

Fishing Opportunity under the Sea Turtle Take Caps for Hawaii Swordfish Fishery using a Spatial Bio-economic Model

Shichao Li
JIMAR, University of Hawaii

Minling Pan and Samuel G. Pooley
PIFSC, NOAA Fisheries Service

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Presentation Outline

- ✓ **Research Objective**

- ✓ **Approach and Results**

 - Step I** – build a cost function for net revenue

 - Step II** – refine sea-turtle take *Generalized Additive Models*

 - Step III** – simulation of time-area closures to examine the tradeoff between turtle takes and economic returns

- ✓ **Conclusion**

✓ Research Objective

Construct a bio-economic modeling of multiple time-area closures to evaluate fishing opportunity under the current caps of sea turtle takes for Hawaii-based swordfish fishery

Tradeoff between

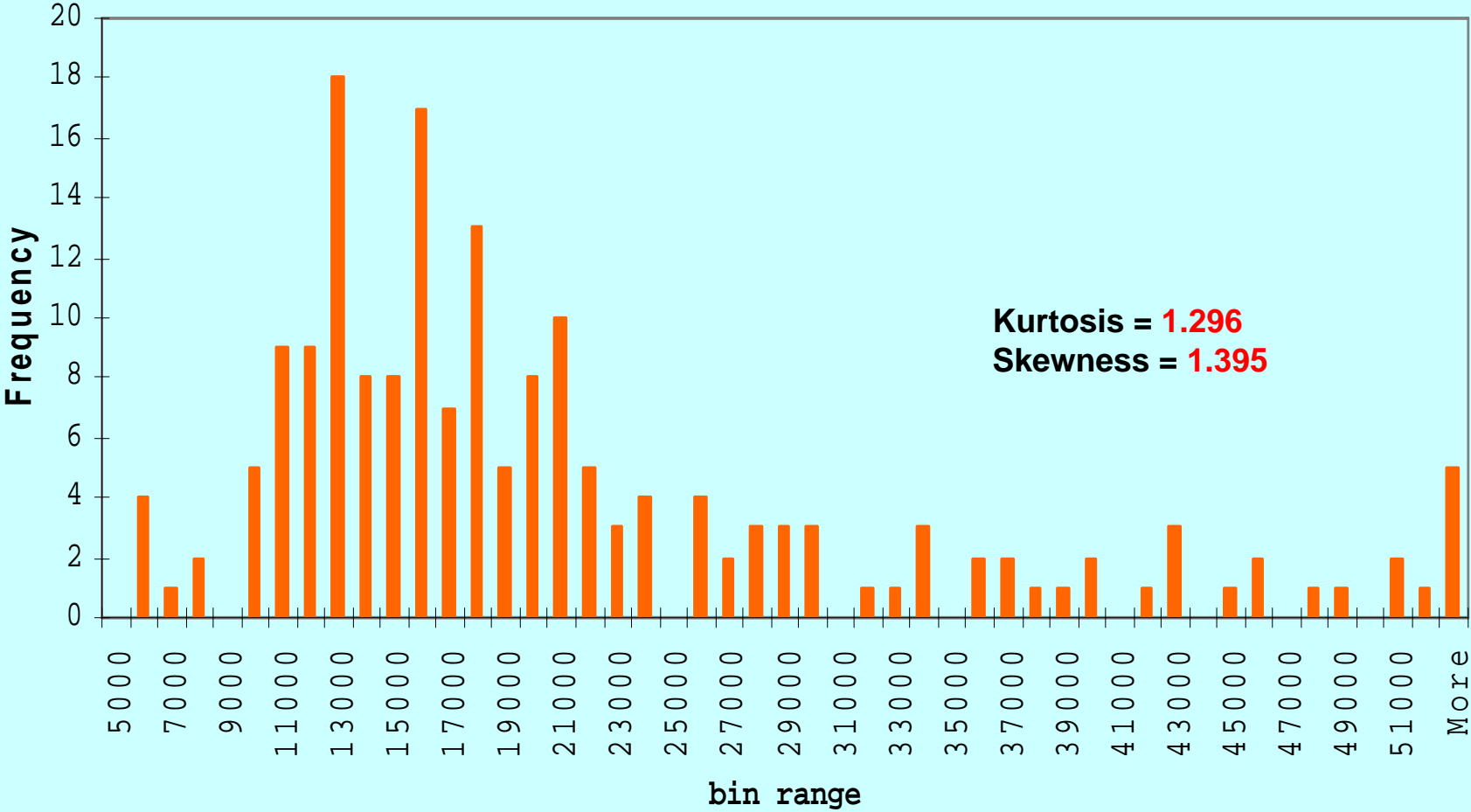
- **Sea turtle bycatch**
- **Economic returns (net revenue)**

✓ Approach and Results

Step I -- Build a cost function into the model

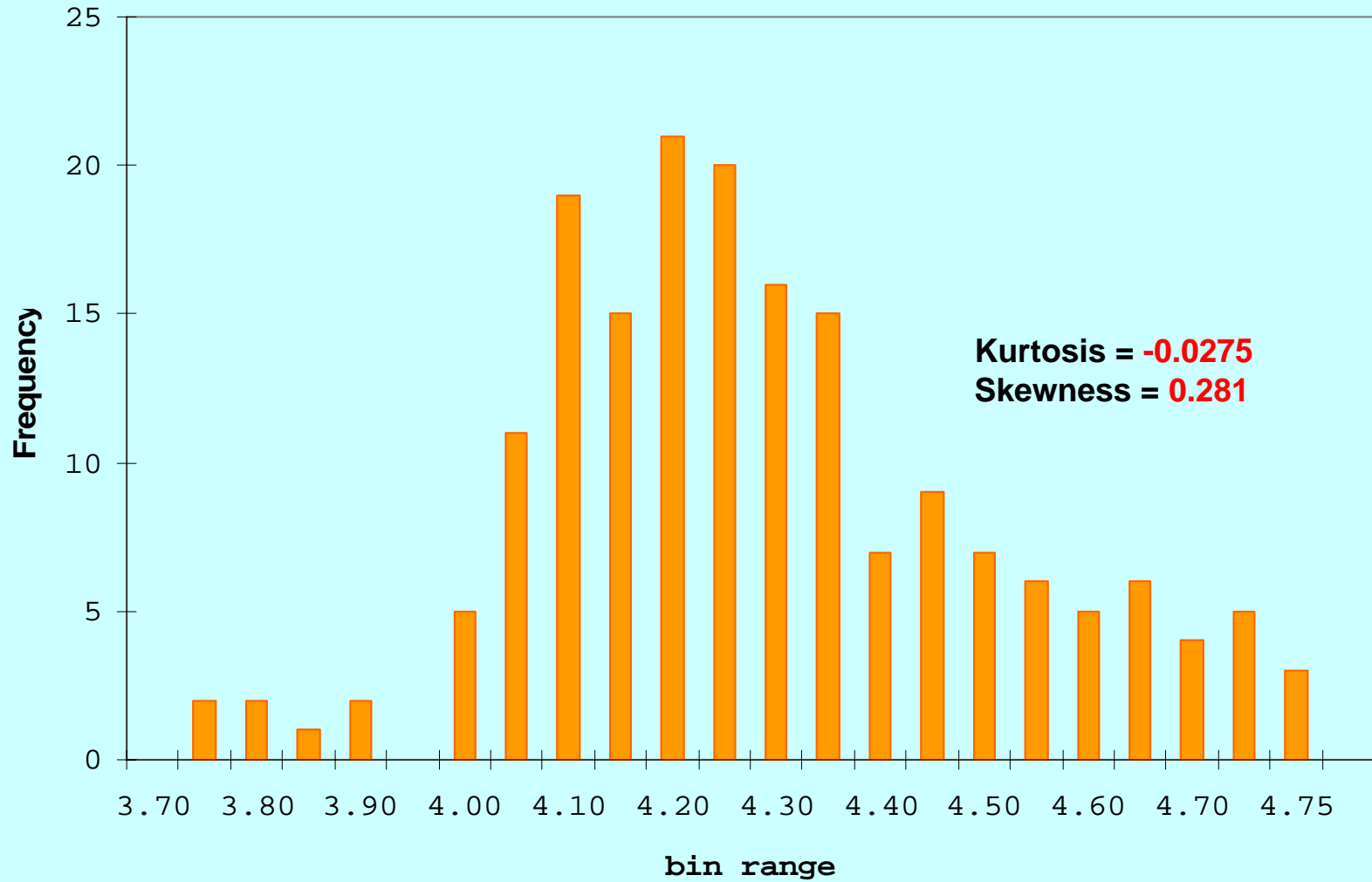
- ❖ Transformed raw data of trip cost into a normal distribution
- ❖ Applied regression statistics to identifying the variables that significantly contribute to trip costs
- ❖ Built a cost function by loops program for each trip cost, so as for each individual sets
- ❖ Calculated net revenue from revenue and cost
Revenue = fish value (\$/piece) * number of catch (kept)

