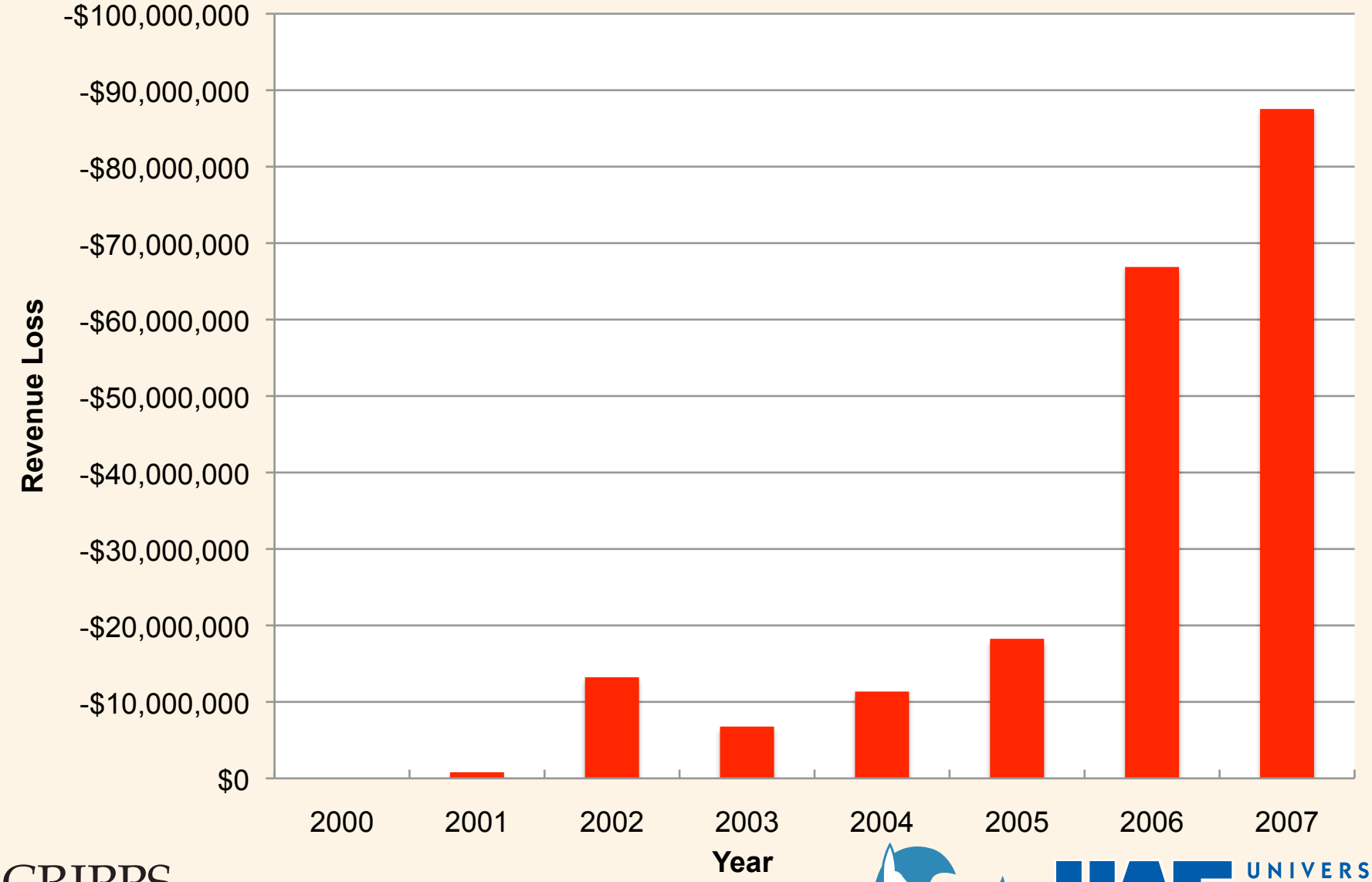
Potential Revenue Loss



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More BAD News

- no stock assessment for Chinook salmon:
  - bycatch levels are proxy for abundance
  - hardcap is not restrictive in years of low bycatch
    - perverse incentive for industry to fish out ALL Chinook salmon when bycatch/ abundance is low!

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ICA requirements

- 60,000 hardcap option
  - annual bycatch < 47,591 in at least 4 years out of every 7 year period
  - reward vessels that avoid salmon or penalize vessels that fail to avoid salmon
  - create incentives to avoid Chinook bycatch at all levels of abundance in all years
  - influences fishing decisions when hardcap is not binding

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Proposed ICA

- Comprehensive Incentive Plan
  - Individual Tradable Encounter Credit (ITEC)
  - 2 main components:
    - allocation and reallocation component
      - long-term incentives
    - market component
      - short-term incentives

ITEC

- 1 ITEC = 1 Chinook salmon
  - vessels are allocated ITEC at the beginning of each fishing season
  - for each Chinook salmon caught, vessels must "pay" 1 ITEC
    - vessels without ITEC cannot fish
    - vessels with bycatch > ITEC supply must buy additional ITEC

Simulation

- inshore catcher-vessel sector
  - daily data from 2000 to 2007
  - per-vessel catch and bycatch
- 33,390 credits (total)
  - 20,916 (A-season)
  - 12,474 (B-season)
  - 100% carry-forward (all unused ITEC from A-season will rollover to B-season)

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Allocation Rule

- $C_{s,y,i} = P_{s,y,i} \cdot F_{s,y,i} \cdot I_s$
  - $C_{s,y,i}$ is the number of credits vessel i receives for season s of year y
  - $P_{s,y,i}$ is the proportional allocation factor for vessel i in season s of year y
  - $F_{s,y,i}$ is the fraction of the sector's pollock TAC received by vessel i in season s of year y
  - I_s is the amount of ITEC the sector receives for season s

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Proportional Allocation Factor

- initialized at 1.0
  - vessels receive ITEC pro-rata to TAC fraction
- represents relative ITEC allocation
  - e.g. 1.1 => 10% more ITEC
- fluctuates based on bycatch performance
  - increases as a result of bycatch reduction
  - decreases when bycatch is high
  - trends back to 1 (past behavior discounted)

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Proportional Allocation Factor

- $P_{s,y,i} = \alpha + \beta \cdot P_{s,y\text{-}1,i} + \gamma \cdot Q_{s,y\text{-}1,i}$
- β = "legacy" weighting (time decay)
- γ = "incentive" weighting (year to year change)
  - Q = function of bycatch performance
- α = fixed constant
  - $\alpha + \beta + \gamma = 1$

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Bycatch Function

- Q is a function of relative bycatch rate
  - $Q > 1$ increase allocation
  - $Q = 1$ reset allocation
  - $Q < 1$ decrease allocation
  - any reasonable monotonic function suffices

