Science, Service, Stewardship

Fishery Dependent Data and Bycatch Estimation

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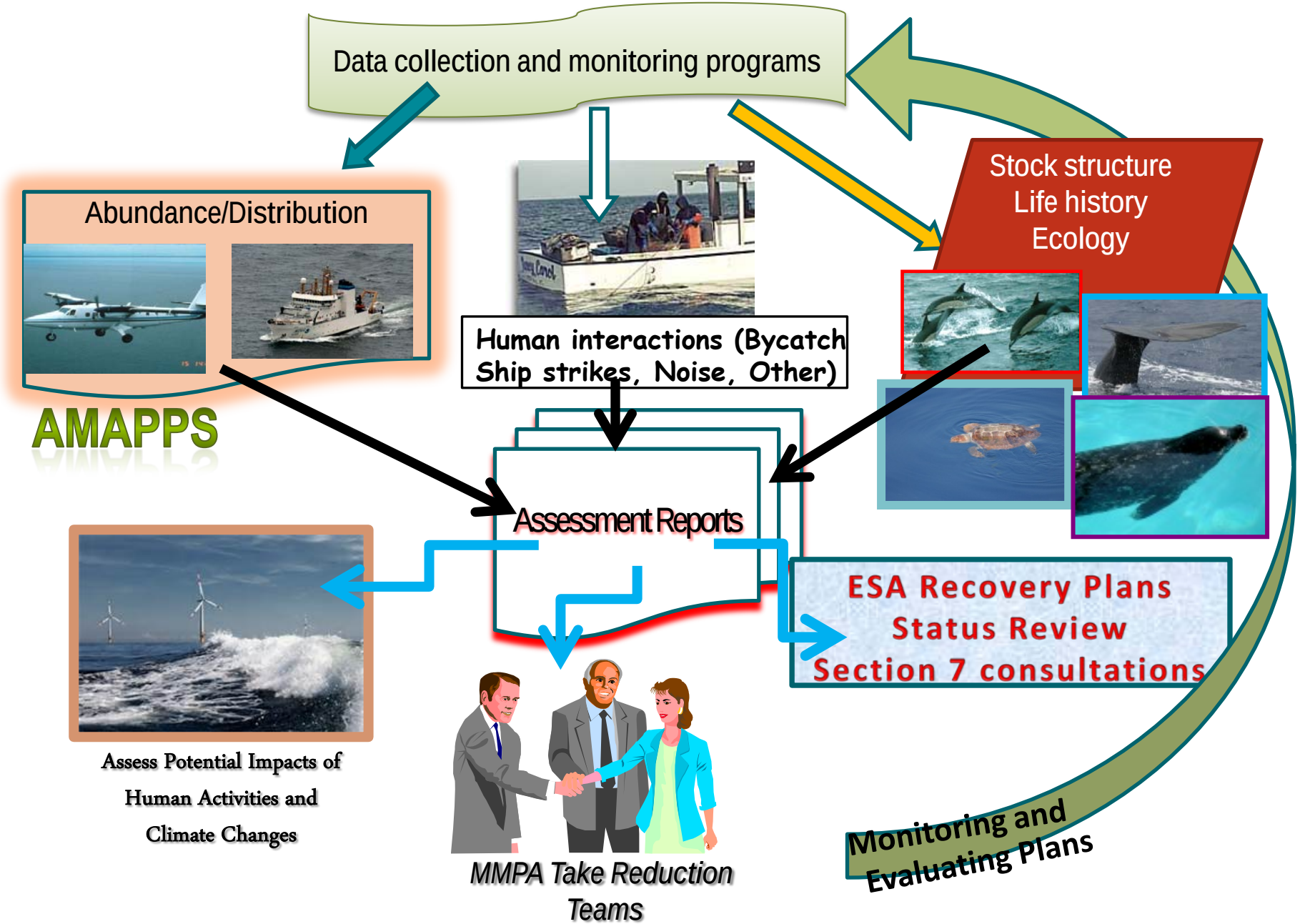
NOAA FISHERIES SERVICE

Overview

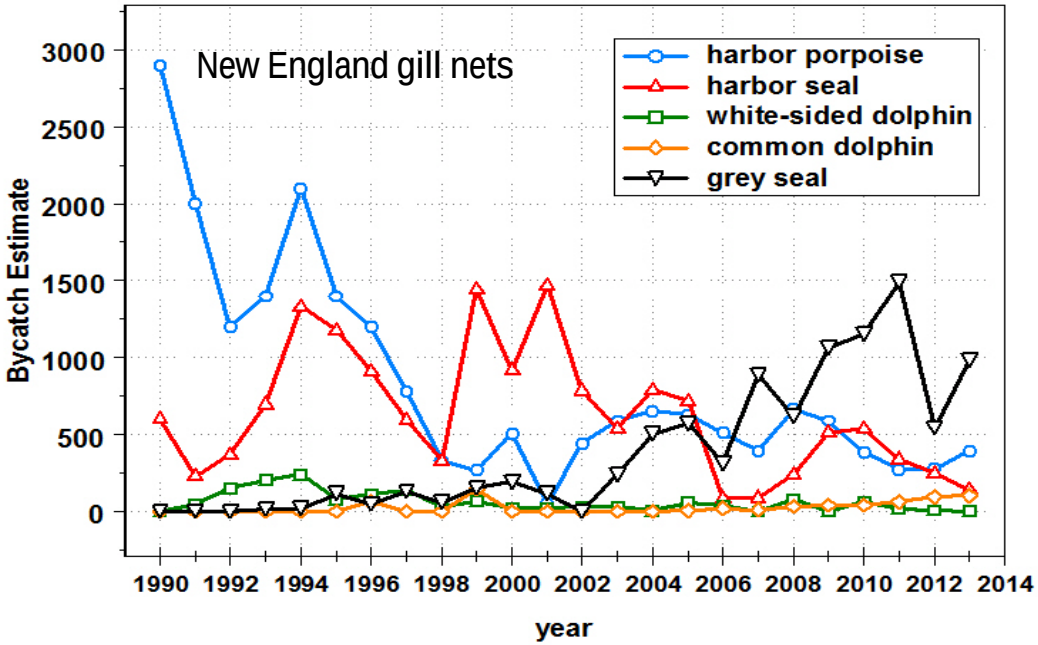
- How fishery dependent data and bycatch estimates fit into our programs
- Data sources
- Uses of data
- Strengths/challenges/recommendations


Data collection and monitoring programs
Abundance/Distribution
AMAPPS
Human interactions (Bycatch
Ship strikes, Noise, Other)
Stock structure
Life history
Ecology
Assessment Reports
ESA Recovery Plans
Status Review
Section 7 consultations
Assess Potential Impacts of
Human Activities and
Climate Changes
MMPA Take Reduction
Teams
Monitoring and
Evaluating Plans

Fishery dependent management needs

- Bycatch related needs
  - Identify and quantify protected species bycatch including number of interactions, life stage impacted, number of serious injuries/ mortalities by fishery
  - Assess spatio-temporal variation in foraging and diet
  - Coordinate with Canada on transboundary stocks and threats
  - Project future distribution under changing environment
  - Provide science to inform ecosystem models
- Management related needs
  - Provide input to management bodies, including MMPA Take Reduction Teams and status review teams/recovery teams
  - Identify hot spots of bycatch
  - Identify areas of concern for species to inform spatial management
  - Identify mitigation options (e.g., changes in fishing gear or practices)
  - Monitor effectiveness of regulations
  - Predict future bycatch hot spots
  - Quantify population level impact of takes
- Social science/economic related needs
  - Fisheries displacement/behavioral model – predict fleet's response to proposed regulations and environmental change
  - Evaluate cost-effectiveness of alternative fishing regulations