Histogram of Raw Trip Cost Data



data source: 2005 trip cost expenditure

Histogram of Log of Trip Cost



Correlation between variables for trip cost

	#Sets	Avg-distance	Vessel-length	Set-type	Avg-hooks
#Sets	1				
Avg-distance	0.2909	1			
Vessel-length	0.4193	0.3463	1		
Set-type	0.4660	0.3938	0.3361	1	
Avg-hooks	-0.3703	-0.2584	-0.1106	-0.8906	1
Cost	0.7319	0.4922	0.6094	0.7276	-0.5761

Dummy variable: Deep set = 0; Shallow set =1

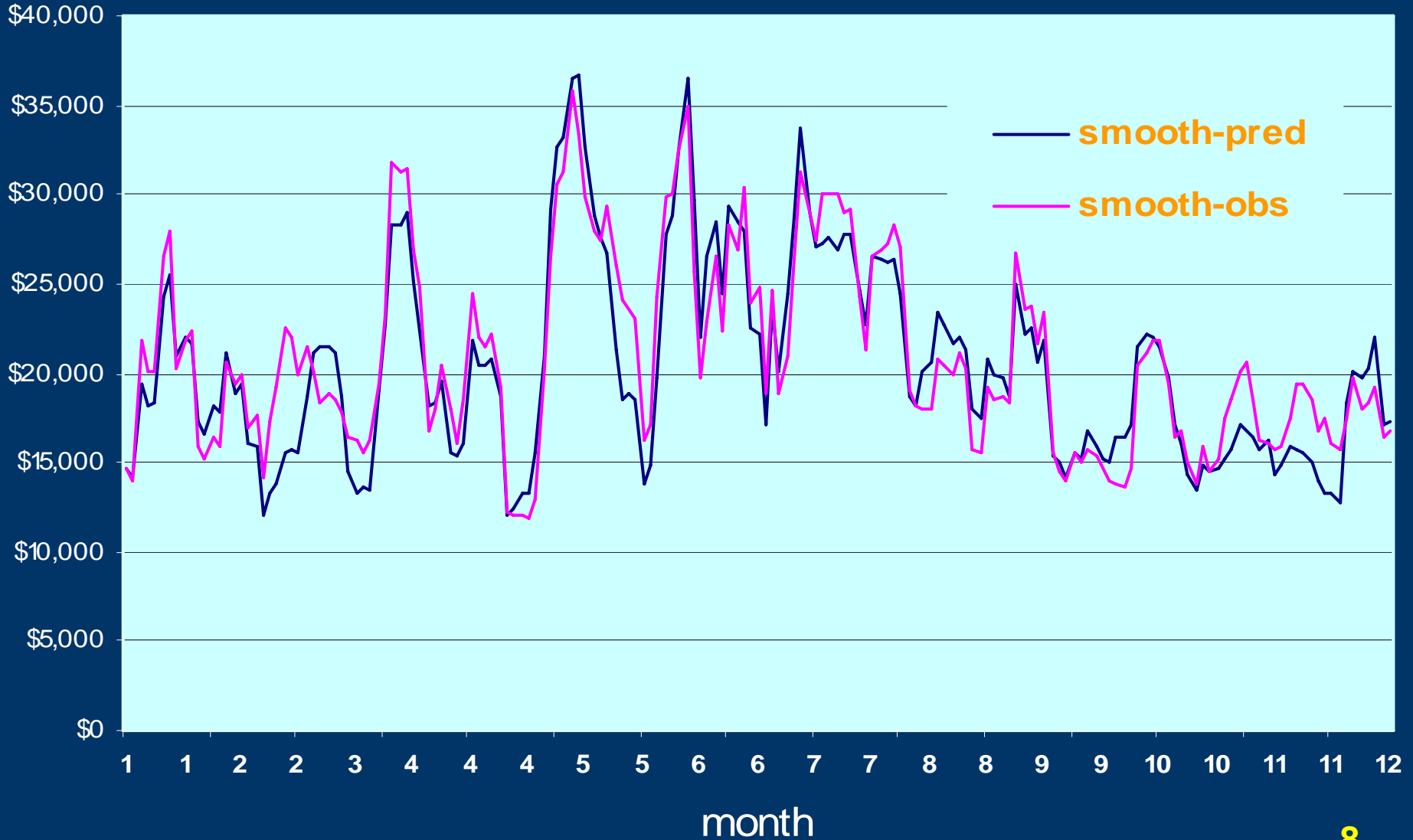
Data sources: 1) 2005 observer economic add-on data
2) 2005 Hawaii longline logbook data

Regression statistics for trip cost

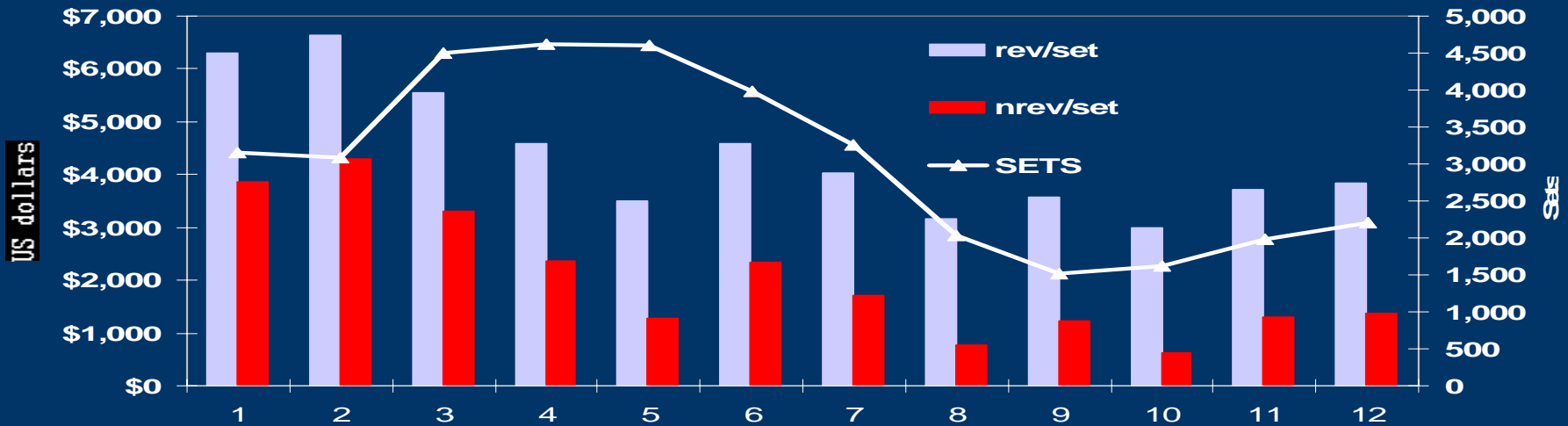
Variables	Multiple R	Adjusted R ²	Sig F	T-test	<i>P-value</i>	Coefficients
Intercept	0.898	0.803	0.000	69.49	0.000	3.50558
#SETS				10.03	0.000	0.02126
AVG-DIS				3.39	0.001	0.00012
VESSEL-LENGTH				6.94	0.000	0.00529
SET-TYPE				10.24	0.000	0.19984

Number of observations = 181

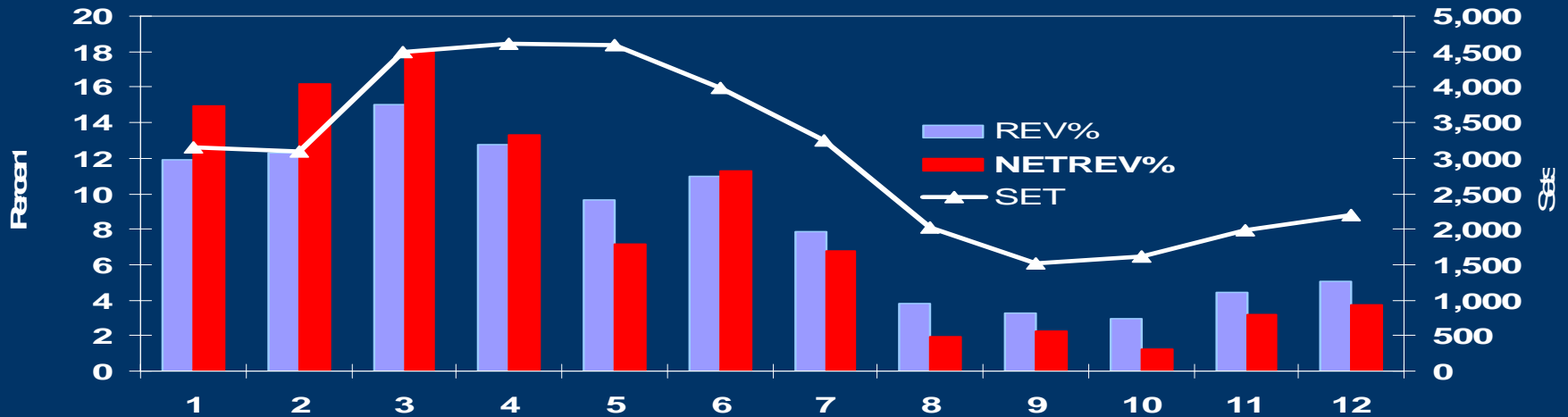
Predicted and observed trip cost (five- smooth)