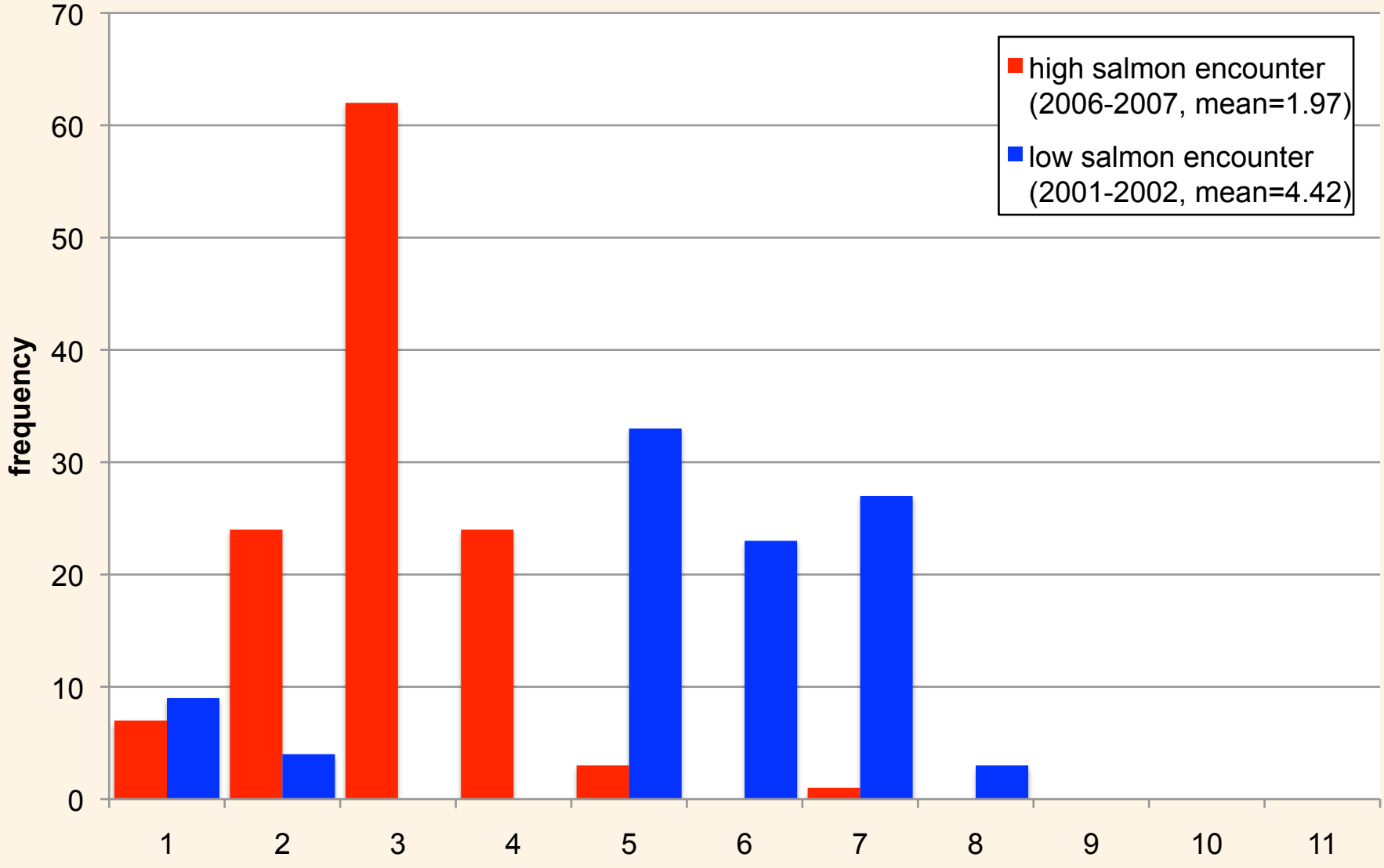
Proportional Allocation Factor

- $P_{s,y,i} = \alpha + \beta \cdot P_{s,y-1,i} + \gamma \cdot Q_{s,y-1,i}$
- asymptotically stable for constant Q
  - bounds for Q create asymptotic bounds for P
  - for example:
    - $\alpha = \beta = \gamma = 1/3$
    - $Q \in [1/3,\ 5/3]$
      - $\Rightarrow P \in [2/3,\ 4/3]$

General Properties

- proportional allocation, P, changes depending on Q
- Q is calculated based on relative bycatch rate
- relative bycatch rate dependent on total bycatch
  - sensitivity increases during years of low bycatch
    - larger incentives to reduce bycatch!

Bonus Credits



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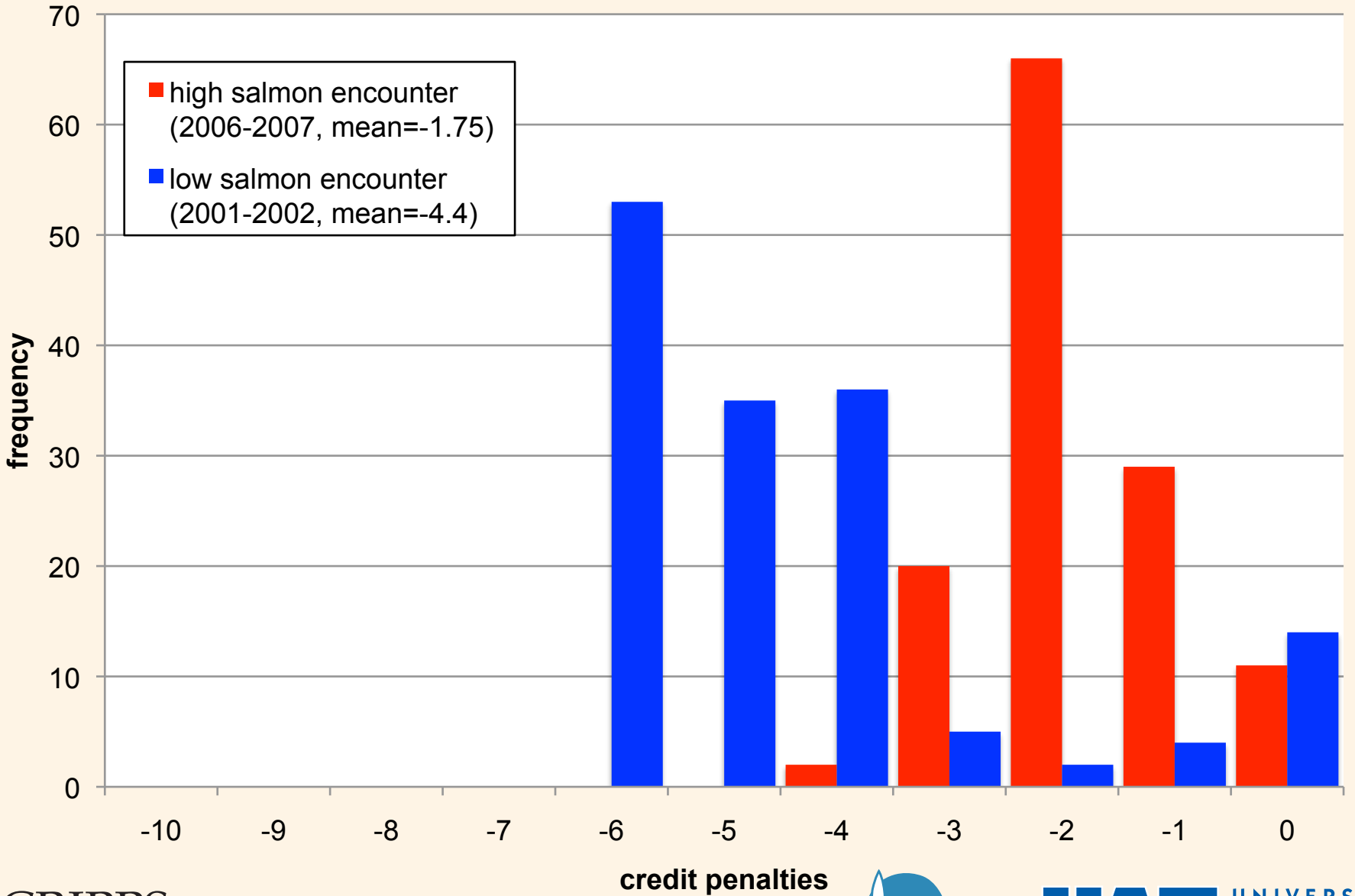
Credit Penalties