Typical species bycaught in New England (NE) and Mid-Atlantic (MA) fisheries



Species	NE gillnet	MA gillnet	NE Bottom trawl	MA bottom trawl	NE midwater trawl	MA midwater trawl	Scallop dredge
Atlantic white sided dolphin	X		X			X	
Bottlenose dolphin		X	X	X			
Gray seal		X	X			X	
Harbor porpoise	X	X	X	X			
Harbor seal	X	X	X	X		X	
Harp seal	X	X	X		X		
Minke whale			X				
Pilot whale spp.	X		X	X	X	X	
Risso's dolphin		X	X	X		X	
Short-beaked common dolphin	X	X	X	X	X	X	
Loggerhead turtle		X		X			X

Data Sources

- Sources of human-related interactions
  - Fishery Observer Program
  - Strandings and Entanglements
- Sources to expand fishery-related interactions
  - Vessel trip reports
  - Dealer landings
  - State landings
  - Fishery experimental trips
  - Vessel Monitoring System (VMS; http://www.greateratlantic.fisheries.noaa.gov/vms/index.html)
- Environmental Data (talked about this already)

Reviewed during the 2013 Data Collection and Management Fisheries Science Program Review

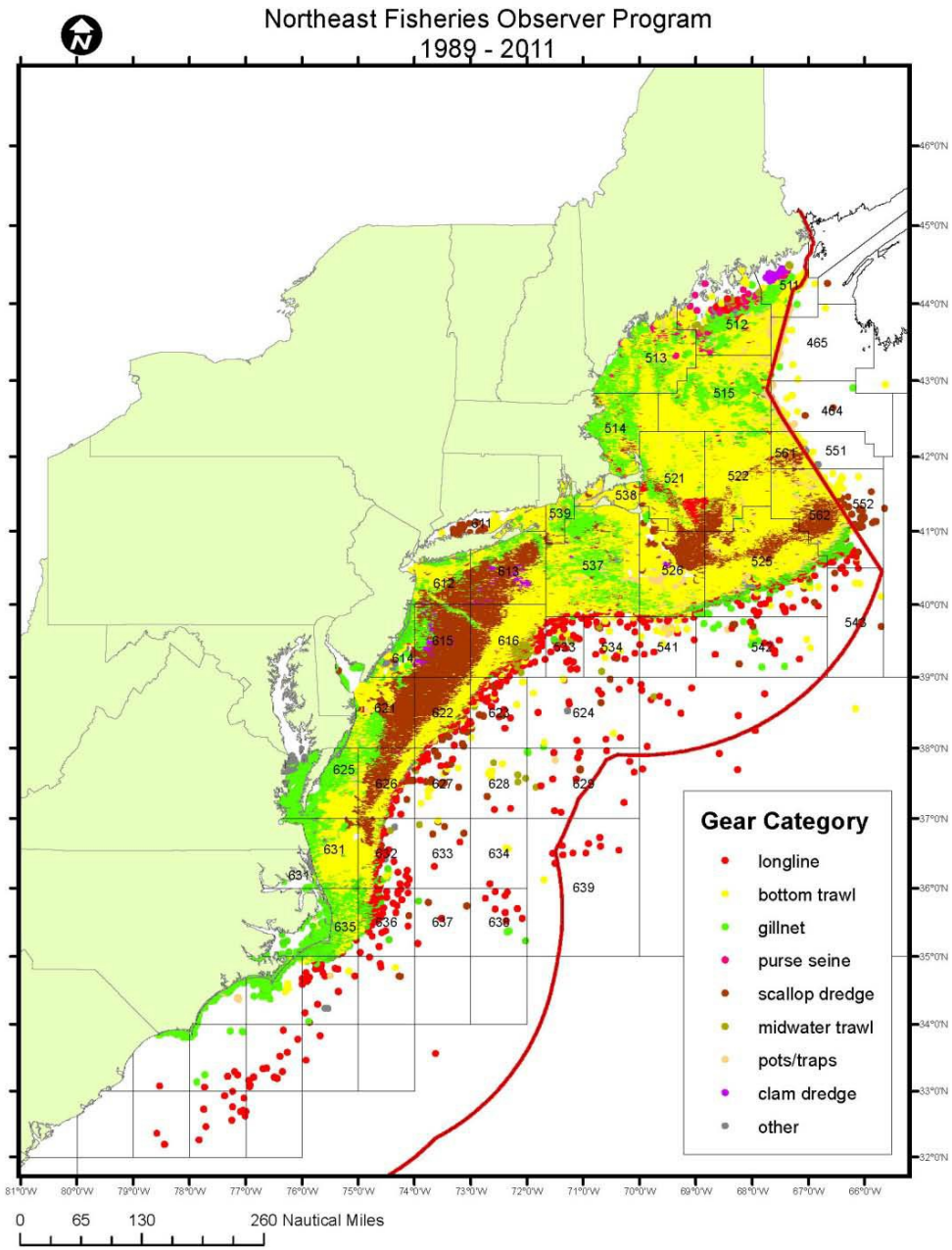
Observer data

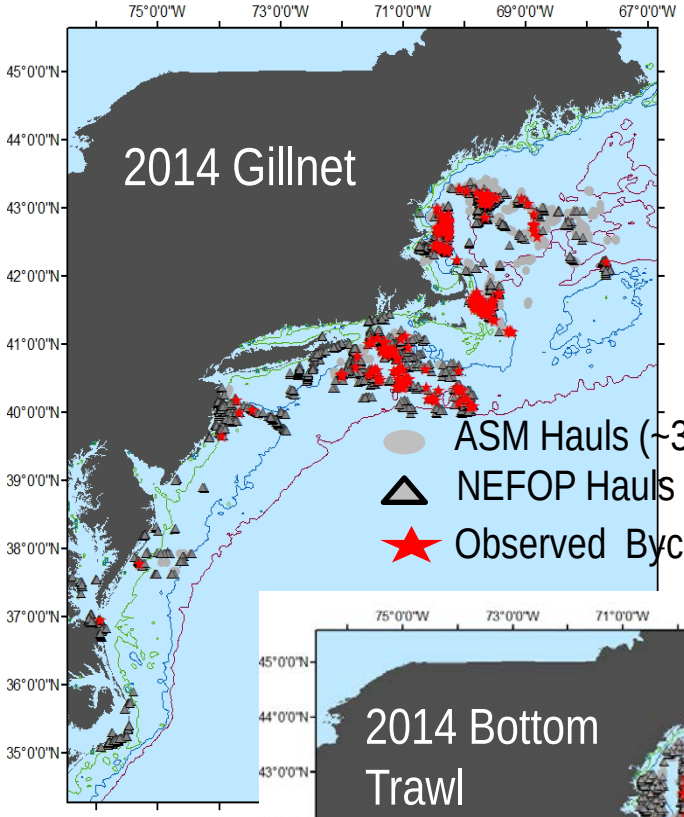
(Used extensively in bycatch and management related analyses)