Revenue and Net Revenue Per Shallow Set by Month (1994-2005)

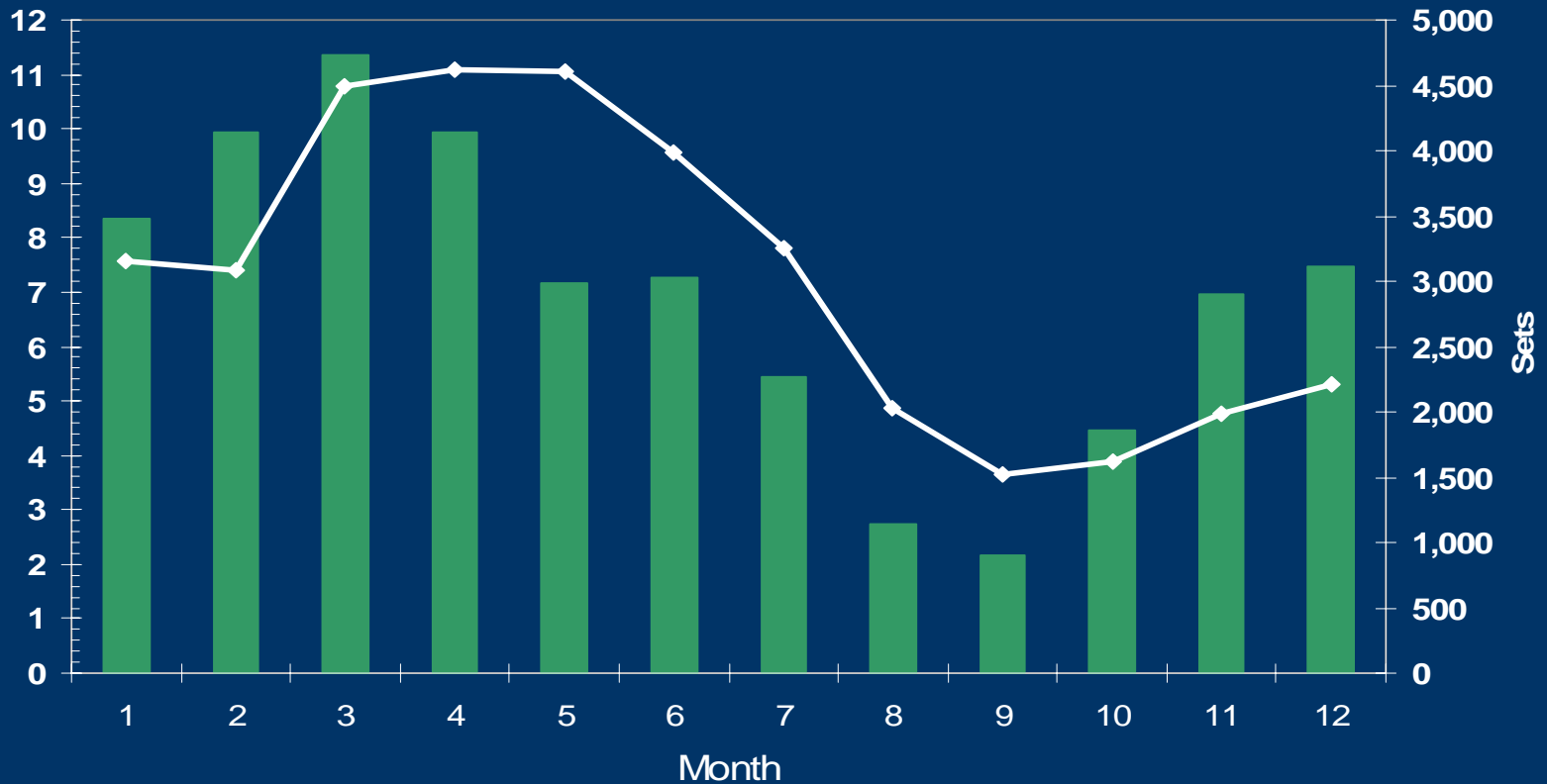


Economic Returns and Fishing Efforts from Hawaii Shallow Set Trips (1994-2005)



Data sources: 1) 2005 dealer data; 2) 2005 economic add-on data; 3) Hawaii Longline Logbook

Swordfish Catch Per Shallow Set (1994-2005)



Data sources: 1994-2005 Hawaii Longline Logbook

Economic Returns

- From **January** to **April**, the percentage of net revenue is higher than the percentage of revenue
- CPUE of swordfish during January and April are higher
- Fishing costs are lower because of fishing areas during January and April are not far away from the departure ports

Step II – Refine the turtle-take GAMs

- ❖ Variables -- year, month, latitude, longitude, set-type, hooks per float, moon phase, sea surface temperature
 - use **set type** instead of trip type for historical data
 - use **month** as numeric variable to adopt daily variation

GAM for sea turtle prediction (rearward stepwise):

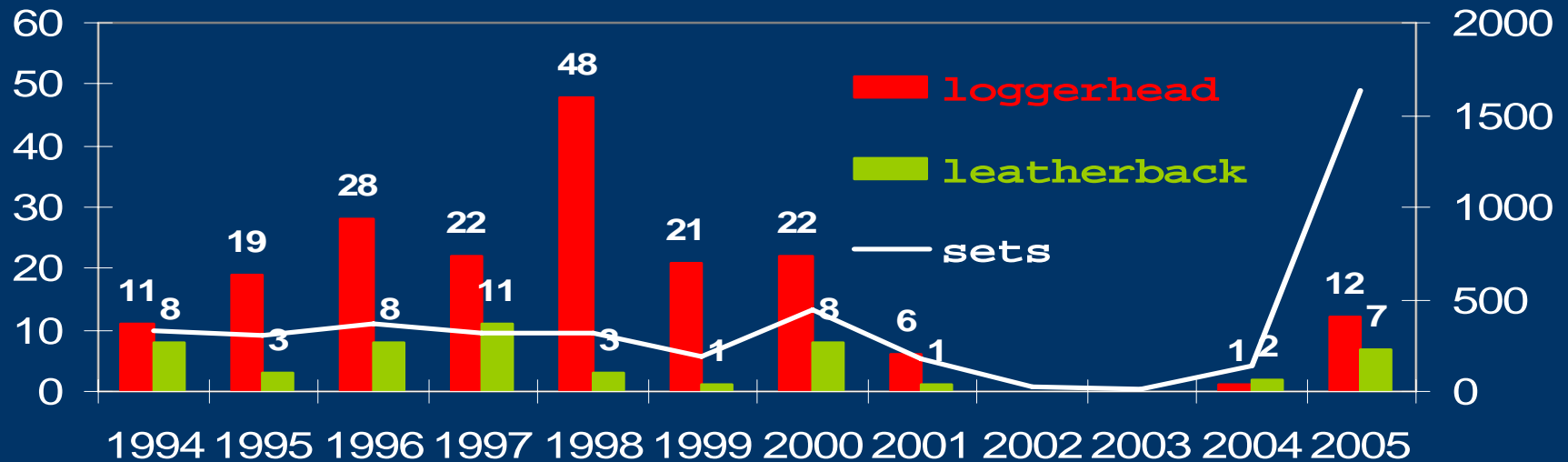
Loggerhead ~ year + s(month, 4) + s(hooks, 2) + s(temperature, 2) + moon phase + s(latitude, 2) + s(longitude, 2)

Leatherback ~ year + s(month, 4) + s(hooks, 2) + s(temperature, 2) + s(moon phase, 2) + s(latitude, 2)