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Summary

- vessels are incentivized to reduce bycatch to increase future allocation
  - future increases in allocation act as insurance against high bycatch years and/or stochasticity in bycatch
  - incentives to reduce bycatch exist regardless of level of bycatch or whether hardcap is binding
    - incentives are stronger in low bycatch years (~ low abundance)

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Trading Rules

- buying restrictions
  - a vessel may not buy more than 1/3 of its allocation for that season
- selling restrictions
  - vessels may only sell a fraction of unused credits
  - fraction fluctuates based on bycatch level in current year

Purchase Limit

- poorly performing vessels (consistently high bycatch) cannot completely offset low allocations through ITEC purchases
- increasing allocation (through bycatch avoidance) also increases size of buffer (amount of purchasable ITEC)
  - enhances insurance-like incentives of reallocation

Dynamic Salmon Savings

- early in B-season, estimate how much ITEC is needed
  - excess ITEC determines salmon savings rate (SSR)
  - ITEC transactions "taxes" according to SSR
    - for example, SSR = 20%
    - vessel has 100 excess ITEC
      - can sell 80 ITEC
      - 20 ITEC are "retired"

Salmon Savings Rate

$$\text{SSR} = \min\left(50\%, \frac{\text{ITEC}_{excess}}{\text{ITEC}_{initial}}\right)$$

- maximum SSR = 50%
- transactions that occur before SSR is calculated are "taxed" at 50%
  - refunds occur when SSR is calculated
  - like tax withholding

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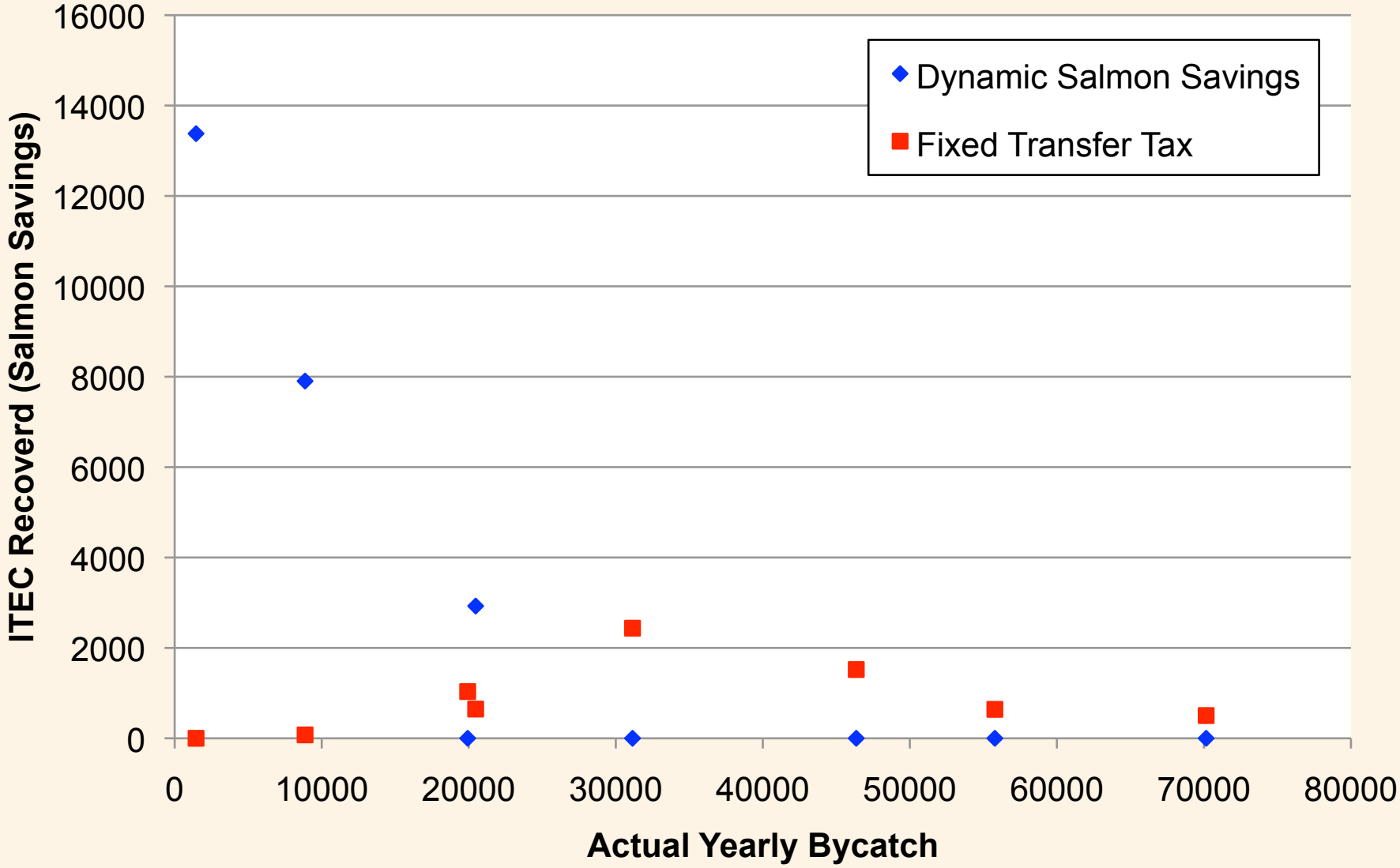
Compared to Fixed Tax

- fixed tax on transfer
  - all transfers in all years taxed at a fixed rate
- transfers needed in years of mid-high bycatch
  - fixed tax = revenue loss
- transfers NOT needed in years of low bycatch
  - fixed tax = irrelevant (no protection of Chinook salmon)