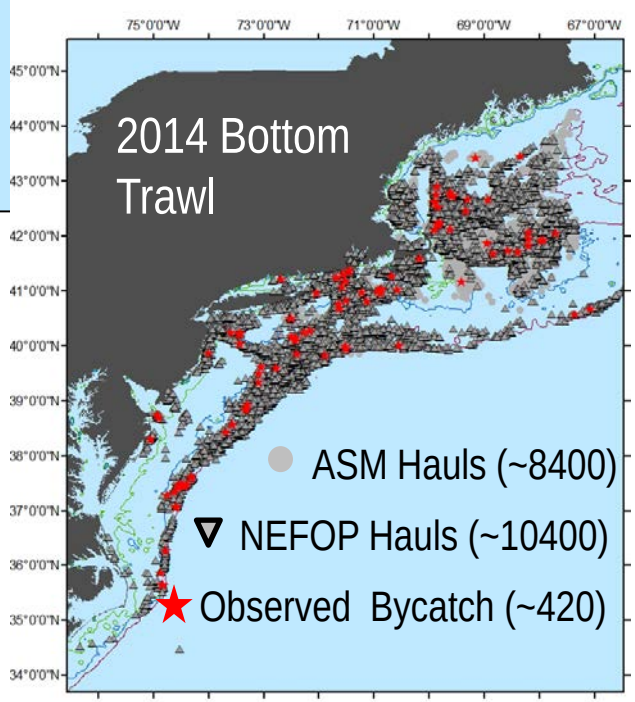
- Types of data
- Quality of data and timeliness

(http://www.nefsc.noaa.gov/fsb/)

	Northeast Fisheries Observer Program (NEFOP)	At-Sea Monitoring Program (ASM)	Industry Funded Scallop Program (IFS)
Start date	1989	2010	2005
Area	ME - NC	ME - CT	MA – NC
Fisheries covered	gillnets (anchored, drift, sink, stake), trawls (bottom, paired midwater, single midwater, scallop trawl), scallop dredge, pot and traps, purse seine, beach seine, long line and other line fisheries, clam/quahog dredge	gillnet, bottom trawl, bottom long line	Scallop trawl Scallop dredge
Selection method	Standardized Bycatch Reporting Methodology (SBRM), Protected Species Branch, Pre-trip Notification System (PTNS), Herring call-in system	PTNS	Call-in system







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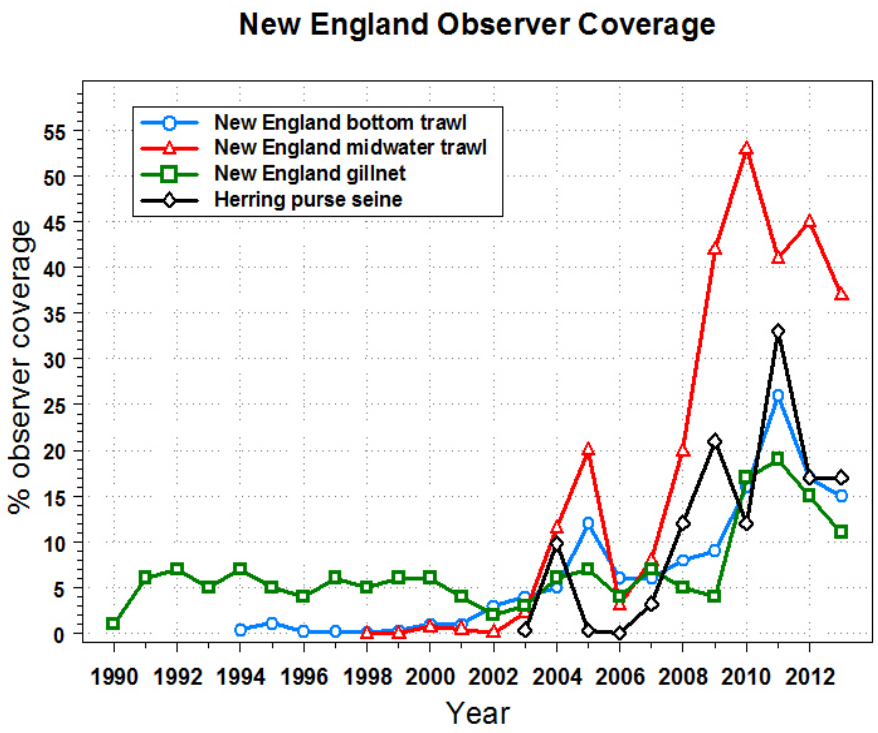
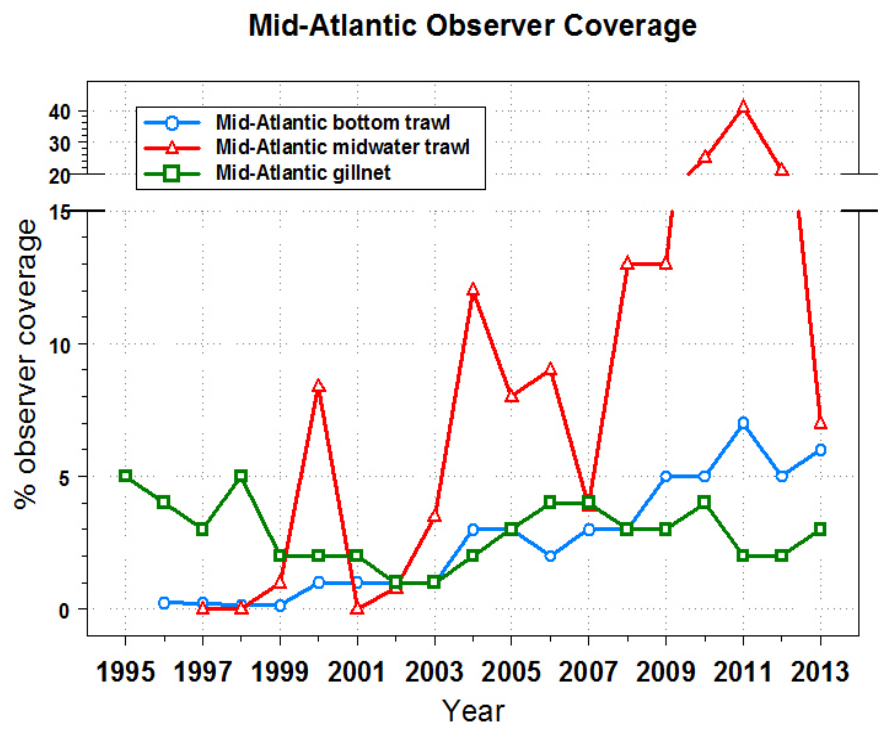
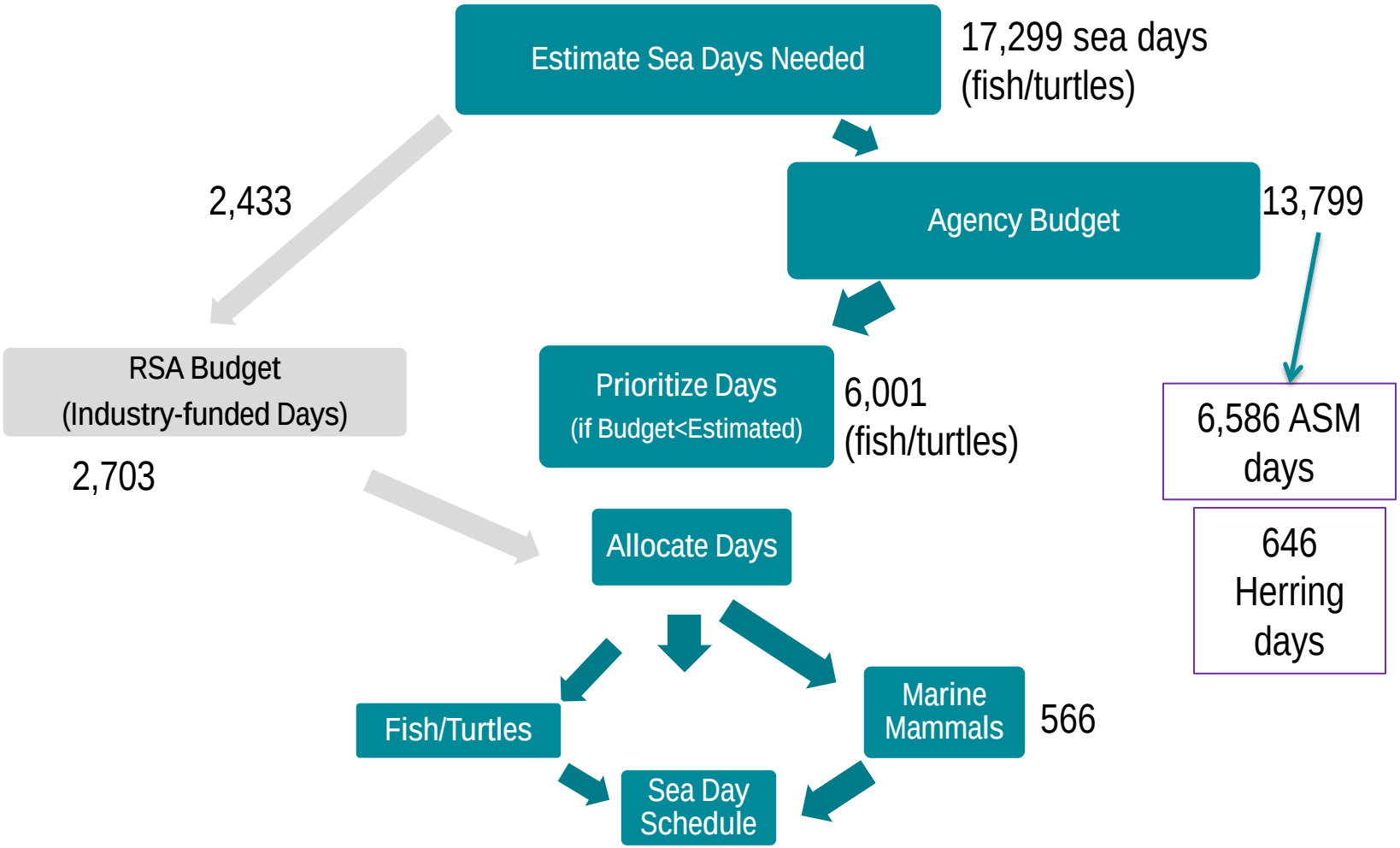
Observer coverage





