Modeling silky shark bycatch

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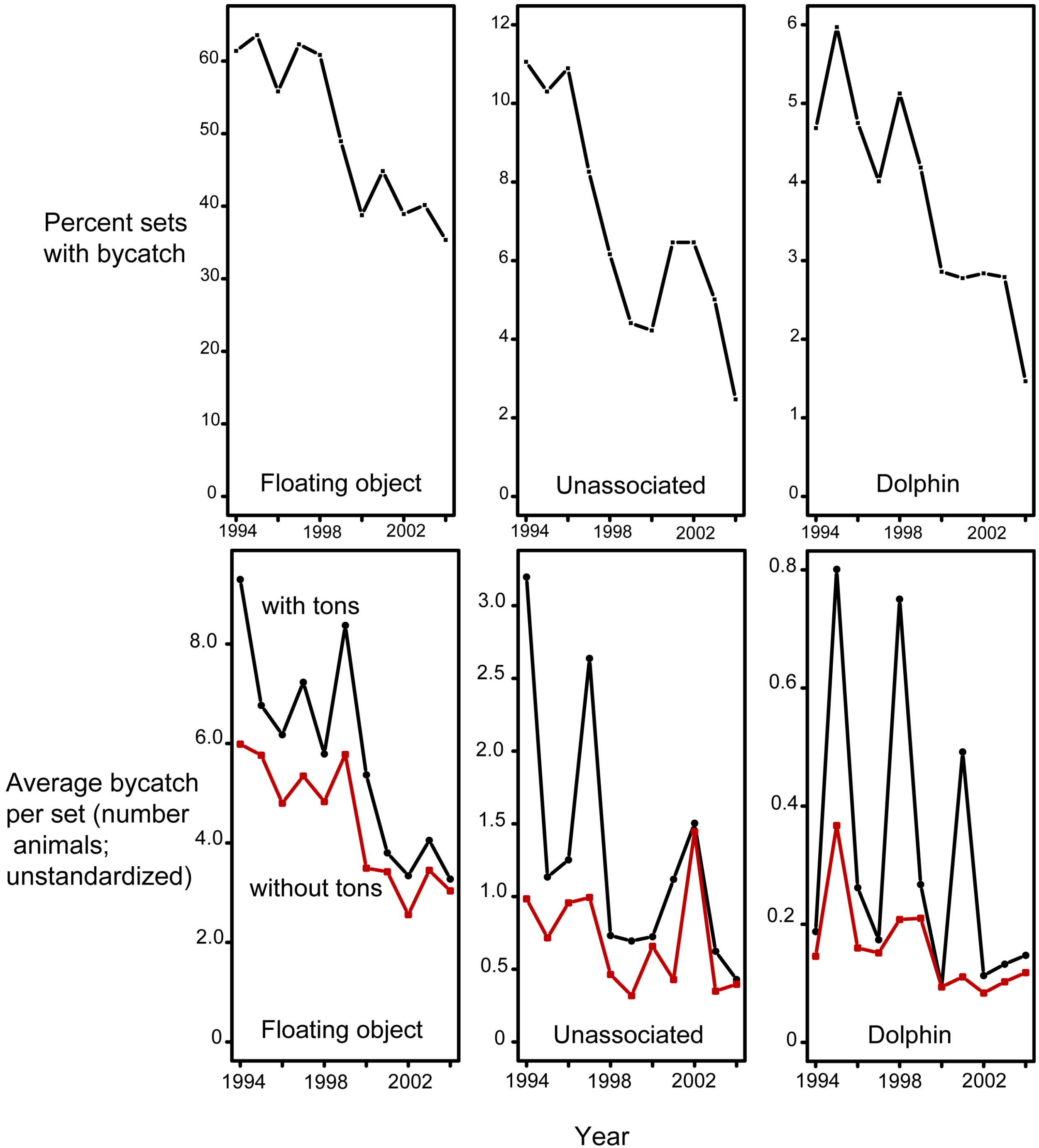
Why model silky shark bycatch?