Numerical Comparison



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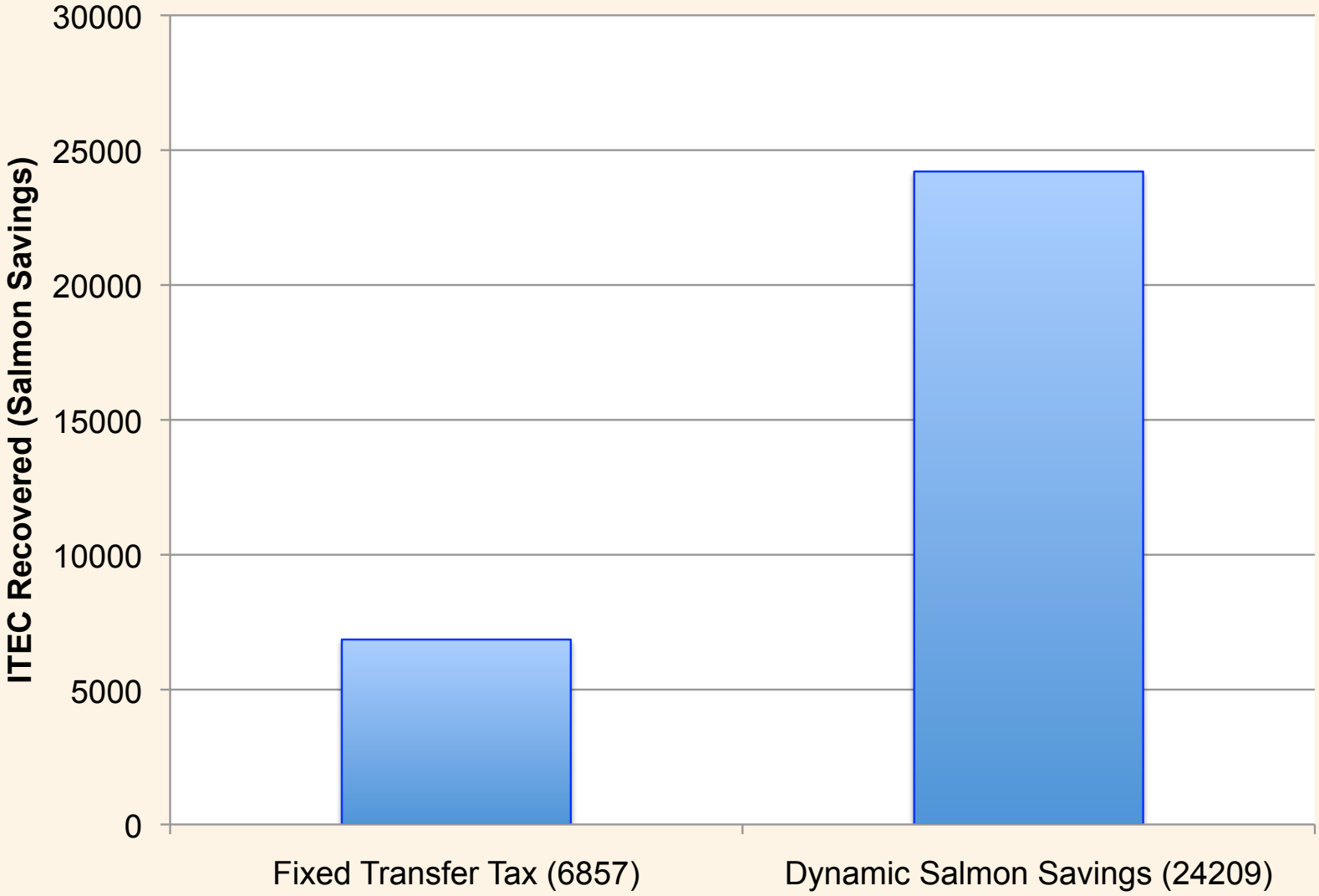

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Discussion

- highly tunable
  - parameters can be adjusted to manage behavior
- scalable
  - ITEC can be used to manage any bycaught species in the same or other fisheries
  - gives fishermen flexibility to optimize revenue by exploiting variability in bycatch performance (per vessel)

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Discussion

- no artificial pricing structure
  - cost of ITEC on market depends on perceived value by vessels in the fishery
  - penalities for ITEC reduction determined by potential revenue loss
- promotes continual improvement (i.e. lowering) of bycatch rates
  - vessels compete for increased allocation
  - reallocation benefits decay with time

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Discussion

- resistant to collusion between vessels
  - e.g. vessels agree to have equal levels of high bycatch (performance is calculated relative to other vessels)
  - collusion is unstable (i.e. not a Nash equilibrium)
  - an individual vessel changes strategy to decrease bycatch -- that vessel benefits to the detriment of all others

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Acknowledgements

- United Catcher Boats
  - John Gruver
  - Brent Paine
- Sea State, Inc.
  - Karl Haflinger
- Alaska Fisheries Science Center (NOAA)
  - Alan Haynie
  - James Ianelli

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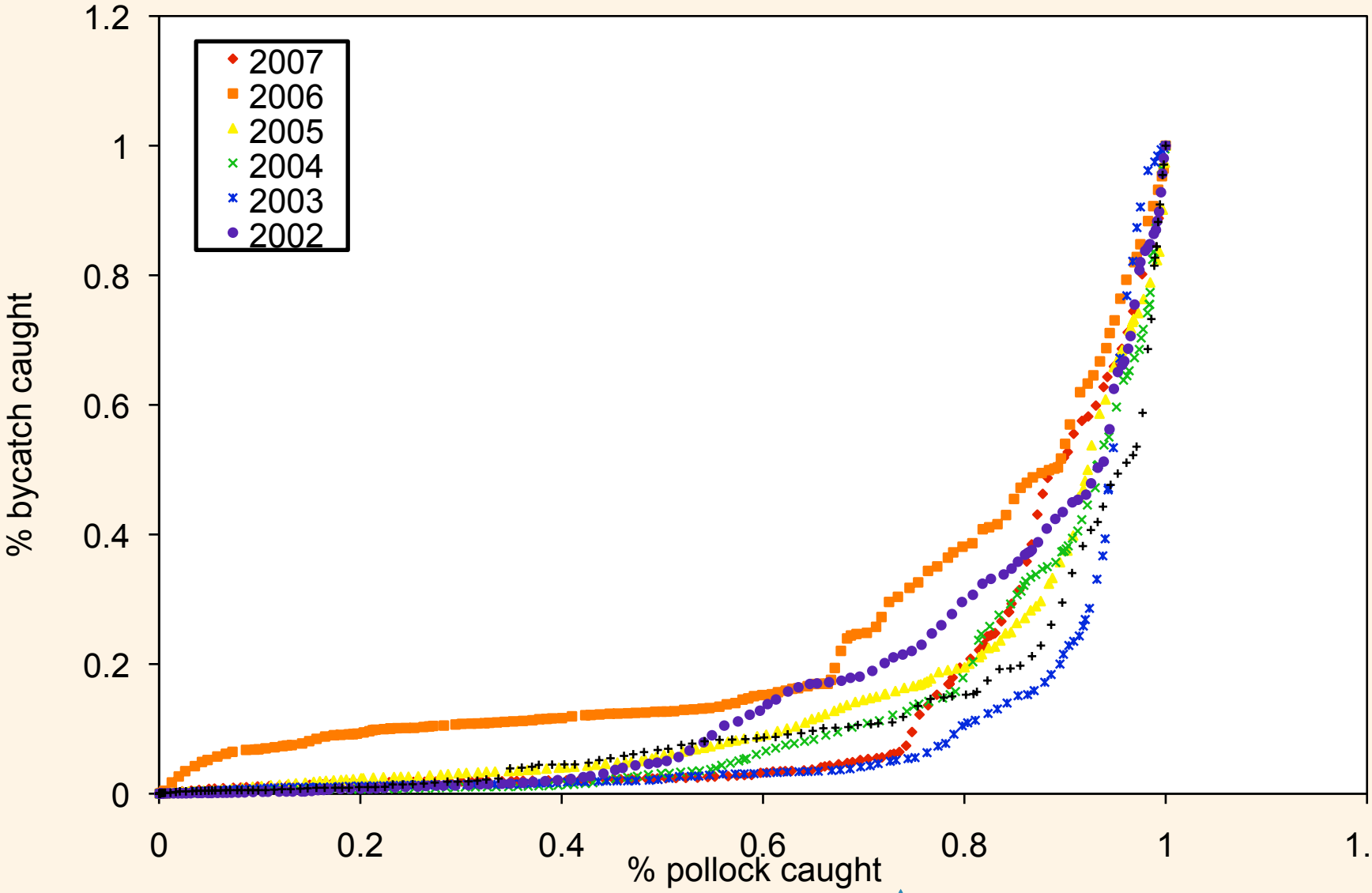
Timing of Bycatch