2014 Sea Day Allocation Process



Data collected by NEFOP (* = collected by ASM)

- Trip
  - Vessel name, permit numbers, target species*
  - Economic info (fuel cost, gallons used, damage, supplies)*
  - Home port, gear onboard but not used, captain experience
- Gear
  - Gear type, mesh sizes, size of gear, pinger usage*
  - Special modification, gear-mounted electronics
- Haul
  - Time, coordinates, weather conditions, target species*
  - Depth, tow speed, gear-mounted electronics, set method
- Species
  - All species (kept and discarded)*
  - Disposition (kept or discarded) and reason*
  - Weight, type (dressed or round) and estimation method*
- Biological sampling of catch
  - Length frequencies
  - Sex, age structures
- Large discarding events
  - Discard reason and estimated weight*
  - Pumping, paired vessel information
- Protected Species Sightings
  - Species name, location, condition, activity, number of animals
- Protected Species incidental takes
  - Species name, entanglement, condition (alive/dead, wounds, etc)*
  - Photographs and detailed comments*
  - Measurements and samples

Observer manuals at:
http://www.nefsc.noaa.gov/fsb/training/

Strandings and Entanglement Data

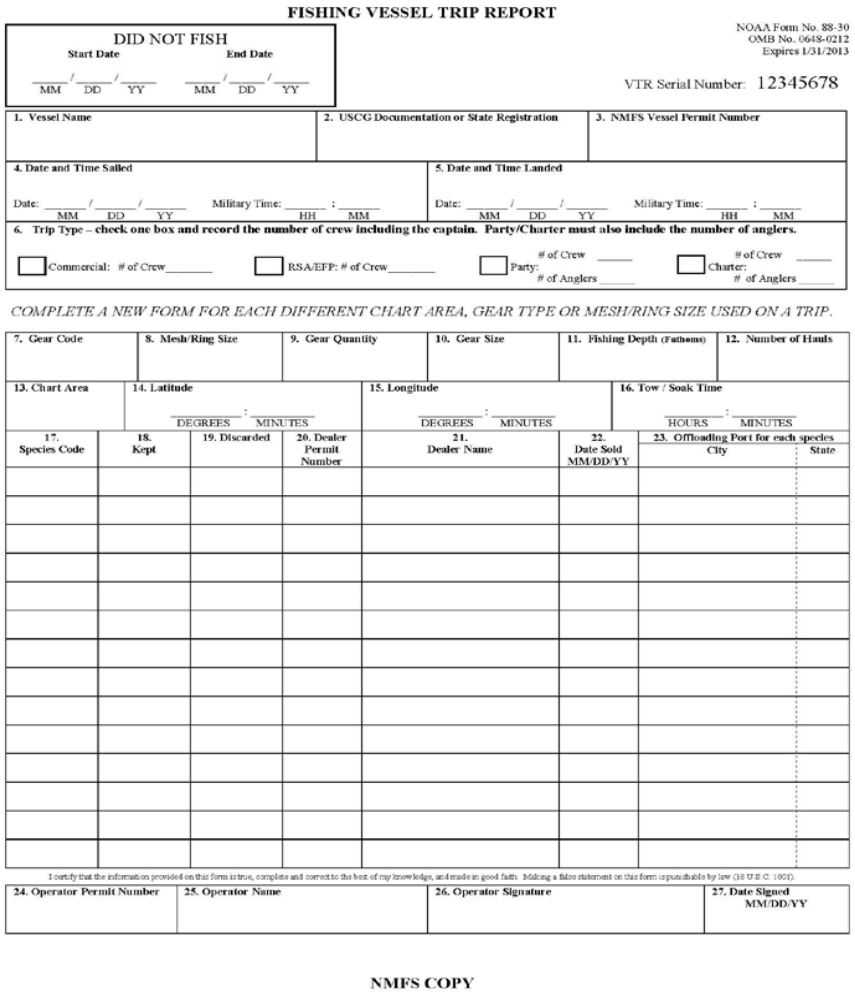
(http://www.greateratlantic.fisheries.noaa.gov/prot_res/stranding/)

- These types of data have been used to provide a minimum count of bycatch and ship strikes
- Are reported in Stock Assessment Reports
- Examples:
  - Large whales and seals (more tomorrow)
  - Bottlenose dolphins (more during SEFSC review)