There is concern about possible negative effects of fisheries catch / bycatch on shark populations.

Silky shark bycatch per set may index abundance, all other things being equal....

Modeling shark bycatch is a first step towards IATTC's mandate to provide preliminary advice on key shark species involved in the purse-seine fishery (IATTC Resolution C-05-03).

IATTC has more data on silky sharks than on other shark species.


Percent sets with bycatch
Floating object
Unassociated
Dolphin
Average bycatch per set (number animals; unstandardized)
with tons
without tons
Floating object
Unassociated
Dolphin
1994
1998
2002
Year

Overall approach for modeling bycatch per set: use generalized linear and additive models to estimate trends.

This has proved somewhat challenging because of the characteristics of bycatch per set.

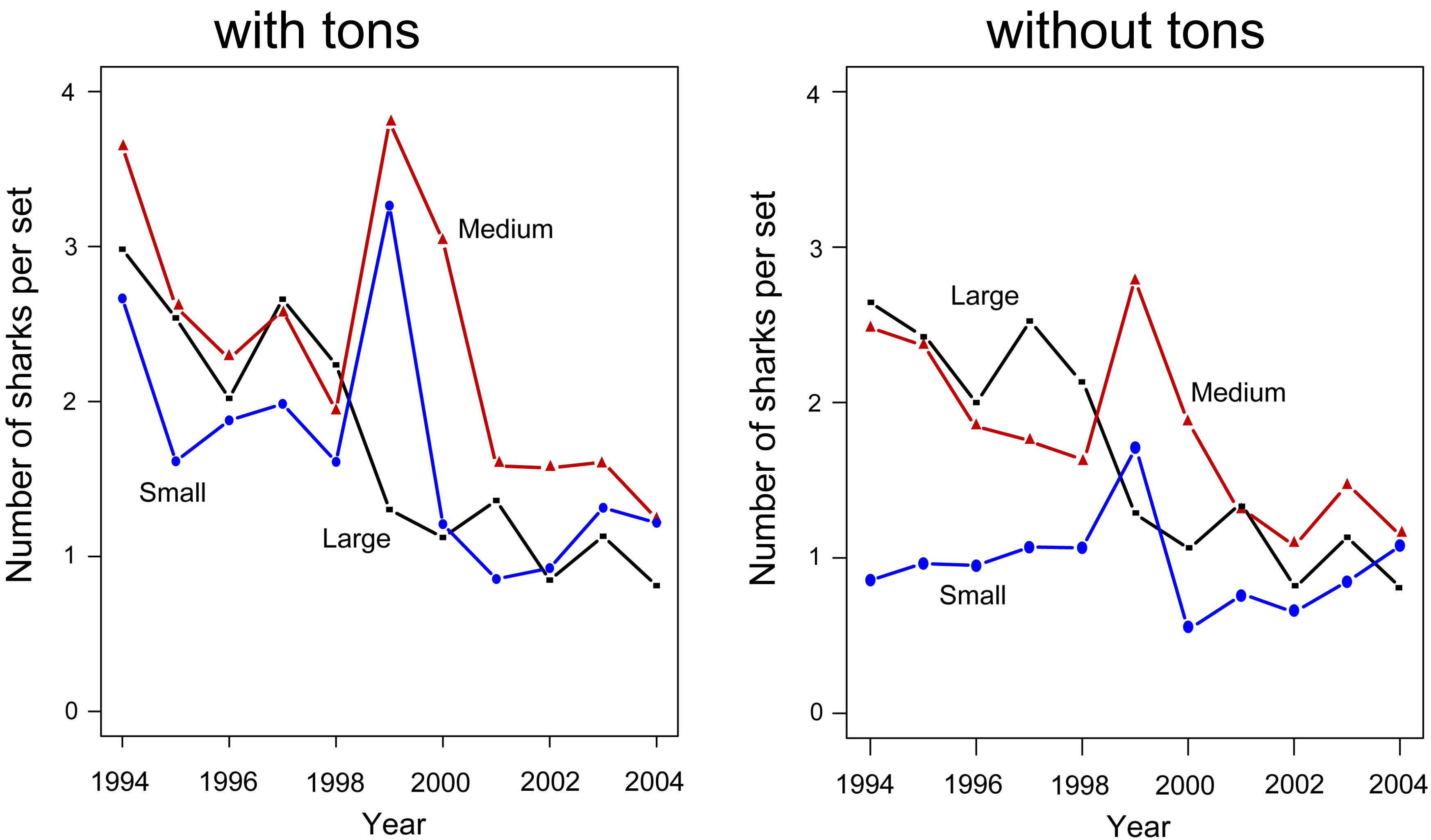
Proceeding in two steps:

1) Explore different probability functions for the “random component” of generalized linear/additive models.

   Started with floating object set data; will expand analysis to dolphin and unassociated sets.

2) Explore in detail spatial/environmental effects.

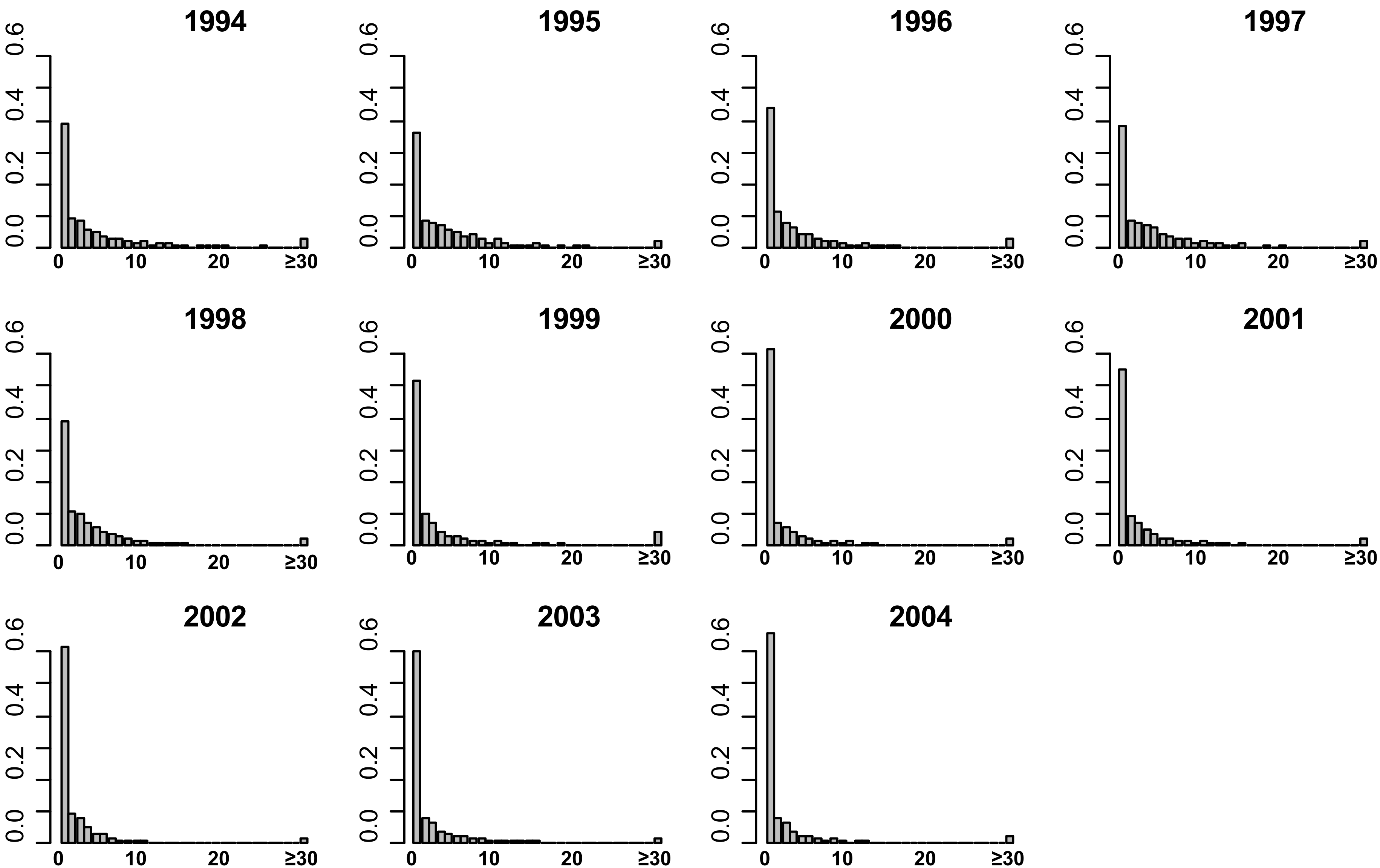
Average silky shark bycatch per set by size category (unstandardized)