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SSR Calculation

Year	A	B	C	D	E	F
2000	16 Sep	9859	254	7540	2319	23.5%
2001	11 Sep	9812	277	7770	2042	20.8%
2002	5 Sep	10236	1655	21550	(11314)	0%
2003	2 Sep	10801	256	7560	3241	30%
2004	31 Aug	9716	1890	23900	(14814)	0%
2005	29 Aug	9668	4142	46420	(25298)	0%
2006	10 Sep	9703	3591	40910	(28728)	0%
2007	2 Sep	9826	1465	19650	(4802)	0%

A = date when 2/3 pollock caught
B = remaining ITEC
C = ITEC used (in B-season)
D = estimated ITEC needed
E = estimated excess ITEC
F = SSR

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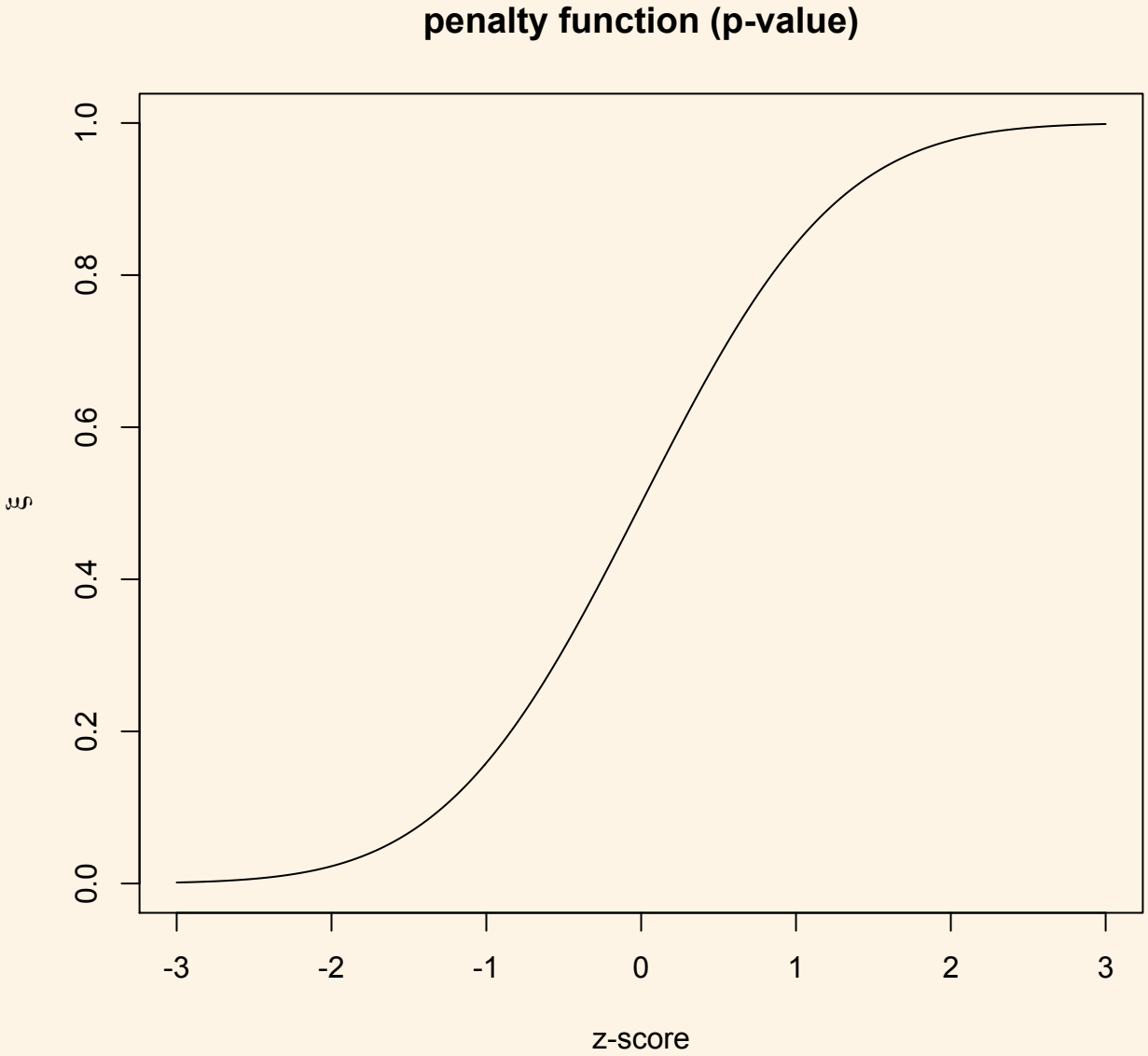
Penalty Functions



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Do Rolling Hotspots Work?

Fishing in January 31 Closure Area

Period		Chinook	Rate	% of Trips	% of Pollock	% of Chinook
Before closure	in	465	0.128	5.4	5.2	15.0
	out	2626	0.040	94.6	94.8	85.0
During closure	in	7	0.078	0.3	0.3	0.8
	out	865	0.029	99.7	99.7	99.2
After closure	in	374	0.181	3.0	3.0	2.8
	out	13072	0.196	97.0	97.0	97.2

Alan Haynie
Alaska Fisheries Science Center (NOAA)

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Ways to Reduce Bycatch

- salmon excluder devices
- change timing of fishing effort
  - Chinook salmon bycatch peaks early in A-season and late in B-season
  - Chinook bycatch rate higher during the day than at night
- better prediction of Chinook salmon spatial distribution
  - requires research into population dynamics