VTR (Vessel Trip Reports) and eVTR data

(http://www.greateratlantic.fisheries.noaa.gov/aps/index.html)

- Mandatory reports for each fishing trip made by all federally permitted vessels
- Data includes area and basic effort information
- Complete before the vessel docks and is due weekly or monthly
- Data audited before loading; vessel owner notified of problems via a send-back process
- Fishery Dependent Data Committee working on improving these data



FISHING VESSEL TRIP REPORT

NOAA Form No. 88-30
OMB No. 0648-0212
Expires 1/31/2013

DID NOT FISH
Start Date ___/___/___ (MM DD YY) End Date ___/___/___ (MM DD YY)

VTR Serial Number: 12345678

1. Vessel Name | 2. USCG Documentation or State Registration | 3. NMFS Vessel Permit Number

4. Date and Time Sailed — Date: ___/___/___ (MM DD YY) Military Time: ___:___ (HH MM)
5. Date and Time Landed — Date: ___/___/___ (MM DD YY) Military Time: ___:___ (HH MM)

6. Trip Type – check one box and record the number of crew including the captain. Party/Charter must also include the number of anglers.
☐ Commercial: # of Crew_____ ☐ RSA/EFP: # of Crew_____ ☐ Party: # of Crew ____ # of Anglers ____ ☐ Charter: # of Crew ____ # of Anglers ____

COMPLETE A NEW FORM FOR EACH DIFFERENT CHART AREA, GEAR TYPE OR MESH/RING SIZE USED ON A TRIP.

7. Gear Code | 8. Mesh/Ring Size | 9. Gear Quantity | 10. Gear Size | 11. Fishing Depth (Fathoms) | 12. Number of Hauls

13. Chart Area | 14. Latitude ___:___ (DEGREES MINUTES) | 15. Longitude ___:___ (DEGREES MINUTES) | 16. Tow / Soak Time ___:___ (HOURS MINUTES)

17. Species Code	18. Kept	19. Discarded	20. Dealer Permit Number	21. Dealer Name	22. Date Sold MM/DD/YY	23. Offloading Port for each species City	State

I certify that the information provided on this form is true, complete and correct to the best of my knowledge, and made in good faith. Making a false statement on this form is punishable by law (18 U.S.C. 1001).

24. Operator Permit Number | 25. Operator Name | 26. Operator Signature | 27. Date Signed MM/DD/YY

NMFS COPY

Dealer Report Data

(http://www.greateratlantic.fisheries.noaa.gov/aps/index.html)

- Considered a census of fishing effort
- Dealers report purchases of all species weekly
- Does not include area and effort information
- Data audited weekly and reconciled with VTR to assure quality
- We use these data to check the VTR data for its representativeness and completeness

State Fishing Report Data

- In places where VTR data are lacking use state data such as:
- Virginia (/http://mrc.virginia.gov/commercial.shtm)
- North Carolina (http://portal.ncdenr.org/web/mf/46)

QA/QC Fishery Dependent Data

- Comprehensiveness
  - Evaluate and adjust (if needed) deficiencies in VTR data
- Representativeness
  - Evaluate spatial and temporal distribution of VTR with regards to total commercial landings
  - Evaluate spatial and temporal distribution of observer data with respect to VTR
- Missing/Erroneous Data
  - Document imputation procedures (Warden & Orphanides 2008)
  - Standardize method to identify “errors” (in development)

Uses of fishery dependent data

Bycatch analyses

Biological information

Management needs

Bycatch estimation methods

Methodology

1. Ratio estimator
2. GLM/GAM
3. Bayesian

Account for species/fishery specific issues:

- Spatial/temporal distribution of animals and fisheries
- Gear specific factors
- Observer data specific factors
- Serious and non/serious injuries

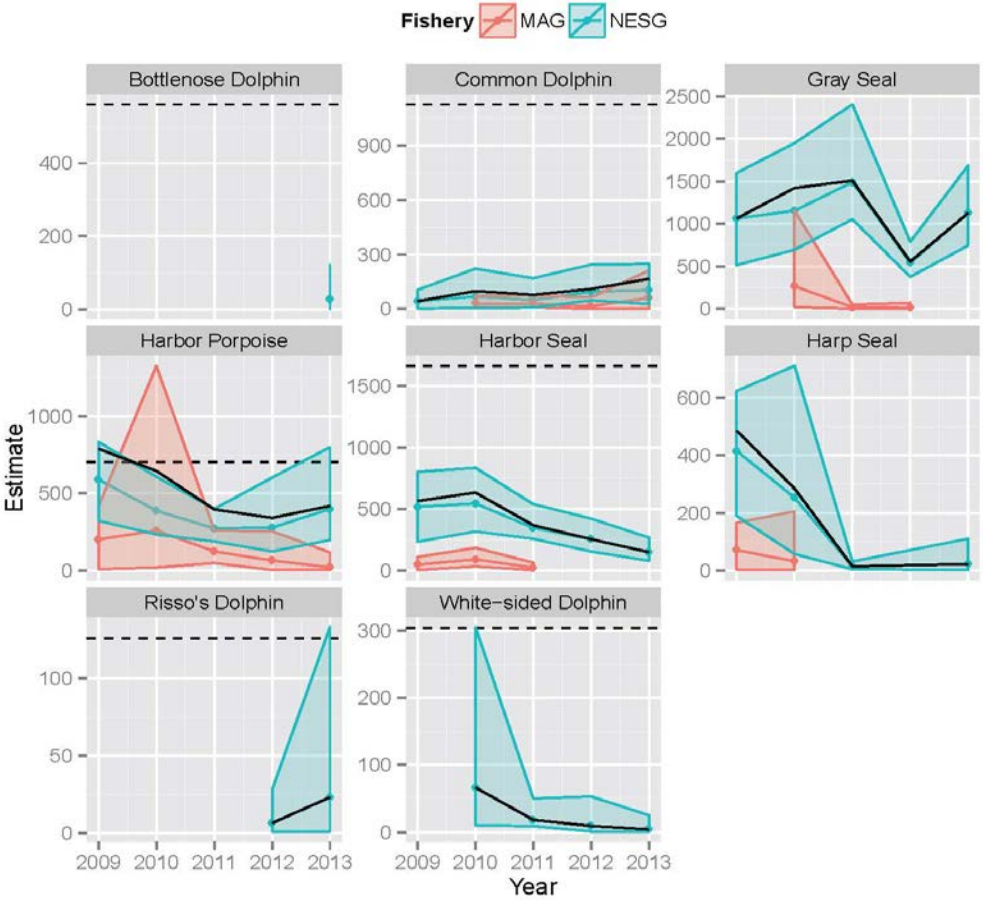
Serious injury determination

- MMPA requires annual levels of human-caused mortality and serious injury to marine mammals.
- National guidelines for distinguishing serious from nonserious injuries
  - (http://www.nmfs.noaa.gov/pr/pdfs/serious_injury_procedure.pdf)
- Includes independent reviews of determinations
- Small cetaceans and pinnipeds (Waring et al. 2014; Waring et al. in review)

Example 1 – ratio estimator in gillnet fishery

Hatch & Orphanides. 2013. Estimates of cetaceans and pinniped bycatch in the 2012 New England sink and mid-Atlantic gillnet fisheries. US Dept Commer, Northeast Fish Sci Cent Ref Doc 14-02.