Number of floating object sets
1994-2004

Silky shark bycatch per set
1994-2004

Bycatch per set – floating object sets



Probability functions used for modeling bycatch per set:

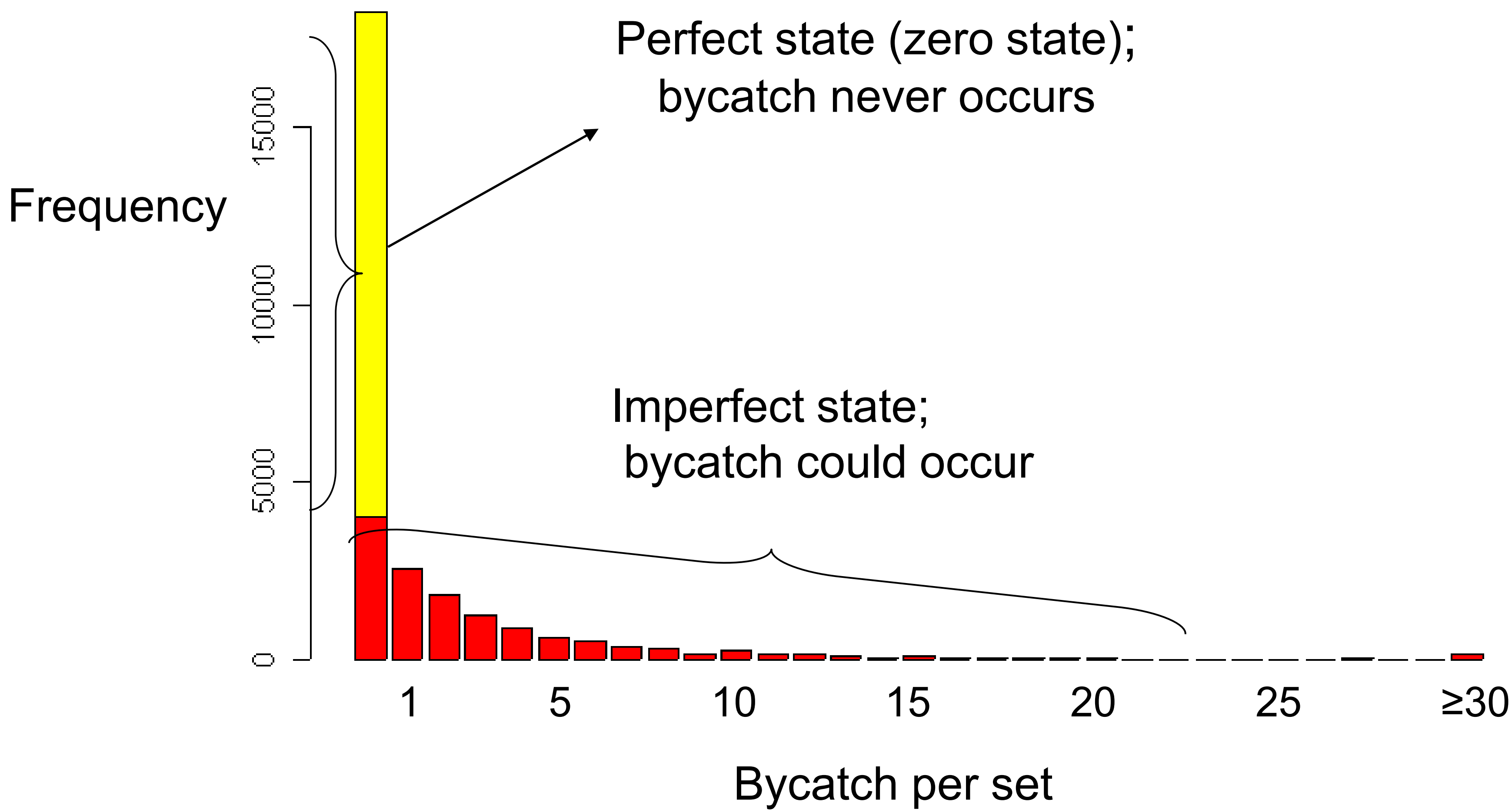
- Poisson
- negative binomial
- zero-inflated Poisson
- zero-inflated negative binomial