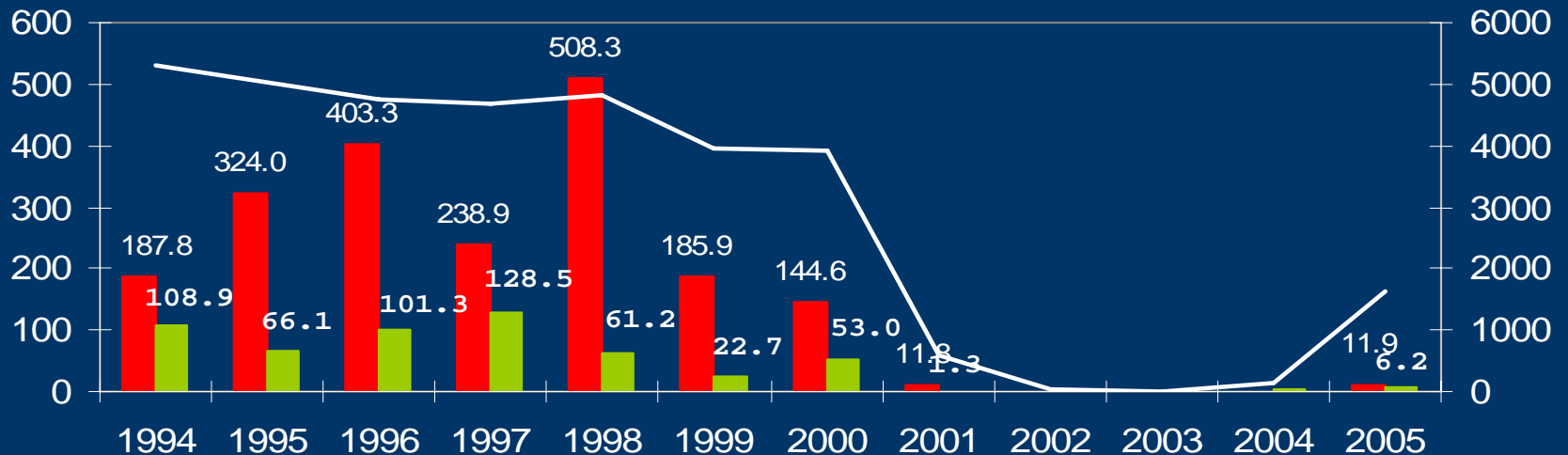
Sea Turtle Takes

- **Turtle takes by year**
- **Turtle takes by latitude and longitude**
- **Monthly turtle take rates per set**

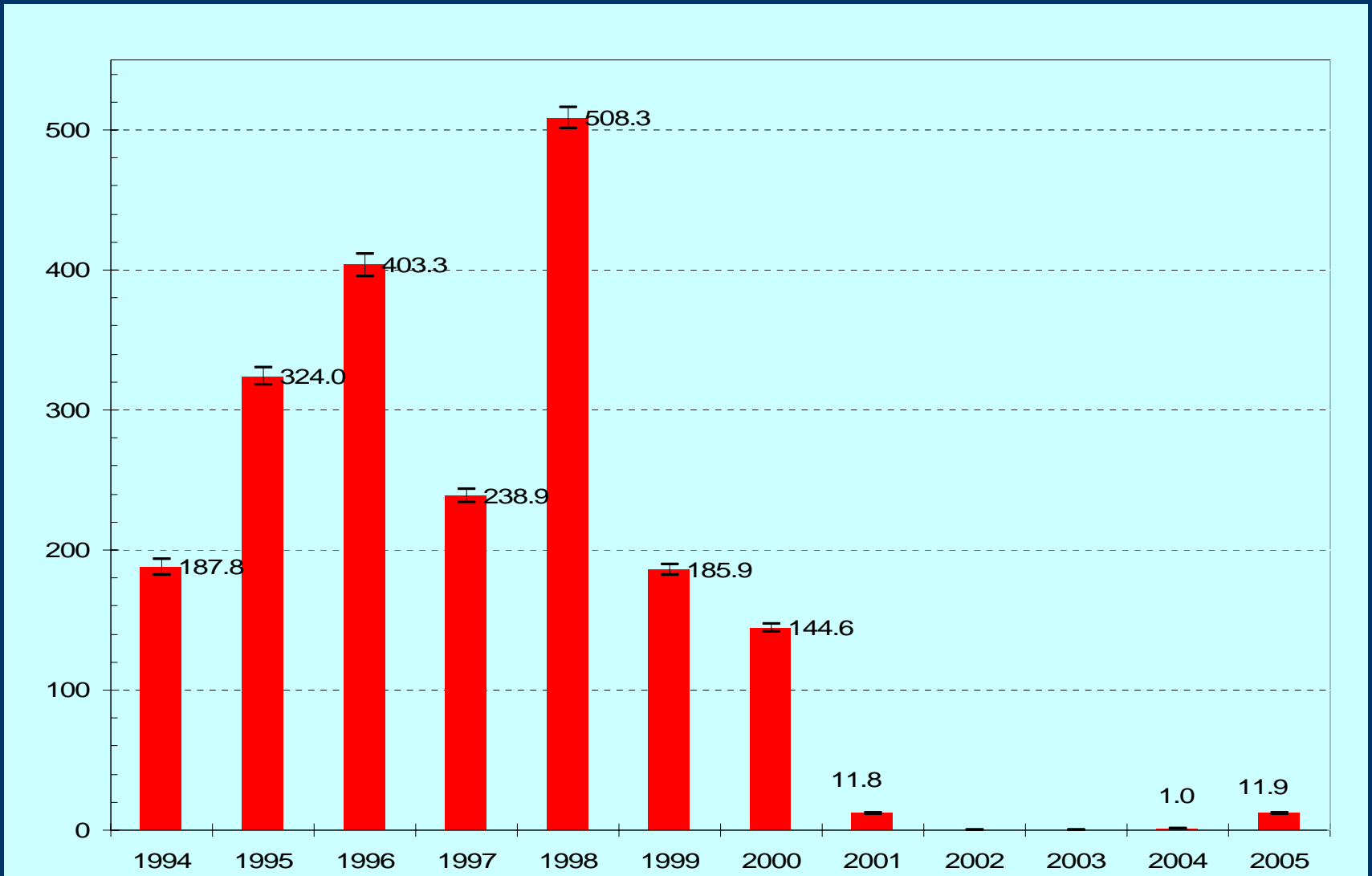
Sea Turtle Takes Observed from Shallow Sets



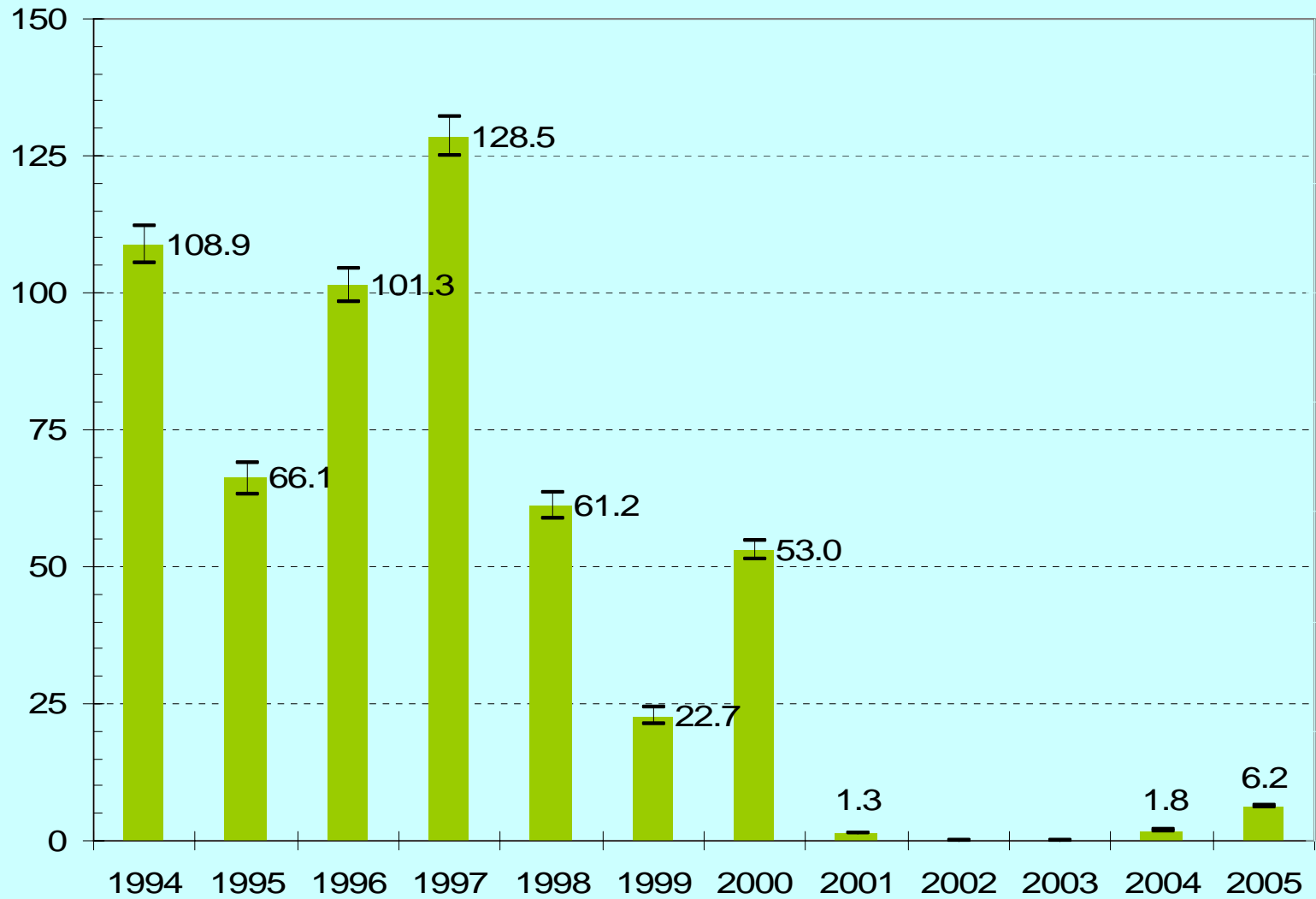
Sea Takes from Shallow Sets Predicted by GAM