Hatch & Orphanides in review. Estimates of Cetacean and pinniped bycatch in the 2013 New England sink and mid-Atlantic gillnet fisheries

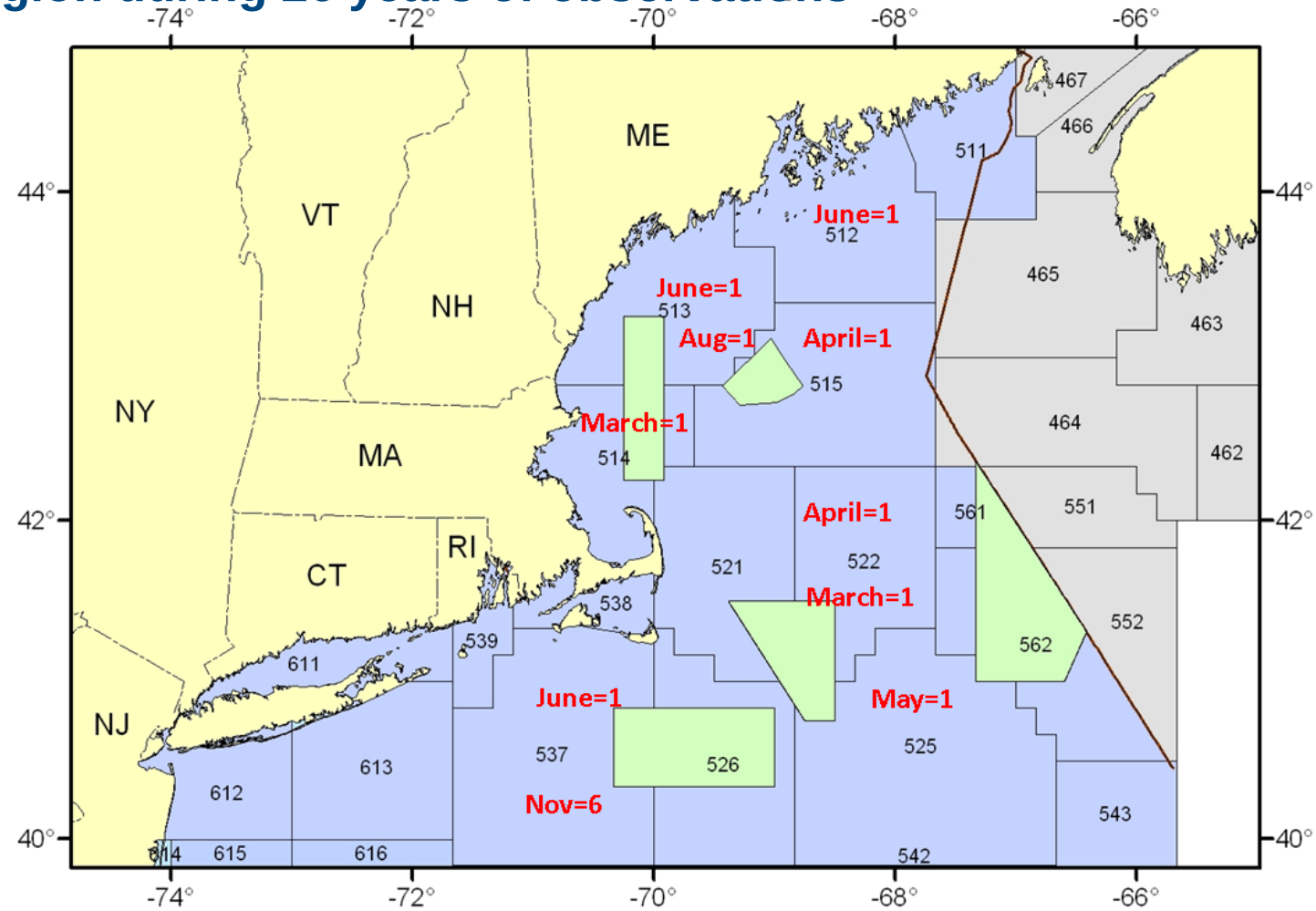


$$Bycatch = \frac{obs\ takes}{obs\ effort} \cdot total\ effort$$

- Annually estimated
- 8 species
- Stratified by:
  - 3 seasons
  - Area (port group/management areas/state)
  - Gear characteristics (mesh size and soak duration)
- Weighted average of:
  - Pinger/no pinger use
  - Groundfish/not groundfish
- Unit of effort = amount of landings
- Bootstrap for variance

Example 2: very rare event - Atlantic Salmon Bycatch

- **15 salmon observed in 7 statistical areas in the Gulf of Maine region during 26 years of observations**



Atlantic Salmon By-Catch Summary

- Bycatch is uncommon, summarized annually
- Total documented = 15 individuals (1989 - Oct 2013)
- Bycatch = 0 in 18 of 25 years, observed in 7 years
- Highest documented 1992 (7 fish)

Year	Fish Count	Weight (lbs)	Weight (kg)
1990	1	1.0	0.45
1992	7	26.0	1.68
2004	1	2.0	0.91
2005	2	6.8	1.54
2009	1	9.0	4.08
2011	1	11.0	4.99
2013	2	16.0	3.63
Totals	15	71.8	Avg = 2.5

From: Kocik, J.F., Wigley, S.E., Kircheis, D. 2014. Annual bycatch update Atlantic Salmon 2013. U.S. Atlantic Salmon Assessment Committee Working Paper.

First expanded salmon bycatch estimate

Wigley SE, Blaylock J, Rago PJ, Shield G. 2014. 2014 Discard estimation, precision, and sample size analyses for 14 federally managed species groups in the waters off the northeastern United States. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 14-05; 157 p. Available from: National Marine Fisheries Service, 166 Water Street, Woods Hole, MA 02543-1026. http://www.nefsc.noaa.gov/publications/crd/crd1405/crd1405.pdf

49 live pounds estimated discarded (CV=0.928) in the NE gillnet large mesh (5.5 – 7.99 in) fishery

Atlantic salmon

- Annual (Jul 2012 – Jun 2013)
- Stratified by:
  - Gear type
  - Region (NE & Mid-Atlantic)
  - Mesh size
  - 4 seasons
- Bycatch rate =