The negative binomial is an extension of the Poisson distribution that can better model highly variable count data.

Similarly, the zero-inflated negative binomial can be considered an extension of the zero-inflated Poisson.

Zero-inflated probability functions are used to model data with both a large proportion of zero-valued observations and also large positive values.

Zero-inflated models



Poisson and negative binomial regression models

Log-linear regression models were used to relate the mean bycatch per set (μ) to covariates:

$$\log(\mu_i) = B_{i0} + B_{i1}\beta_1 + \cdots + B_{ik_\beta}\beta_{k_\beta} = \mathbf{B}_i \boldsymbol{\beta}$$

where

$B_{i0}, B_{i1}, \cdots, B_{ik_\beta}$	values of covariates
$\beta_1, \cdots, \beta_{k_\beta}$	coefficients (parameters)

Zero-inflated regression models

Two stage regression model:

- Which state does a set take (*p* = probability of set being in “perfect” state) ?

logistic regression model

$$\log \frac{p_i}{1-p_i} = G_{i0} + G_{i1}\,\gamma_1 + \cdots + G_{ik_\gamma}\,\gamma_{k_\gamma} = \mathbf{G}_i\,\boldsymbol{\gamma}$$

- Amount of bycatch when set is in imperfect state (*μ* = mean bycatch in imperfect state)?

negative binomial / Poisson regression model

$$\log(\mu_i) = B_{i0} + B_{i1}\beta_1 + \cdots + B_{ik_\beta}\beta_{k_\beta} = \mathbf{B}_i\,\boldsymbol{\beta}$$

where $B_{i0}, B_{i1}, \cdots, B_{ik_\beta}$ $G_{i0}, G_{i1}, \cdots, G_{ik_\gamma}$ values of covariates

$\beta_1, \cdots, \beta_{k_\beta}$ $\gamma_1, \cdots, \gamma_{k_\gamma}$ coefficients (parameters)

Data

- Floating object sets, 1994 – 2004 (32,148 sets)