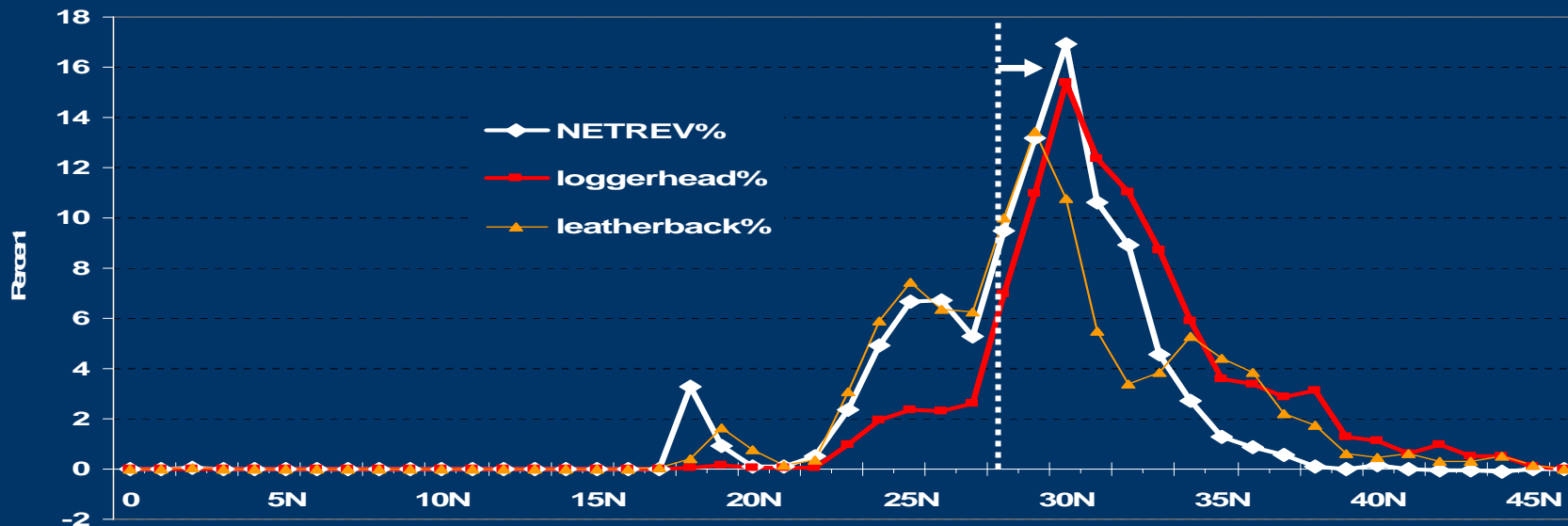
95% Confidence Interval (N=500, 24,485 observer sets) of Loggerhead Takes from Shallow Sets



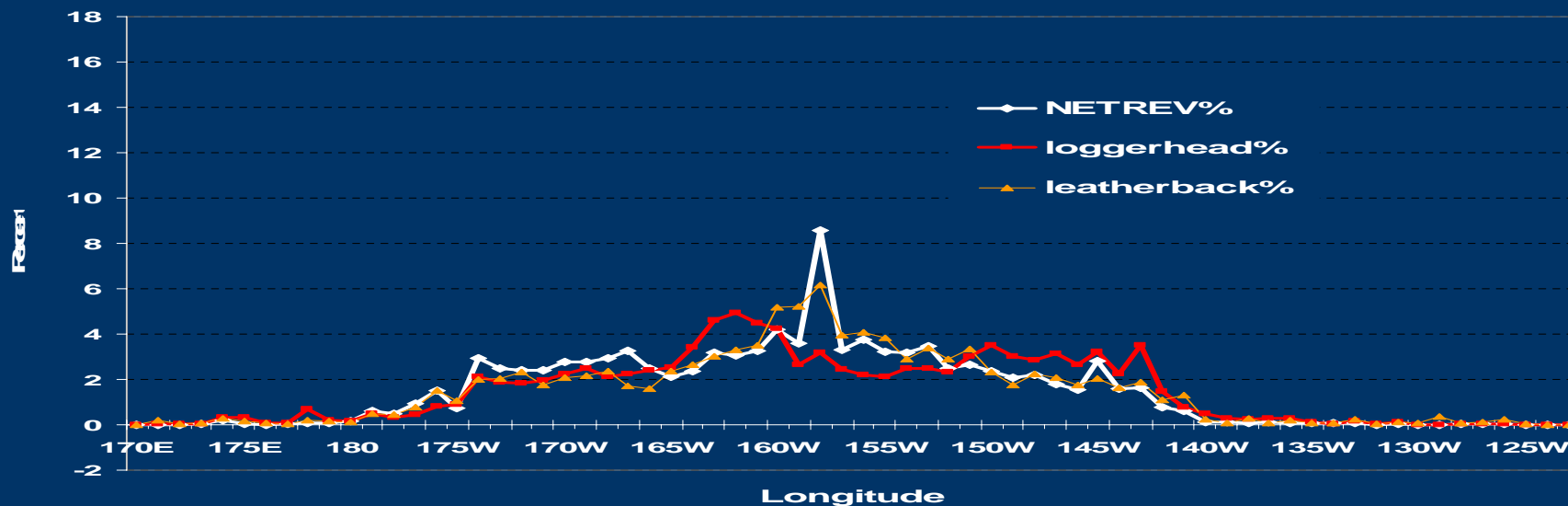
95% CI (N=500) of Leatherback Takes from Shallow Sets



Netrevenue and Turtle Takes in Hawaii Longline Shallow Sets by Latitude (1994-2005)



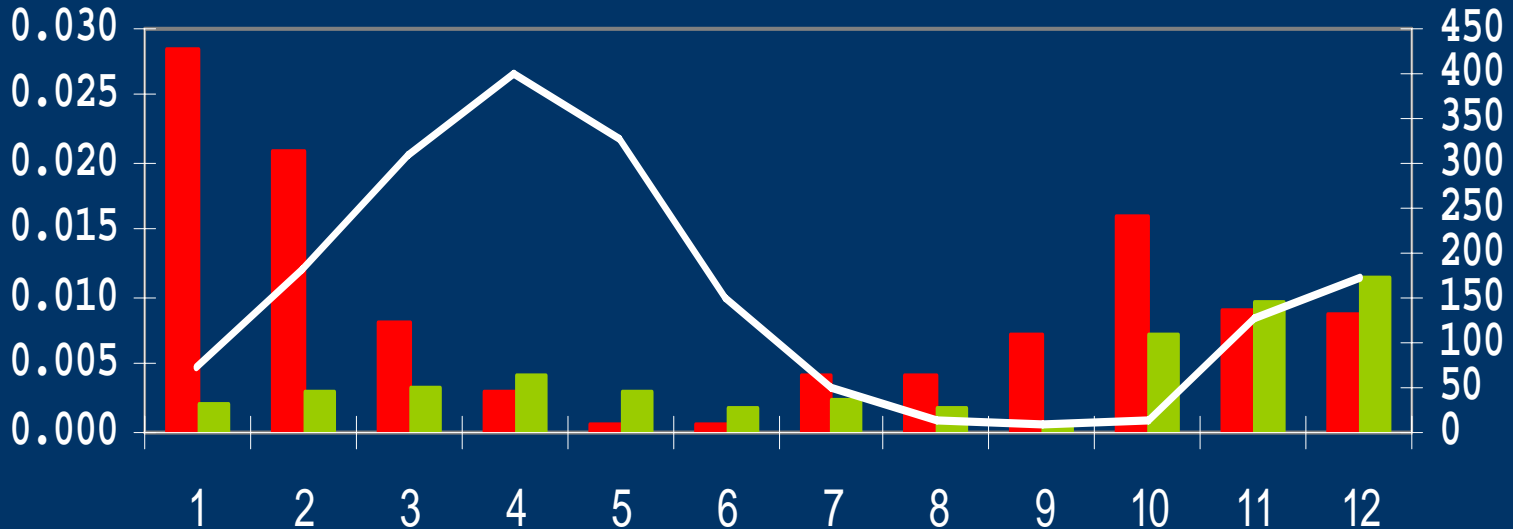
Netrevenue and Turtle Takes in Hawaii Longline Shallow Sets by Longitude (1994-2005)