$$\frac{\text{Live lbs discarded}}{\text{Live lbs kept}}$$

- Expanded by VTR data

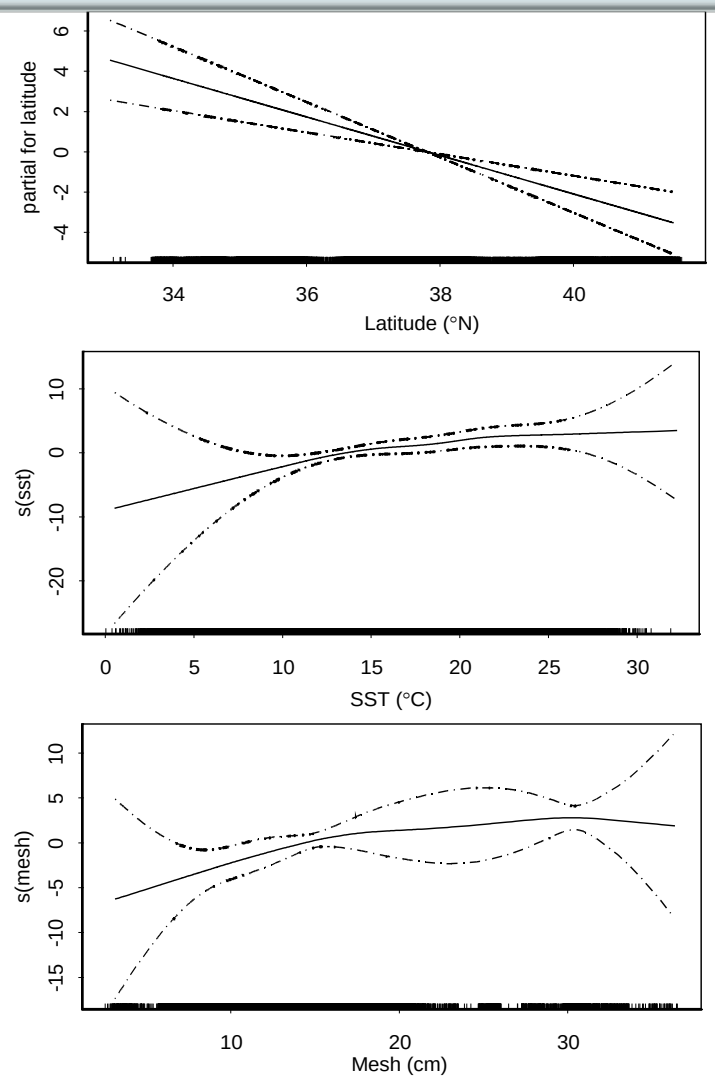
Example 3: GAM modeling loggerhead turtle bycatch

Murray, K. 2011. Interactions between sea turtles and dredge gear in the US sea scallop fishery, 2001-2008. Fisheries Research 107:137-146.

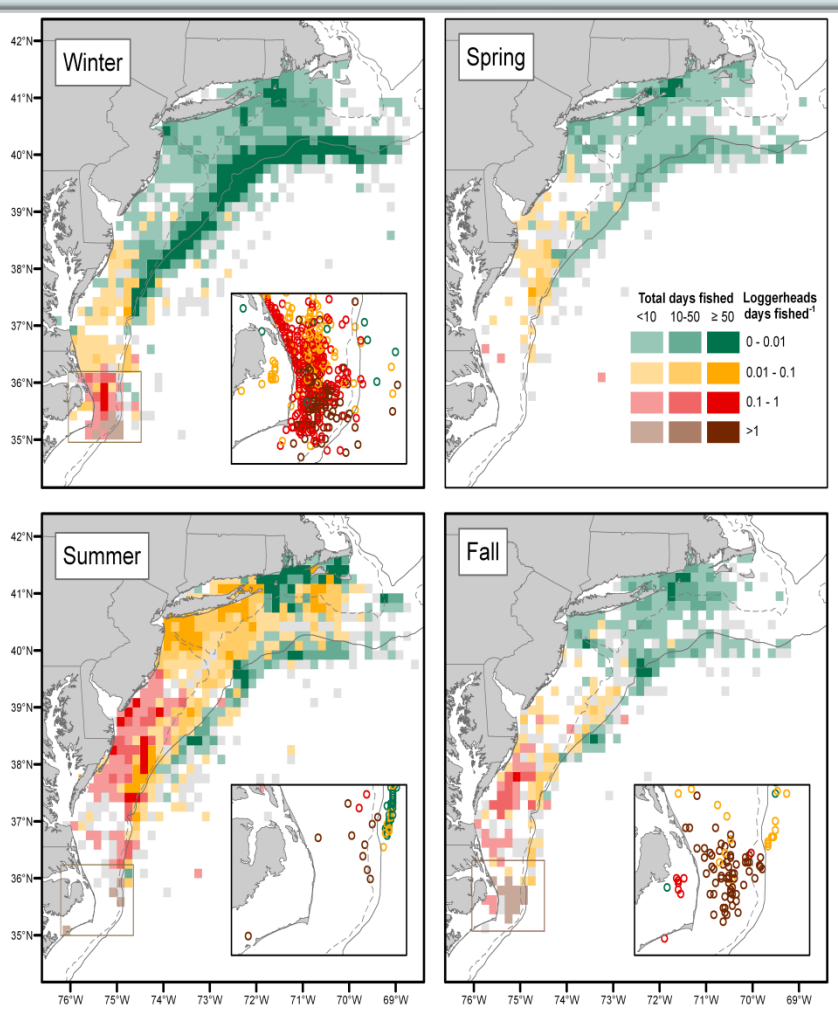
- Bycatch rate = # of turtles / hours spent fishing per dredge
- Observer data when observer was "on-watch"
- VTR data used to expand to fleet
- GAM with a Poisson distribution
- Potential covariates = SST, bottom depth, presence of a chain mat, chlorophyll, latitude, time of day, number of hauls, amount scallops landed, dredge frame, year, spatial area, month

Model structure	Residual d.f.	Residual deviance	Cumulative % of deviance explained	AIC statistic	Pr (Chi)
Primary variables					
Null model	66,580.0	873.6		875.6	
Null + s(SST)	66,576.2	752.0	0.139	761.6	0.00
Null + s(SST) + s(depth)	66,572.2	708.5	0.189	726.2	0.00
Null + s(SST) + s(depth) + chain mat	66,571.2	688.4	0.212	708.0	0.00
Null + s(SST) + s(depth) + chain mat + s(scallop tons)	66,567.3	676.9	0.225	704.4	0.02
Null + s(SST) + s(depth) + chain mat + s(scallop tons) + s(latitude)	66,567.3	679.4	0.222	706.8	0.06
Null + s(SST) + s(depth) + chain mat + s(chlorophyll a)	66,567.3	685.4	0.215	712.8	0.54
Null + s(SST) + s(depth) + chain mat + time bin	66,570.2	687.0	0.214	708.6	0.24
Null + s(SST) + s(depth) + chain mat + number of hauls	66,570.2	688.2	0.212	709.9	0.72
Null + s(SST) + s(depth) + chain mat + dredge frame width	66,570.2	688.0	0.212	709.7	0.35
Secondary variables					
Null + s(SST) + s(depth) + chain mat + year	66,570.2	680.5	0.221	702.2	0.01
Null + s(SST) + s(depth) + chain mat + spatial area	66,566.2	677.5	0.224	707.2	0.05
Null + s(SST) + s(depth) + chain mat + month	66,560.3	687.0	0.214	728.4	0.10