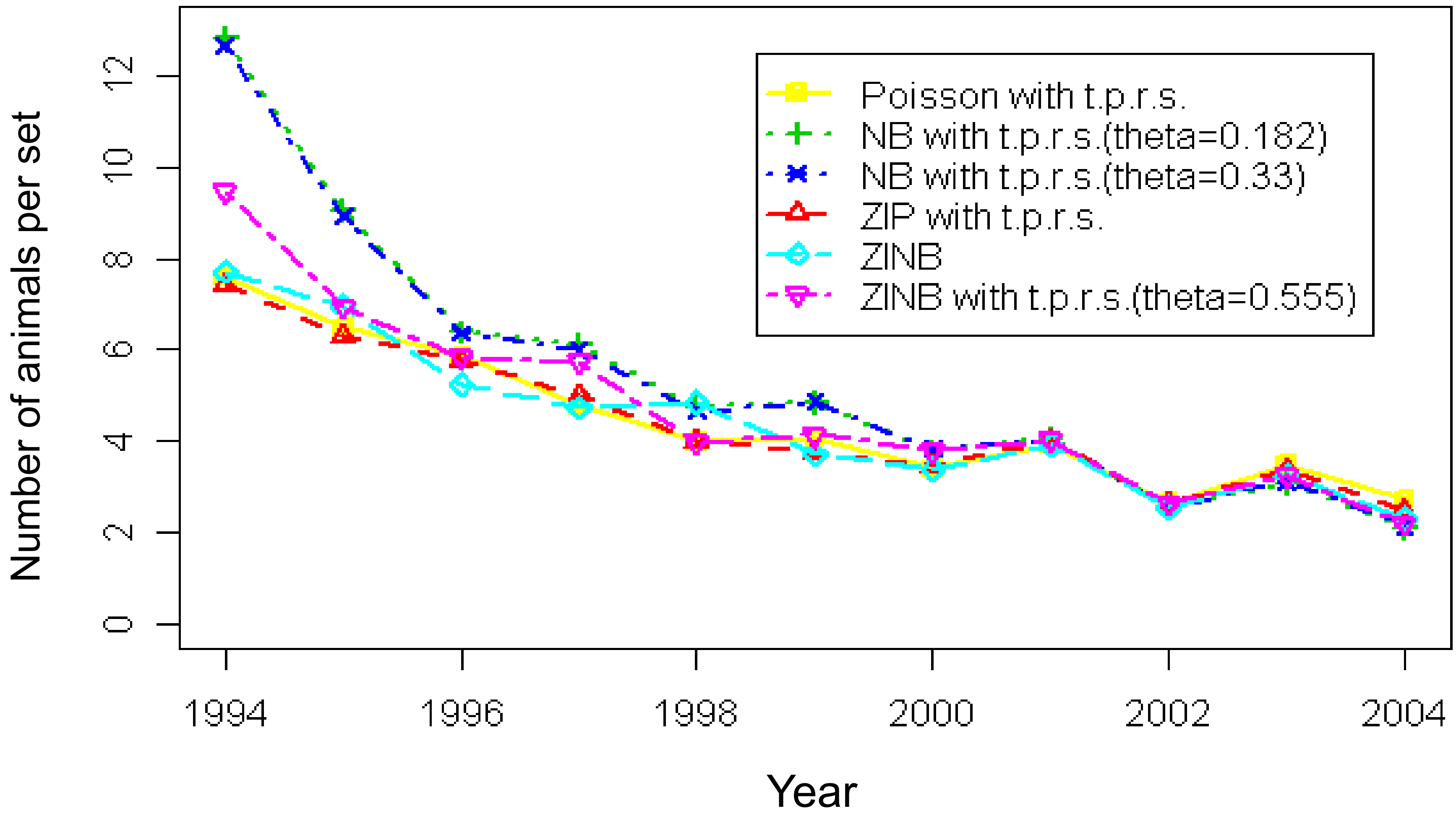
- Data excluded:
  - sets with bycatch reported in tons
  - sets with no catch of target tunas
  - repeat sets on same floating object
  - sets missing data on predictors
  - data for 1993

- Predictor variables
  - location (latitude, longitude), year, calendar date, time
  - net depth, floating object depth
  - sea surface temperature
  - amount of tuna catch (log (tuna))
  - amount of non-silky shark bycatch (log(non-silky+1))
  - two proxies for floating object density

Model comparison

	Log-likelihood (training data)	Generalized Information Criterion (test data)
Poisson	-81849	> 100000
Negative binomial	-32572	65280
Zero-inflated Poisson	-56389	> 100000
Zero-inflated negative binomial (without smoothing)	-32346	64827
Zero-inflated negative binomial	-31862	63921

Partial dependence plot



Interpretation of trends in bycatch per set is/will be complicated by...

Species identification concerns (pre-2005):

- Misidentification of silky sharks
- “Unknown” category: what proportion were silky sharks?

Floating object set data: true object density unknown.

Effect of 2000 IATTC bycatch resolution on live release unknown (pre-2005).

Existence of extremely large bycatches that are difficult to model.