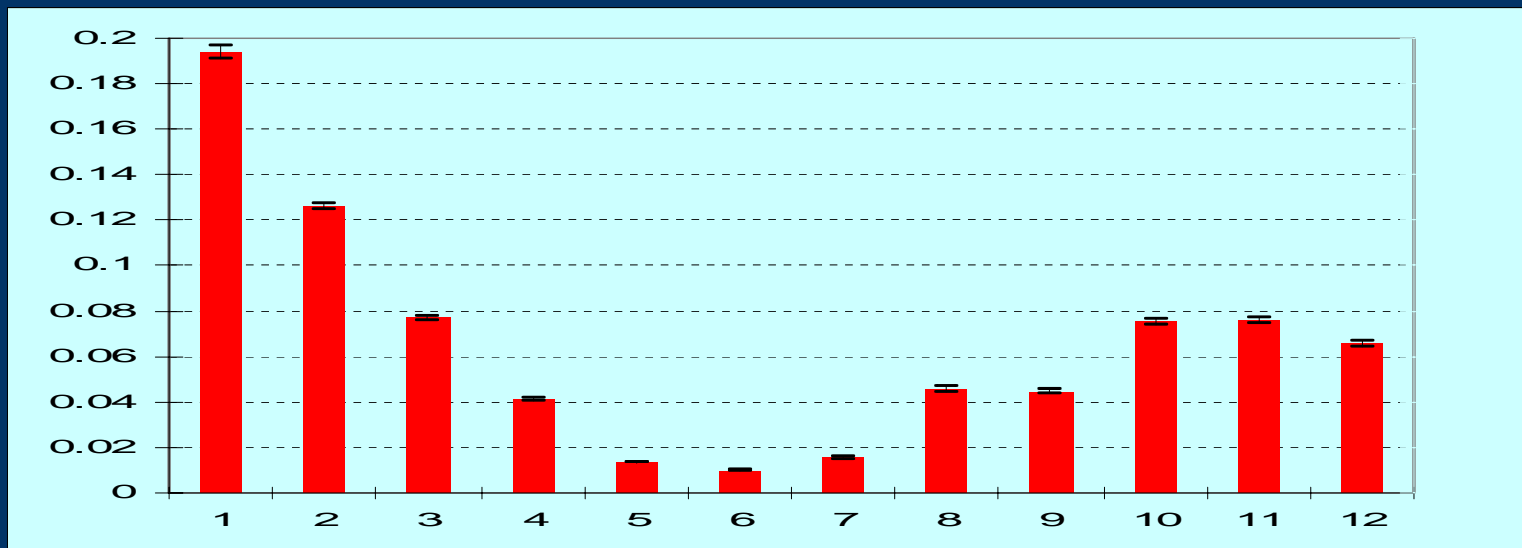
Sea Turtle Monthly Take Rates by Shallow Sets (1994-2001)



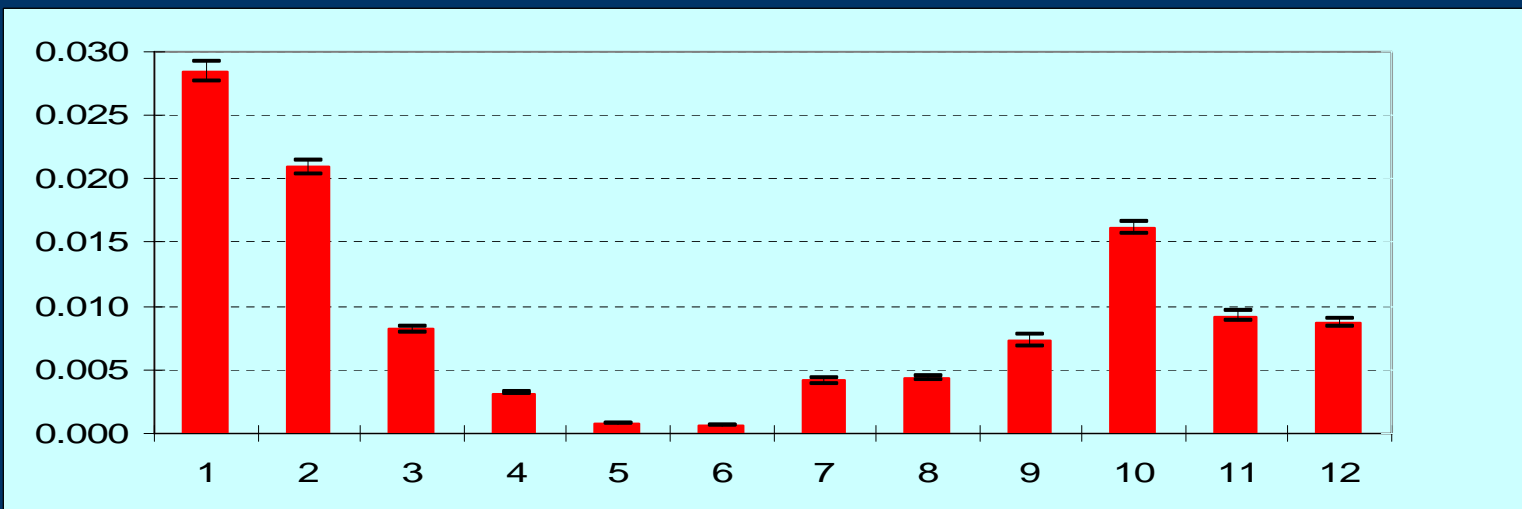
Sea Turtle Monthly Take Rates by Shallow Sets (2002-2005)



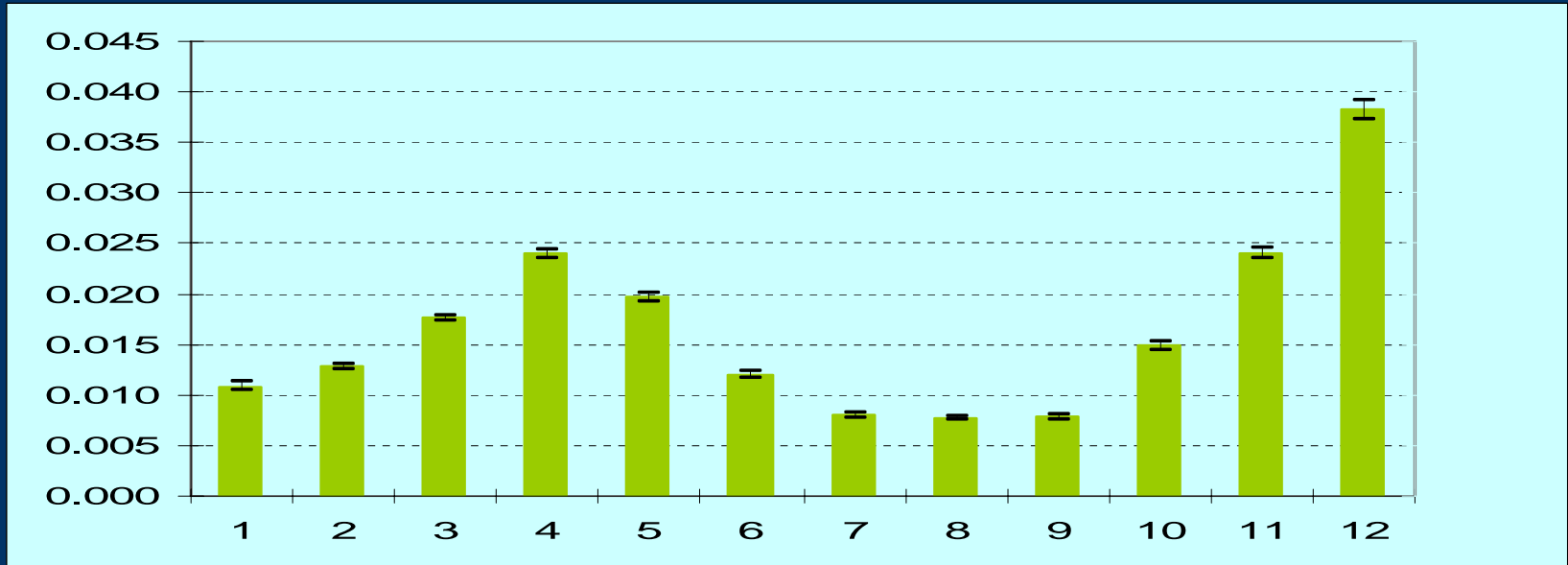
95% CI (N= 500) of Loggerhead Monthly Take Rate by Shallow Sets (1994-2001)



