Using Big Data to Improve Sample Efficiency

BigSurv18

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Where We're Going

- General framework: incomplete list for target population
  - Target population is somewhat rare
- Append target population flags to "big data"
  - Address frame in the United States
  - Large sample from incomplete list
- Use auxiliary data to build model for identifying target pop
  - Census data
  - Consumer/marketing data
- Apply model to "big data" -> identify more likely members of target pop not on list
- Sample!

Motivation

- National Recreation Boating Survey
  - conducted on behalf of the United States Coast Guard
- Measure recreational boating activity to develop water safety exposure estimates
  - All 50 States and District of Columbia
- Target population: boat-owning households

What is a boat?


PANTHER


CT 1435 BJ 17

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- Measure recreational boating activity to develop water safety exposure estimates
  - All 50 States and District of Columbia
- Target population: boat-owning households
- Inclusive of
  - Registered boats, *varies by state* (power boats, sail boats, pontoon boats)
  - Unregistered boats (canoes, kayaks, paddleboards)
- Survey modes: push-to-web and paper (contacts are by mail)

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  - Prevalence of boat-ownership unknown.
  - Industry statistic: 11.9M *registered* boats in U.S. (2016) [1]

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- Implemented a dual-frame survey utilizing both ABS and boat registry.

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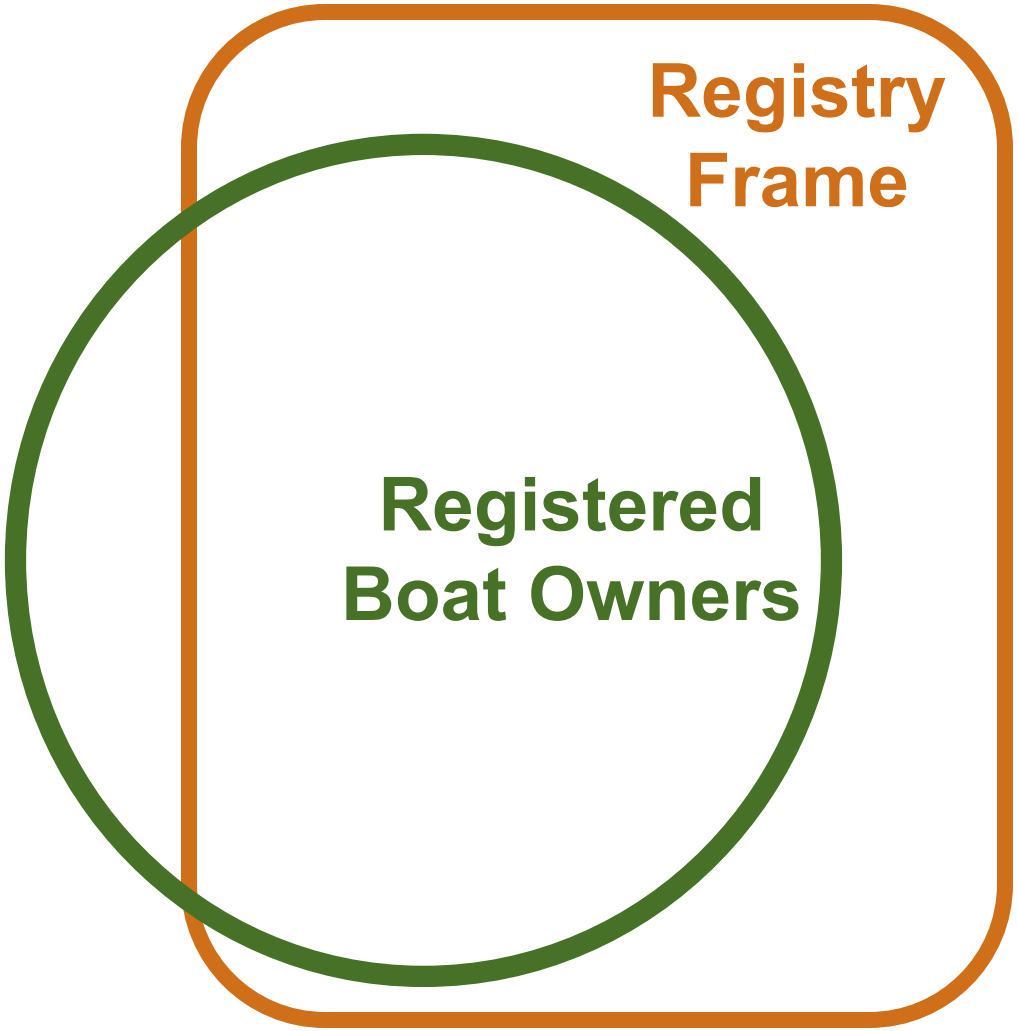
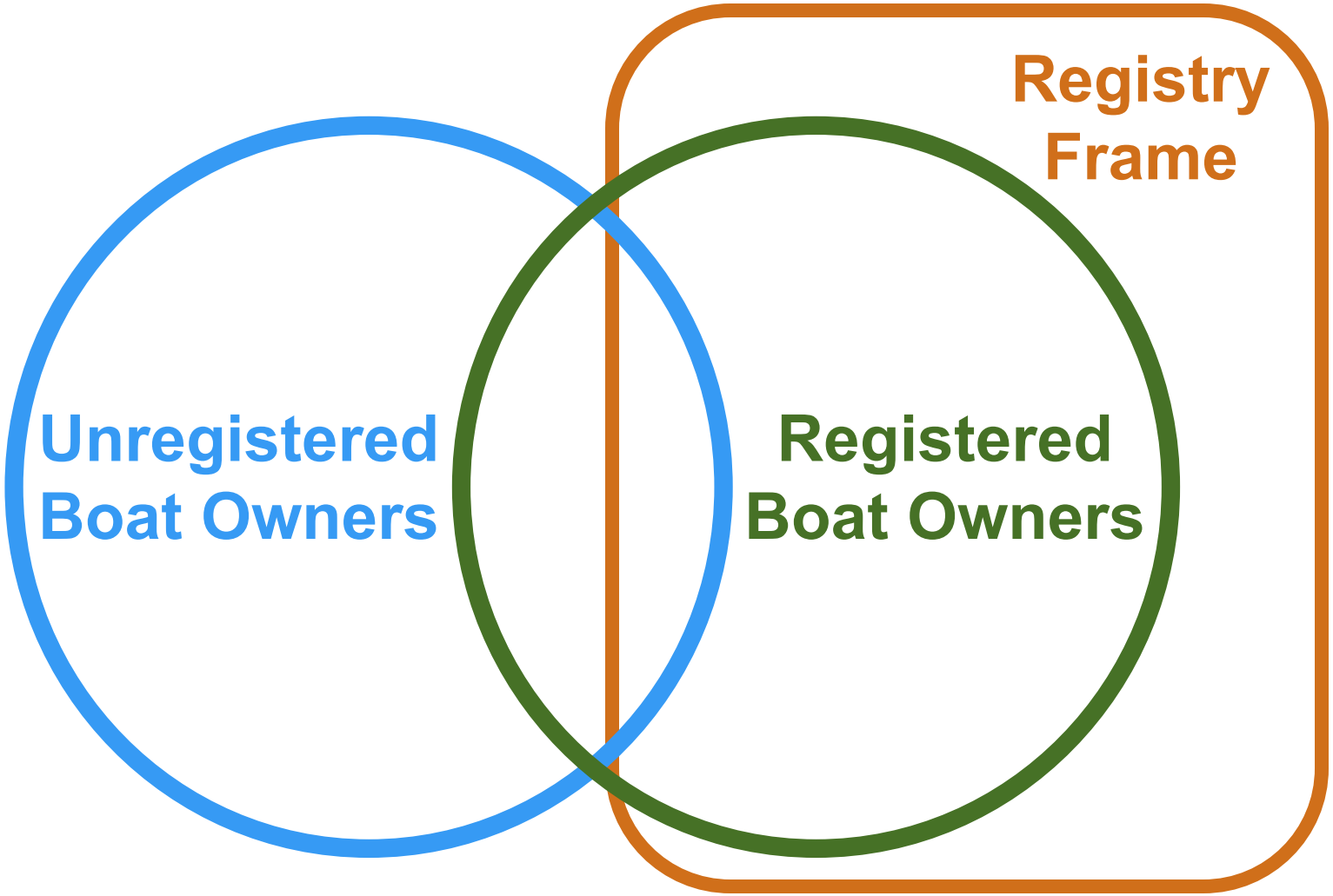
Registered
Boat Owners