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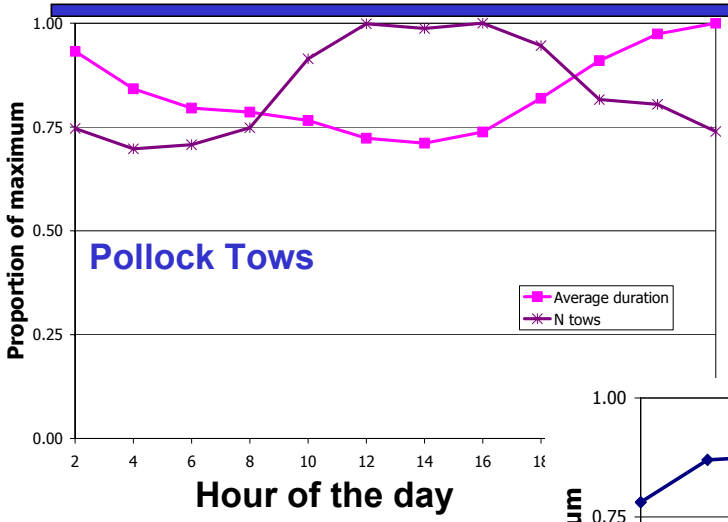
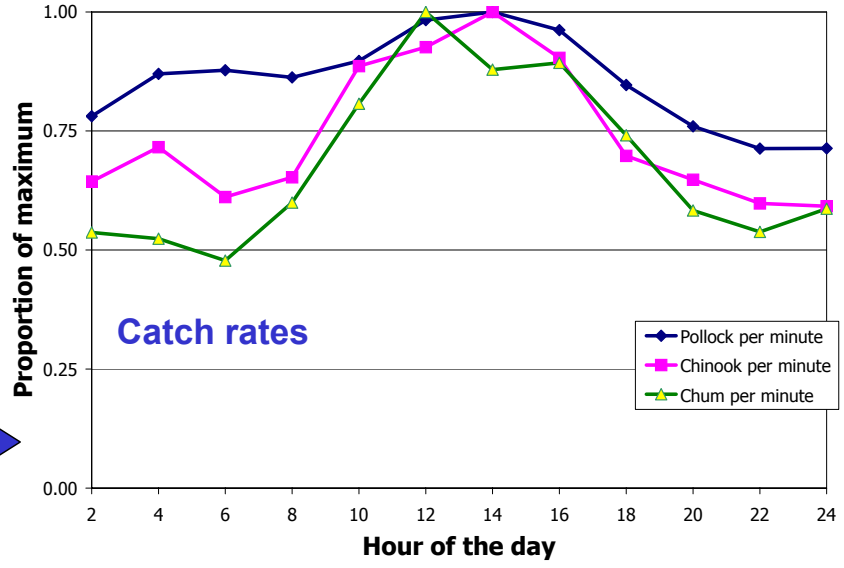
Timing of Chinook Bycatch

Fishing Patterns and bycatch rates



- fewer tows at night
- longer duration



- > catch at mid-day
- > relative rate decrease at night for salmon

James Ianelli
Alaska Fisheries Science Center (NOAA)

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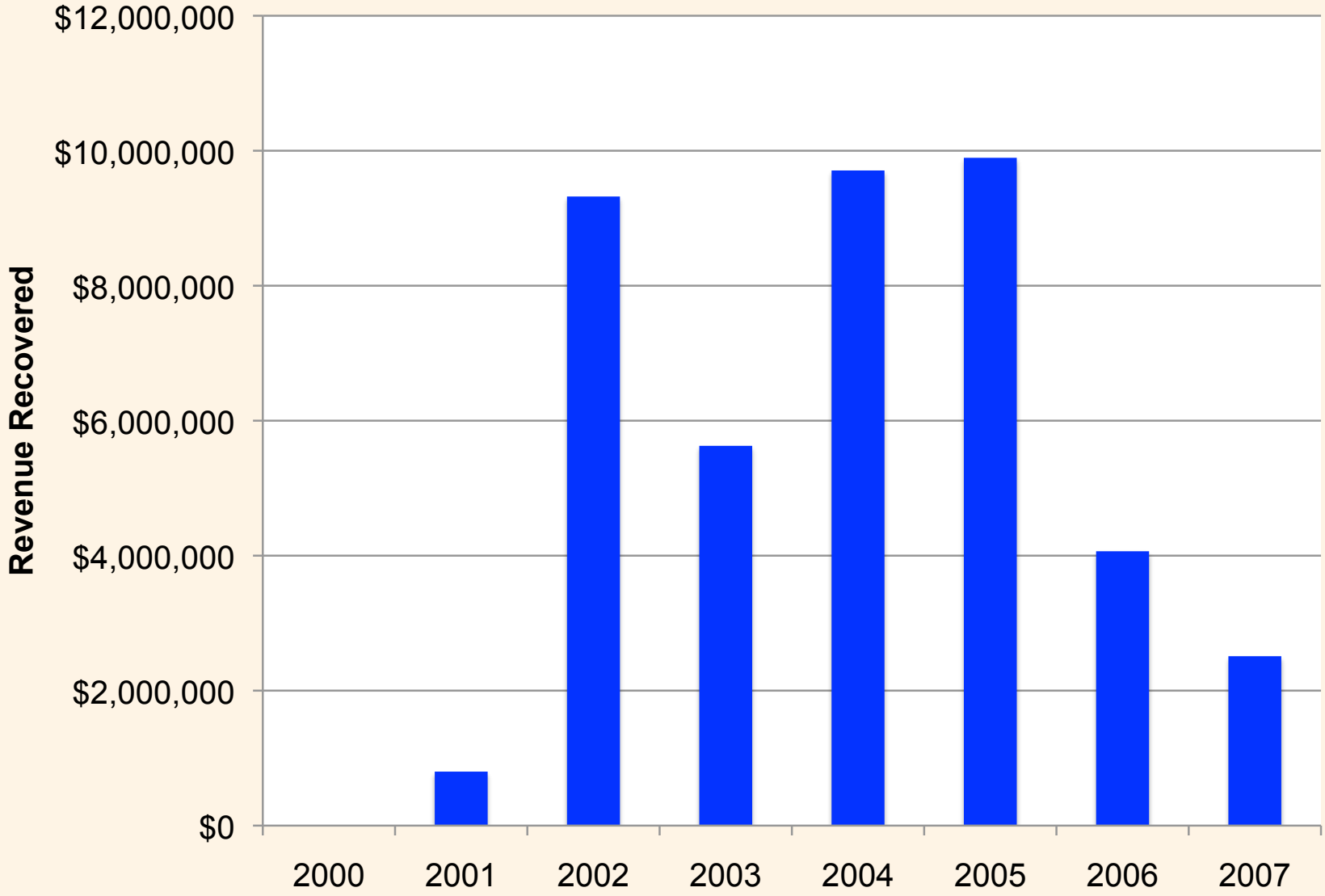
Revenue Recovery (Trading)