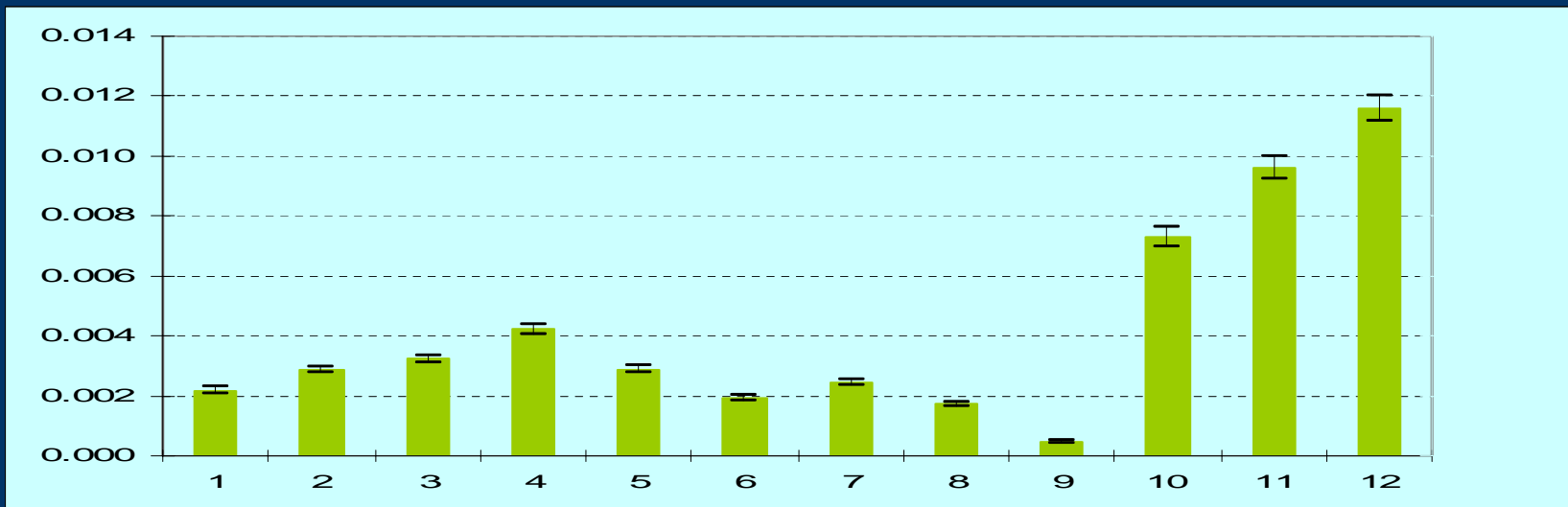
95% CI (N=500) of Loggerhead Monthly Take Rate by Shallow Sets (2002-2005)



95% CI (N= 500) of Leatherback Monthly Take Rate by Shallow Sets (1994-2001)



95% CI (N=500) of Leatherback Monthly Take Rate by Shallow Sets (2002-2005)



Step III – Simulation Design with flexible and multiple time- area closures (based on K-P model)

- ❖ **Allow to test a closure option with a number of areas (by one degree of latitude and/or longitude) and seasons (by 1 to 12 months) with multiple options (see Fig 1 and Fig 2)**
- ❖ **Incorporate the limit of 2120 shallow sets, and the caps of sea turtle takes into the model**
 - a) **Spatial-seasonal patterns for 2120 shallow fishing efforts**
 - b) **Spatial-seasonal turtle take rates from 2002-2005 shallow fishing efforts**
 - c) **Spatial-seasonal net revenue per shallow set from historical fishing efforts**