Registry
Frame
Registered
Boat Owners


Registry
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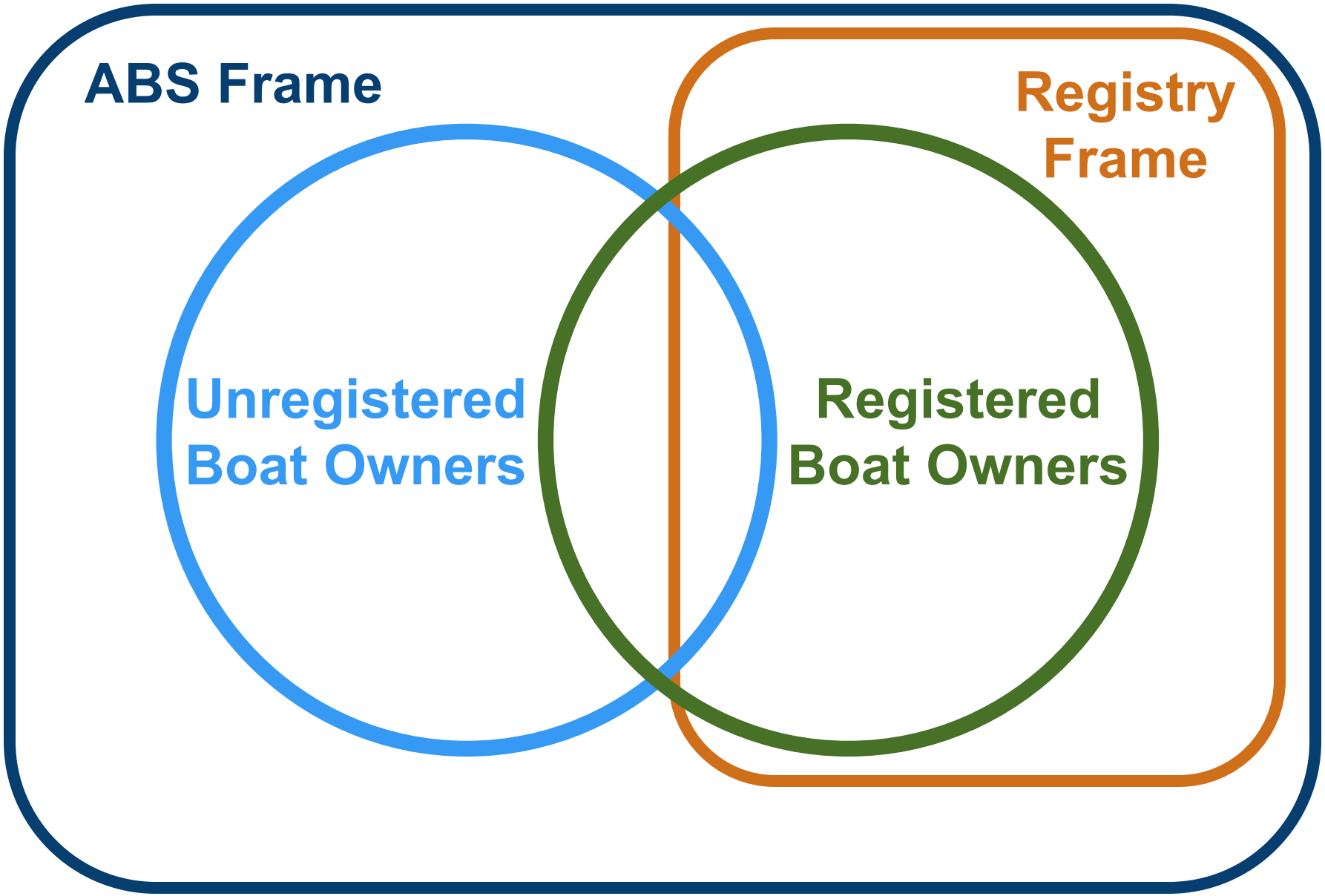

ABS Frame
Registry Frame
Unregistered Boat Owners
Registered Boat Owners

How to find the unregistered boat owners?