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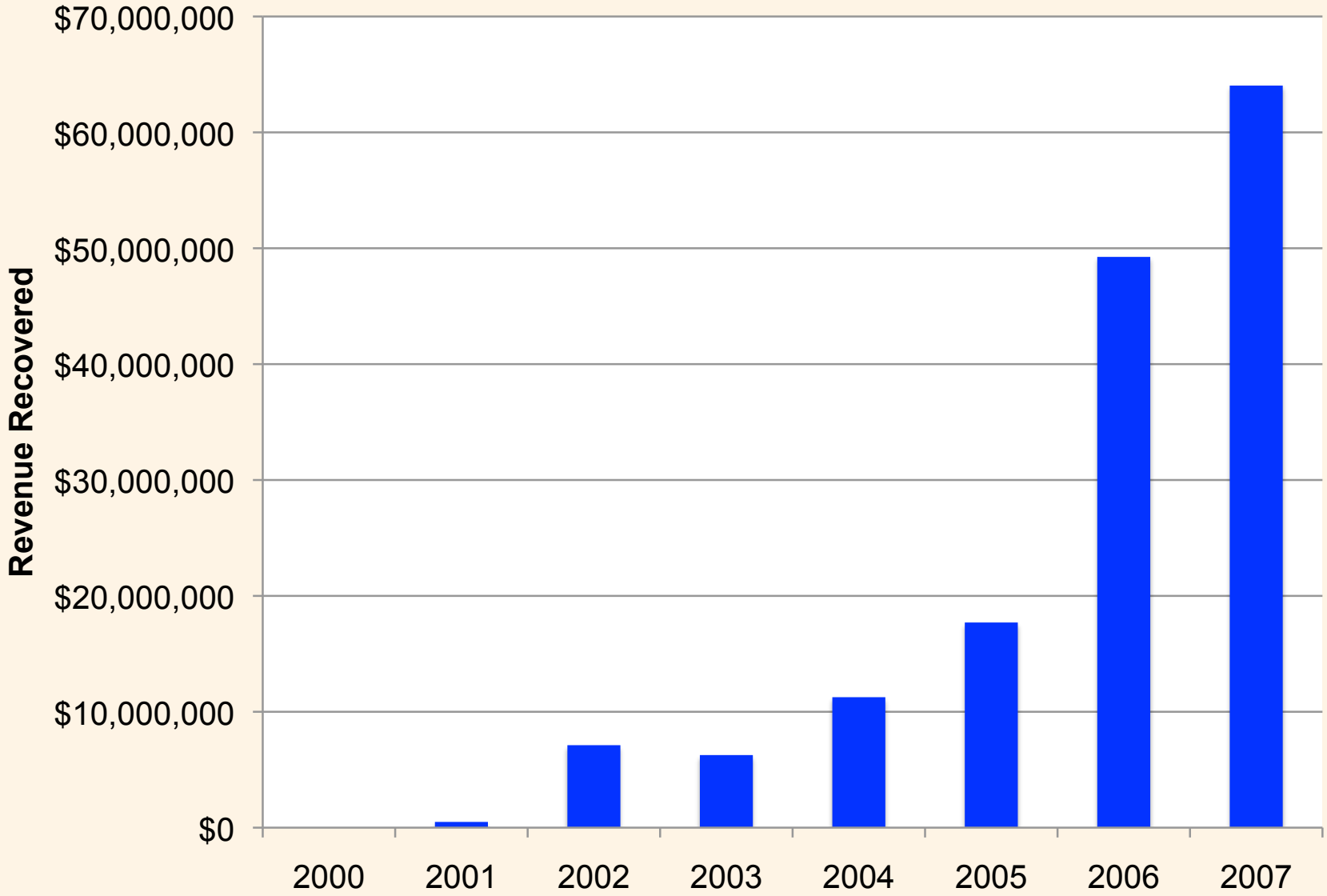
Revenue Recovery (CIM)



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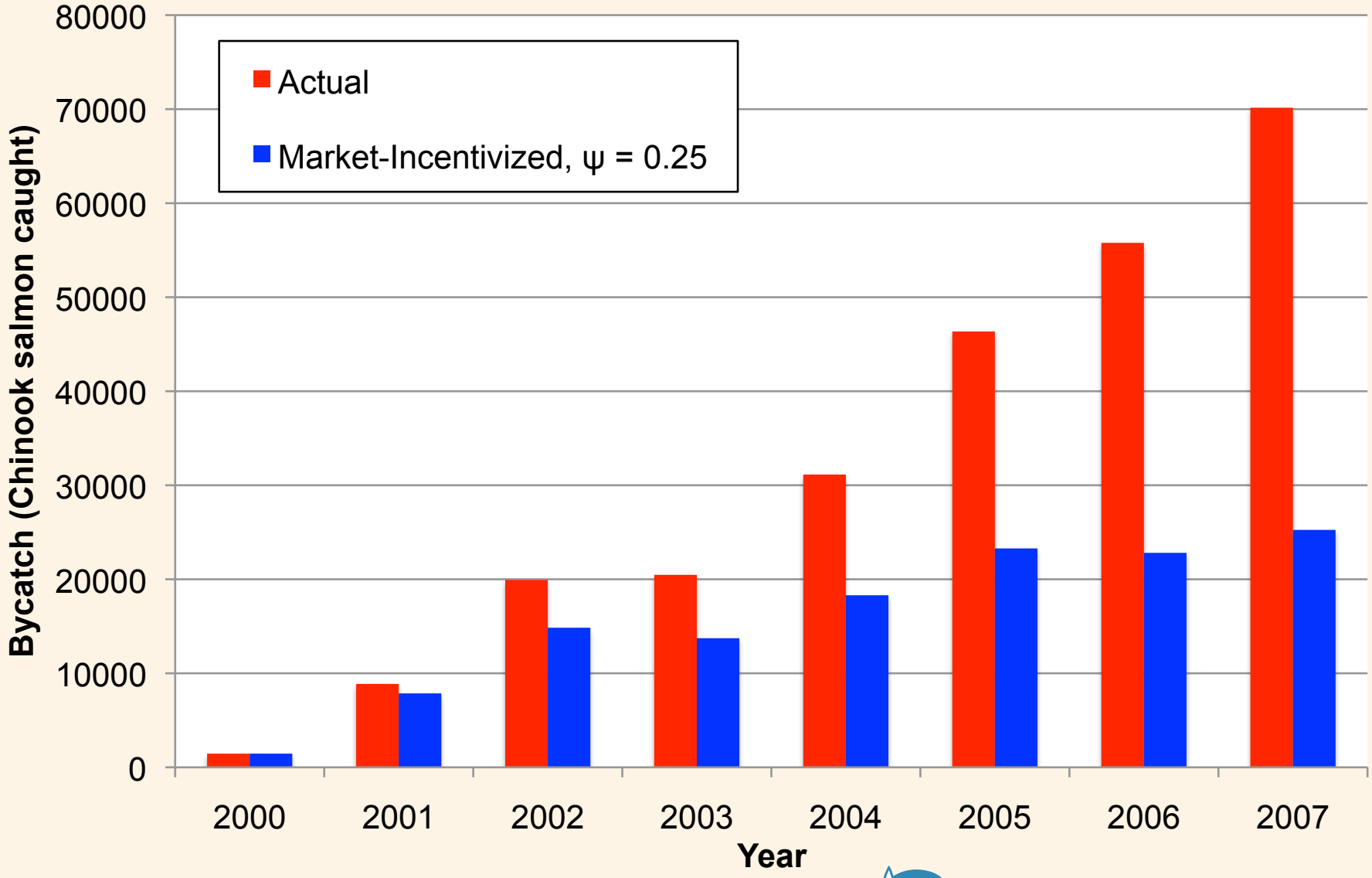
Incentivized Reduction