Fig.1. Example of **assumed** multiple time-area closures

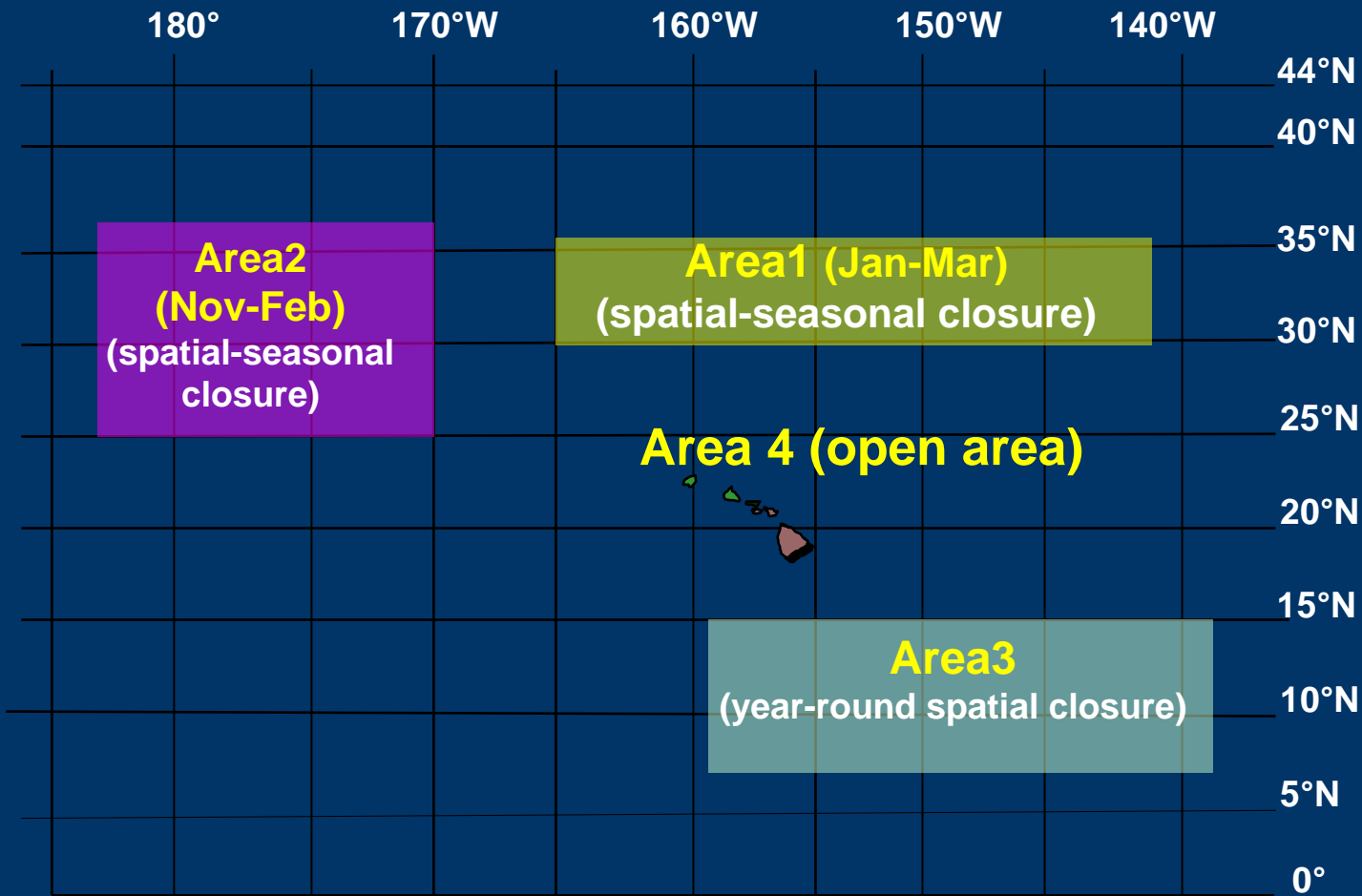


Fig.2. Example of **assumed** seasonal closure

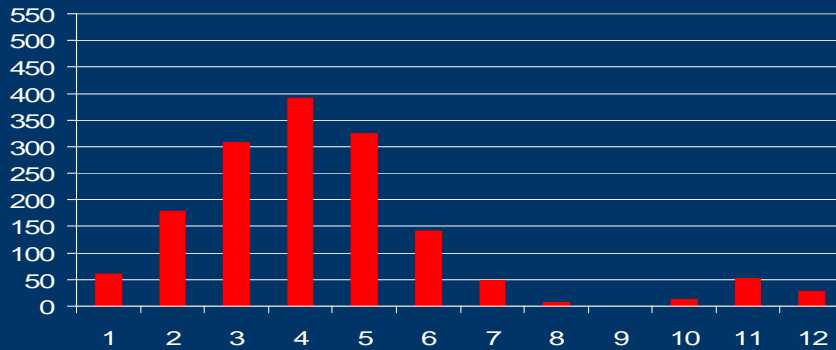


Special case of the model

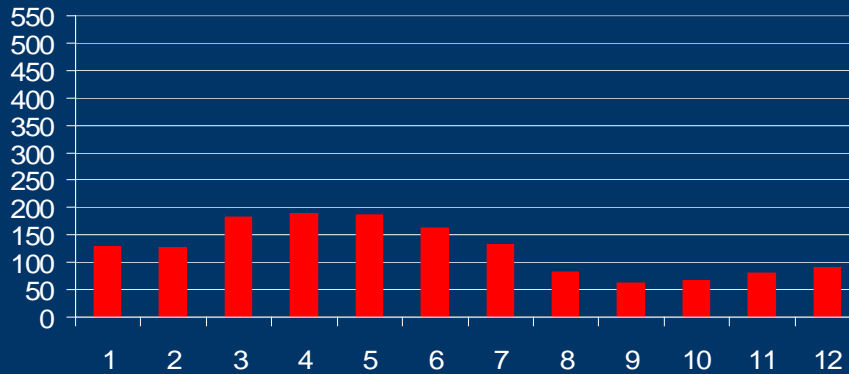
❖ Seasonal closure

- Limit of fishing efforts (2120 shallow sets)
- Assumed that monthly turtle takes and economic returns per set were **homogenous** over degrees of latitude and longitude
- Model results
 - which month reaches to the cap
 - changes in fishing efforts and economic returns

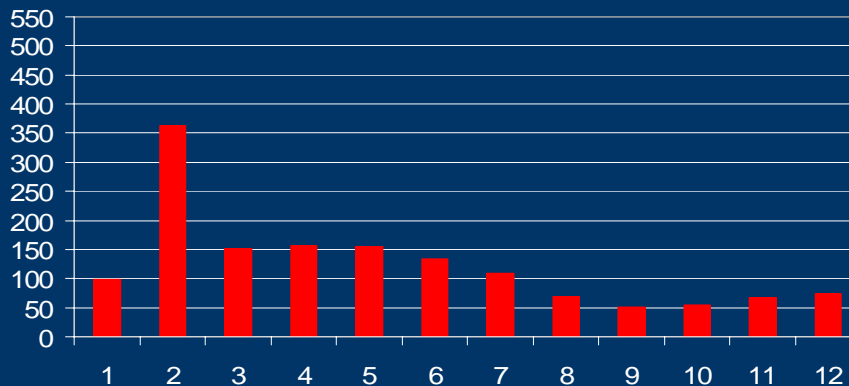
➤ 2005's 1550 fishing sets with different fishing effort distribution



Scenario I
(original 2005's pattern)
Without reaching the caps

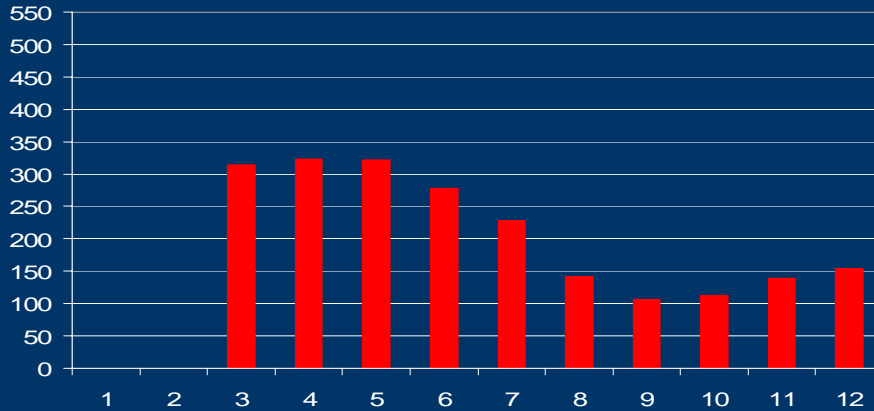


Scenario II
(1994 to 2005 historical pattern)
Without reaching the cap

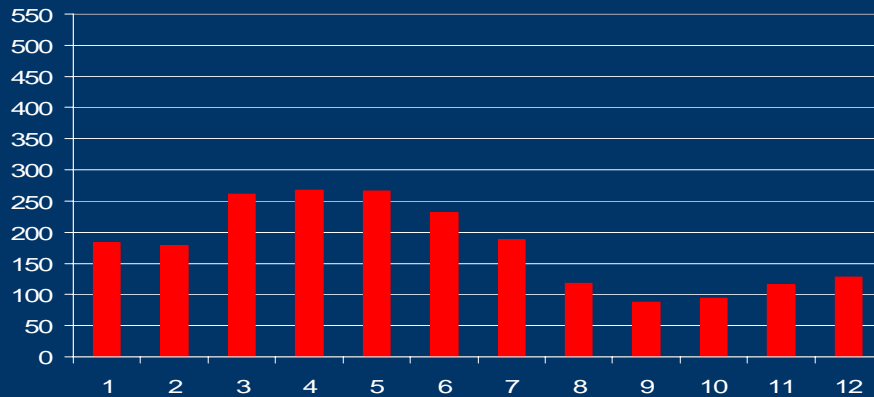


Scenario III
(Jan and Feb in 2006's pattern)
Nearly reach the cap by the end of **Sept**

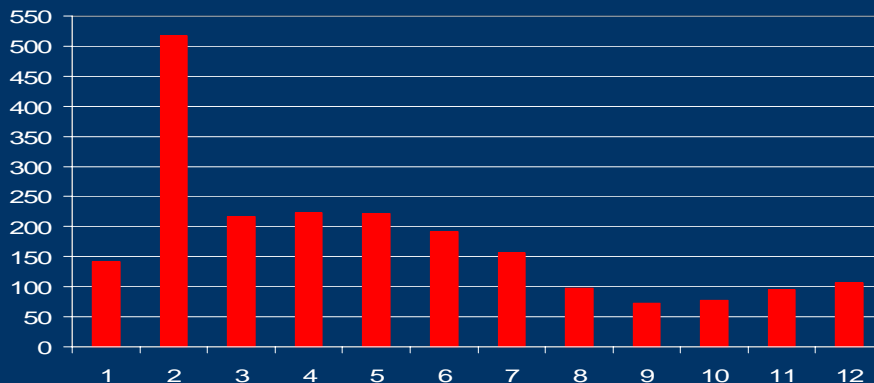
➤ Full number of **2120** sets with different fishing effort distribution



Scenario IV
(historical pattern with closure in Jan and Feb)
Without reaching the caps



Scenario V
(1994 to 2005 historical pattern)
Nearly reach the cap by the end of Sept



Scenario VI
(Jan and Feb in 2006's pattern)
Reach the cap by the end of February

Comparison of sea turtle takes and Economic Returns

Scenarios		Month	#Logger-heads	#Leather-back	Unused sets	Net Revenues from Shallow sets*
2005's 1550 sets	I	Dec	12	7	26.89%	1.00 (\$3,881,339)
	II	Dec	13.09	5.91	26.89%	0.90
	III	Sept	14.05	3.68	36.56%	0.97
2120 sets	IV	Dec	10.79	8.65	0.00%	1.02
	V	Sept	14.21	4.81	15.90%	1.13
	VI	Feb	14.85	1.80	69.96%	0.71

a) 17 loggerheads or 16 leatherbacks as the annual cap of sea turtle takes

b) Economic returns based on monthly net revenue per shallow set from historical data

✓ Conclusion

- ❖ The fishing efforts and their seasonal patterns decide whether the caps of turtle takes will be reached or not

2120 sets based on the **historical pattern of fishing efforts**:

- ❖ It is possible to apply 2120 shallow sets without reaching the caps of turtle takes by seasonal closure of **January** and **February**
- ❖ Without a seasonal closure, the cap of loggerhead would be nearly reached by the end of **September** with 16% unused shallow sets, but economic returns would be the highest
- ❖ Capability of the model -- combination of **spatial** and seasonal analysis for turtle takes and economic returns instead of homogenous assumption across space

Acknowledgement

- ❖ Special thanks to **Dr. Donald Kobayashi** and **Dr. Jeffery Polovina** for sharing their time-area closure model
- ❖ Thanks to colleagues in Fisheries Monitoring and Socioeconomics Division (FMSD) who provided longline logbook data, auction data and Hawaii longline trip expenditure data

Thank You