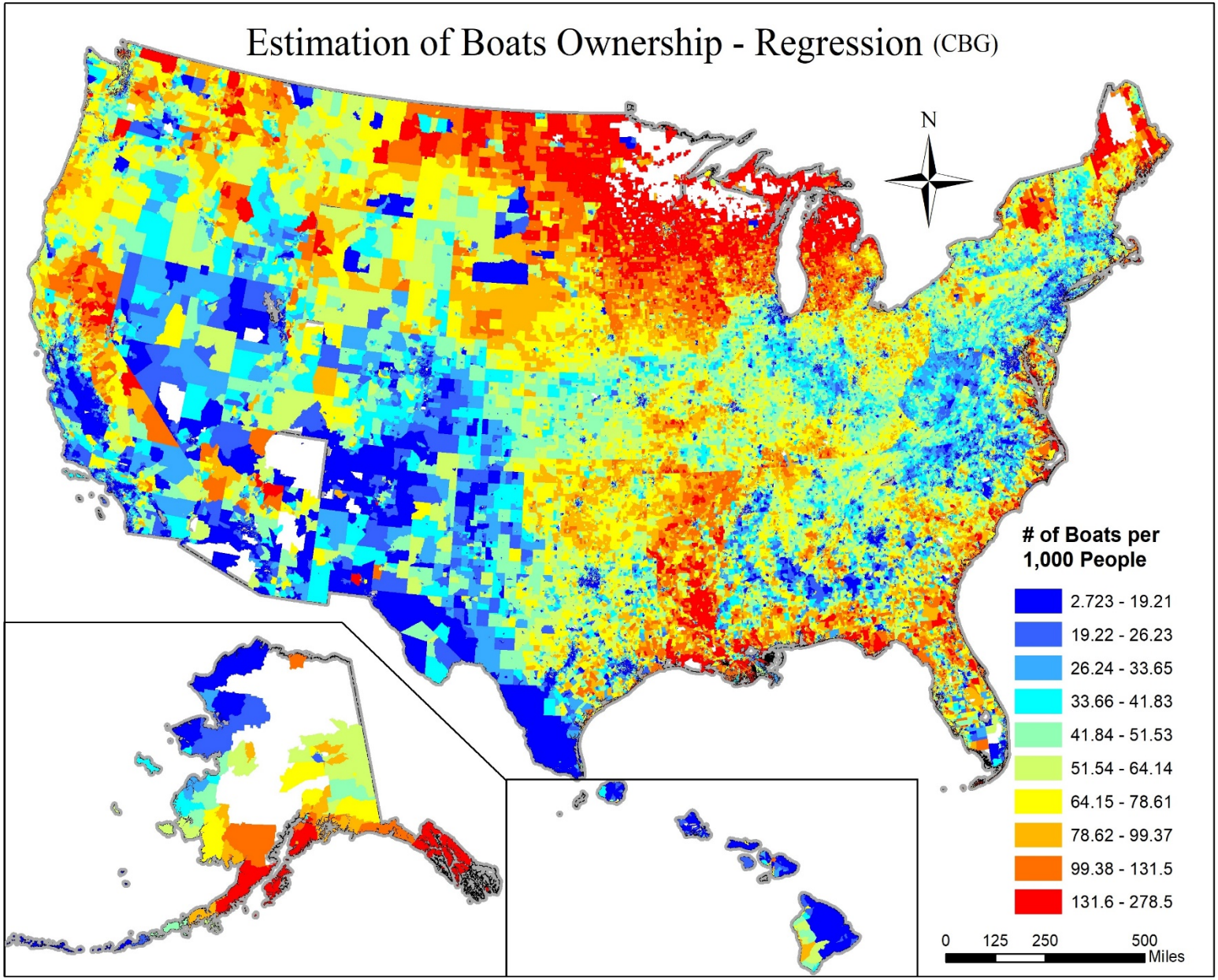
Method

- Not unusual problem: not everyone can have access to all data
- All data sources cannot be put together in entirety at one time
- Registry vendor cannot have access to ABS Frame
- Registry vendor cannot give us all addresses in registry -> take a big sample from all 50 states and DC
- Spatial data collaborator cannot have access to ABS Frame -> builds model predicting boat ownership spatially (Model 1)
- Model 1 results along with Enhanced ABS Frame variables -> build Model 2
- Model 2 predicts boat owner propensity for every address in the U.S.