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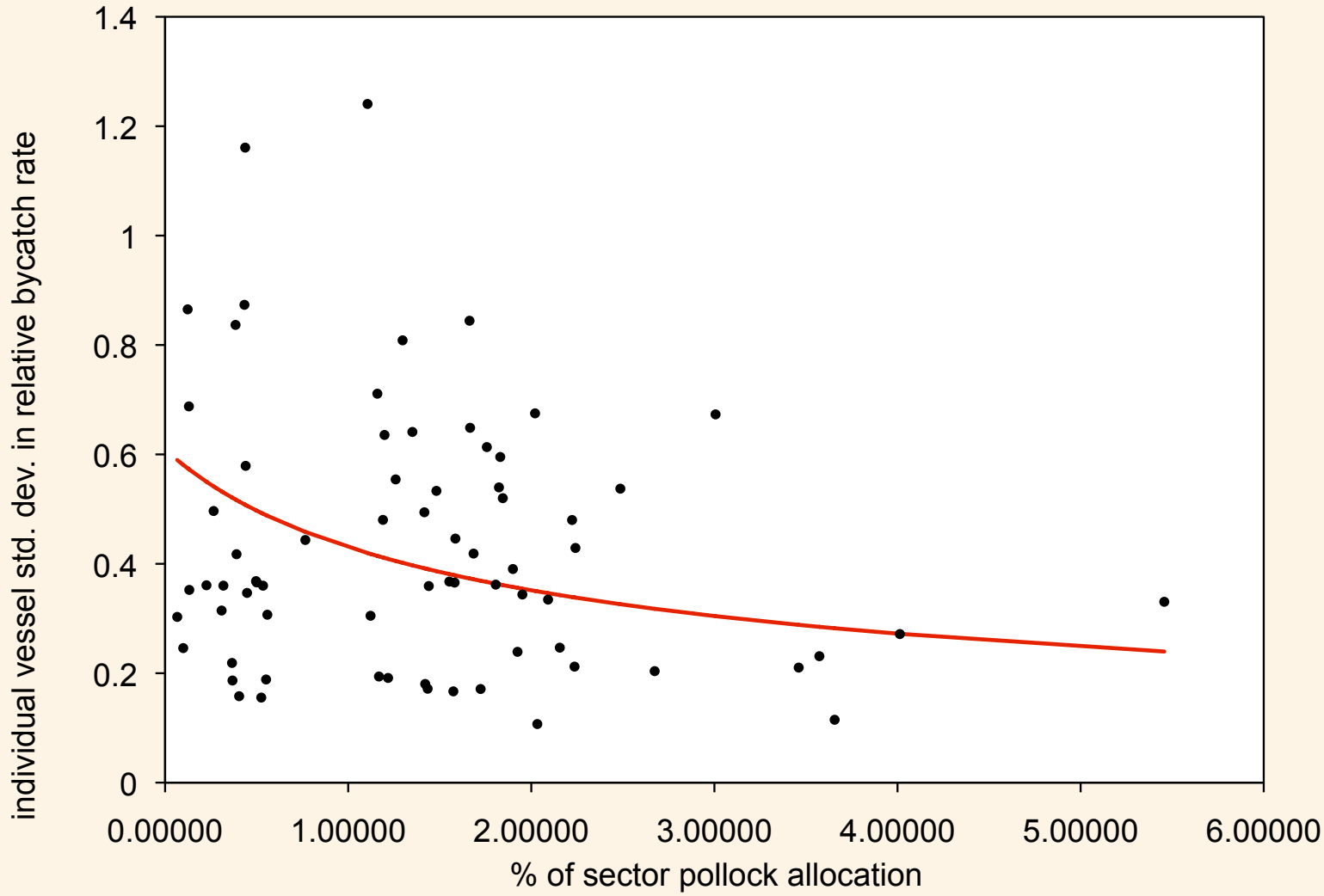
Sampling Variability



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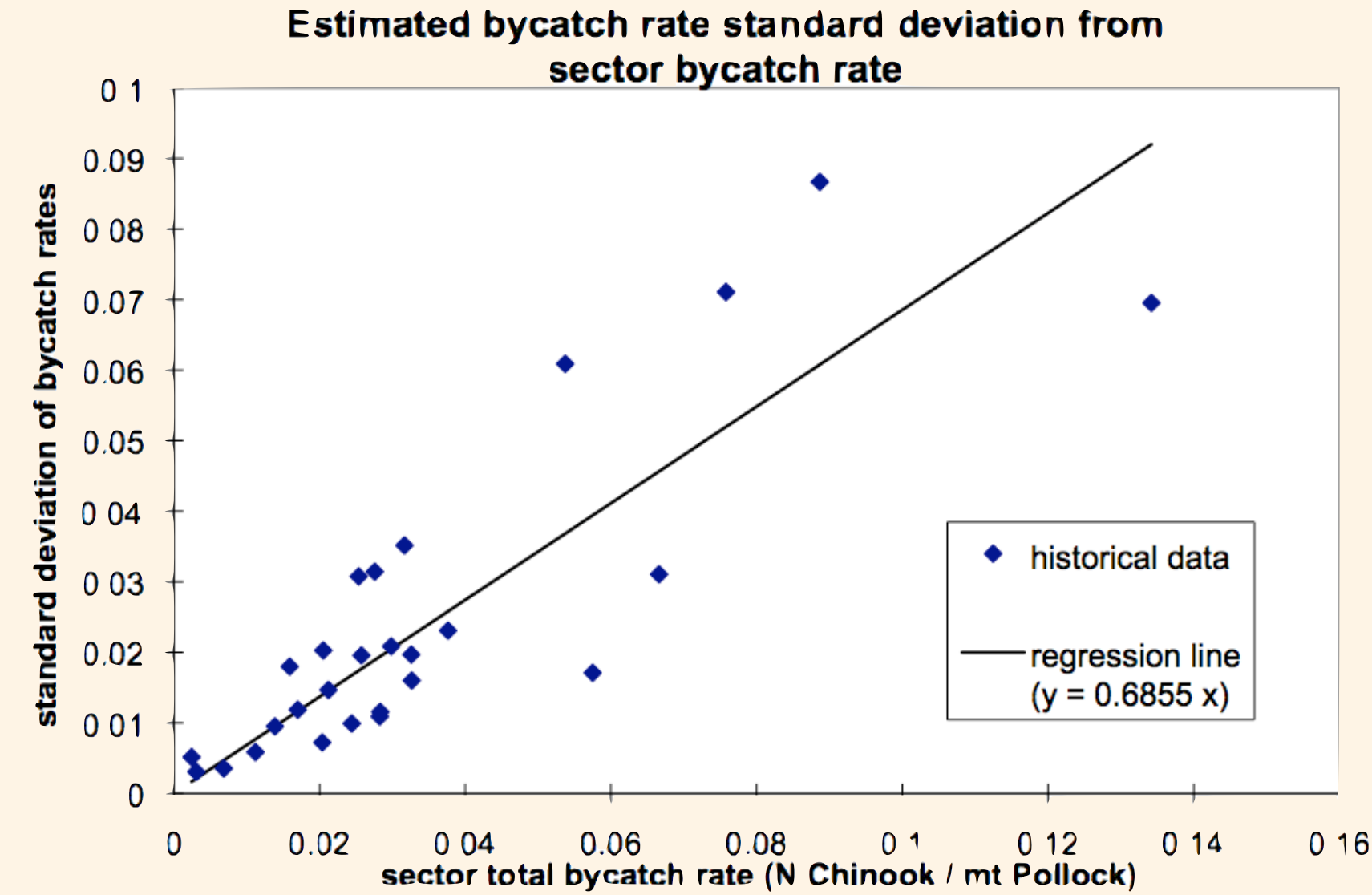
Variance Normalization



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