Model 1 – predict number of boats in CBG

- Goal: take number of boats from ZCTA-level data and assign to Census Block (CB)
  - CB can later be aggregated to Census Block Group (CBG)
- Predictors include population density, number of owner-occupied housing units, per capita income, seven types of distance to water variables, and others.
- Linear regression model in Python ($R^2 = 0.641$)
- Model coefficients for ZCTA data applied to CBG, then normalized to total in ZCTA
- Output: estimated number of boats in CBG

Model 1 Results



Improving ABS Frame Utility

- RTI's Enhanced ABS Frame
  - CDS
  - Complete coverage of all postal delivery points in the U.S. (140M)
  - Axciom InfoBase - consumer database at person-level (over 300M)

- Boat ownership propensity model
  - Large sample of addresses matched to boat registry data from all states* (350k addresses)
  - Merged to Enhanced ABS Frame
  - Result: boat ownership propensity for all addresses

Model 2: Boat Ownership Propensity Model

- Modeling the probability of a household being eligible as a function of explanatory variables
  - Address-level model (~140M addresses in US)

- Model covariates
  - Proportion of HH in a zip code that are registered boat-owning HH
  - Estimate of boat owning household rate by Census Block Group (i.e., output from Model 1)
  - Enhanced ABS Frame variables including address-level demographic and socioeconomic indicators
  - Administrative areas public census data

Model 2: Boat Ownership Propensity Model

- Assigned 10% of data to validation dataset and developed model on remaining 90% training data
  - Stepwise-selection
  - Allowed for two-way interactions of main effects
- Prediction error measured with validation data
  - Used to terminate model-building
  - Stopping criterion: minimum average square error
- SAS PROC HPLOGISTIC

Model Selection

Statistic	Training	Validation
Area under the ROCC	0.71	0.71
Average Square Error	0.07	0.07
Misclassification Error	0.08	0.08
R-Square	0.04	0.04
Max-rescaled R-Square	0.09	0.09

Model 2: Boat Ownership Propensity Model

- Propensity variable for all addresses on ABS Frame
  - Grouped into 20 strata based on 5-percentile cut-points
  - Disproportionate allocation
  - ABS sample de-duplicated against registry frame

Data Collection Results*

	Registry Frame		ABS Frame		Total (both frames)	
	Total	Rate	Total	Rate	Total	Rate
Total	37,650		56,685		94,335	

*Results based on 6 of 12 completed cohorts

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Registry frame yields high, as expected, ABS frame completes coverage.

ABS alone would have been cost prohibitive.

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ABS Eligibility Propensity Strata Results

Propensity Strata	Screening Rate (%)	Eligibility Rate (%)	Yield (%)
1-5 (low propensity)	11.0	28.9	3.2
6-10	13.3	35.1	4.7
11-15	14.0	35.3	5.0
16-19	16.5	37.4	6.2
20 (high propensity)	17.7	45.4	8.0

Other Results

- Most registered boat owners originate from list frame (84%)
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  - Respondent error in knowledge of boat registration
- Non-registered boat owners originate from both frames
  - 55% list frame, 45% ABS

Other Results

- Households with only unregistered boats own more boats
  - Only unregistered average 3.1 boats in HH
  - Registered average 1.6 boats in HH

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- Boat operated more than three nautical miles from shore in past 12 months
  - 10.3% of registered boat owners say yes, 8.7% of non-registered boat owners say yes ($p = 0.003$)

Conclusions

- When there exists a list frame that is incomplete and/or inaccurate supplement with larger data
  - Draw sample from list frame (in this case boat registry)
  - Merge to large data (in this case ABS)
  - Build model to predict eligibility
  - Apply to large data
  - Create propensity strata and allocate
- This approach maximizes coverage while controlling for screening costs
- Limitations
  - List frame is of registered boats only though supplemented with other data

More Information

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Extra Info

Recreational boat: power boat, cabin boat, pontoon boat, air boat, house boat, personal watercraft, sail boat, canoe, kayak, paddleboard, row boat, or inflatable boat.