Generalized Additive Modeling



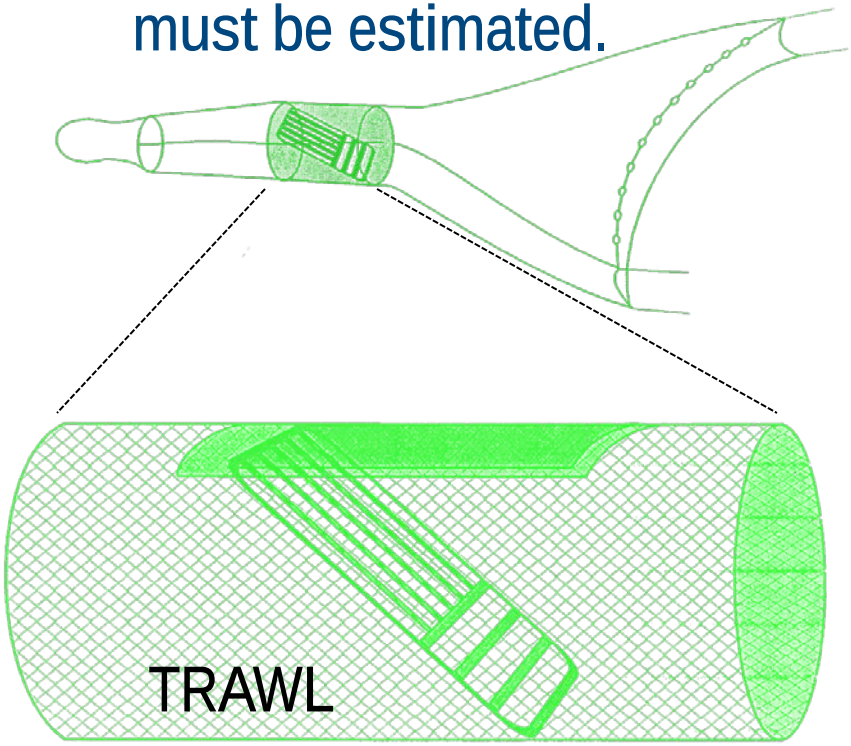
From Murray, KT. 2009.. Characteristics and magnitude of sea turtle bycatch in US mid-Atlantic gillnet gear. *Endang. Sp. Res.*8(3)

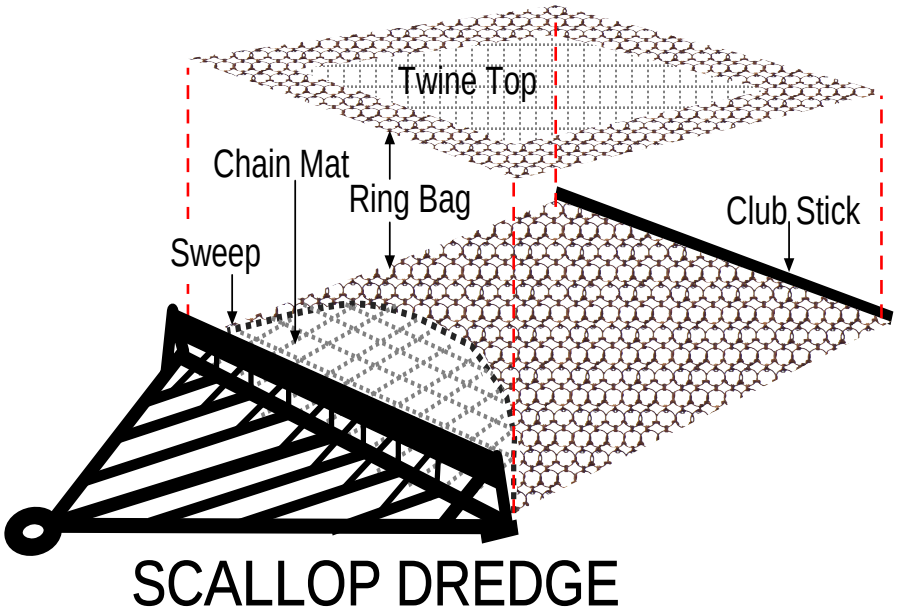


From Warden, M 2011. Modeling loggerhead sea turtle (*Caretta caretta*) interactions with mid-Atlantic bottom trawl gear for fish and scallops, 2005-2008. *Biol. Cons.*144(9)

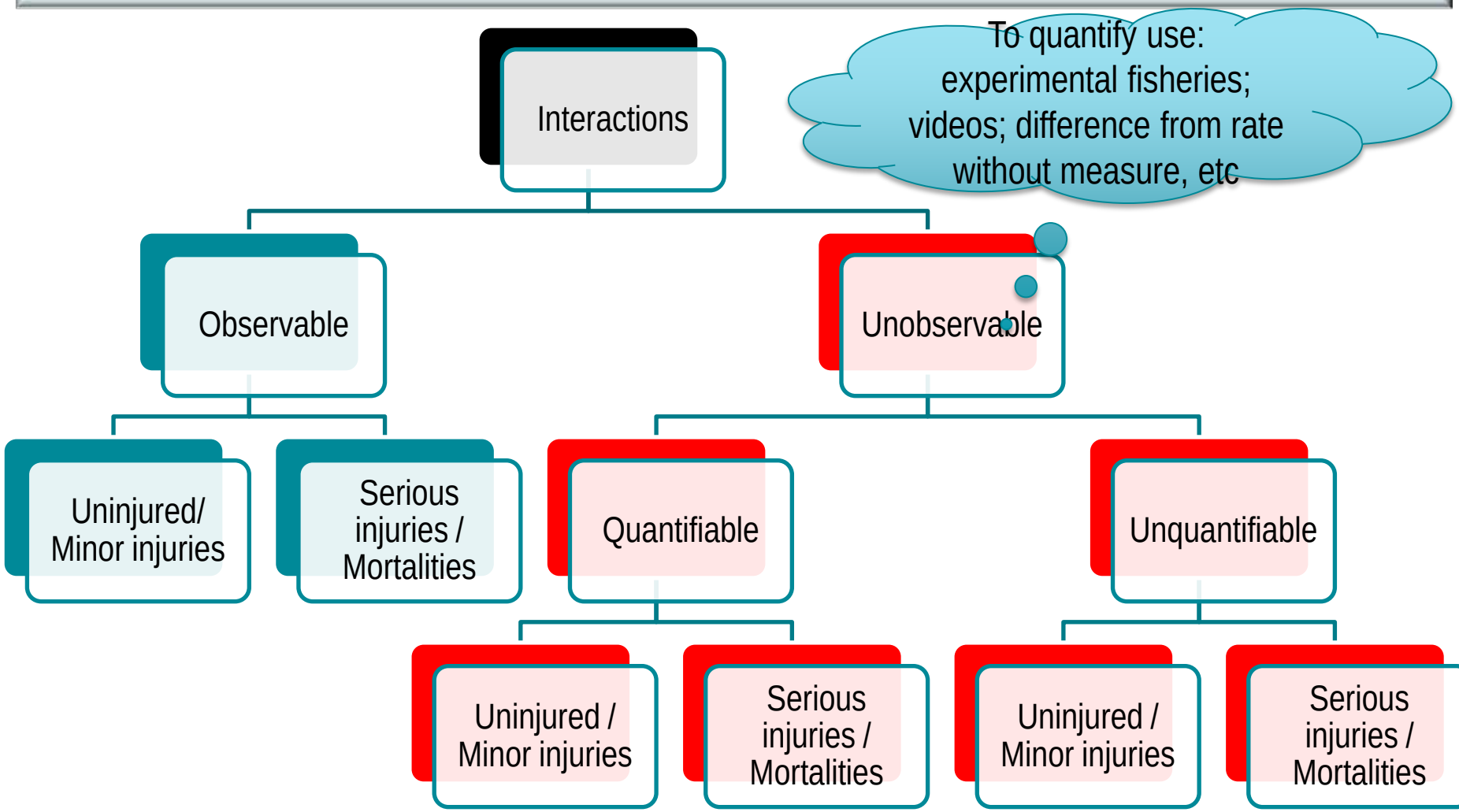
Unobserved takes – How do we monitor this?

- Due to effective management measures (chain mats in scallop dredge fishery, turtle excluder devices (TEDs) in trawl fishery), many turtles are not caught and brought on deck but they still may be interacting with the gear and so are an ESA "take" which must be estimated.





Conceptual Framework

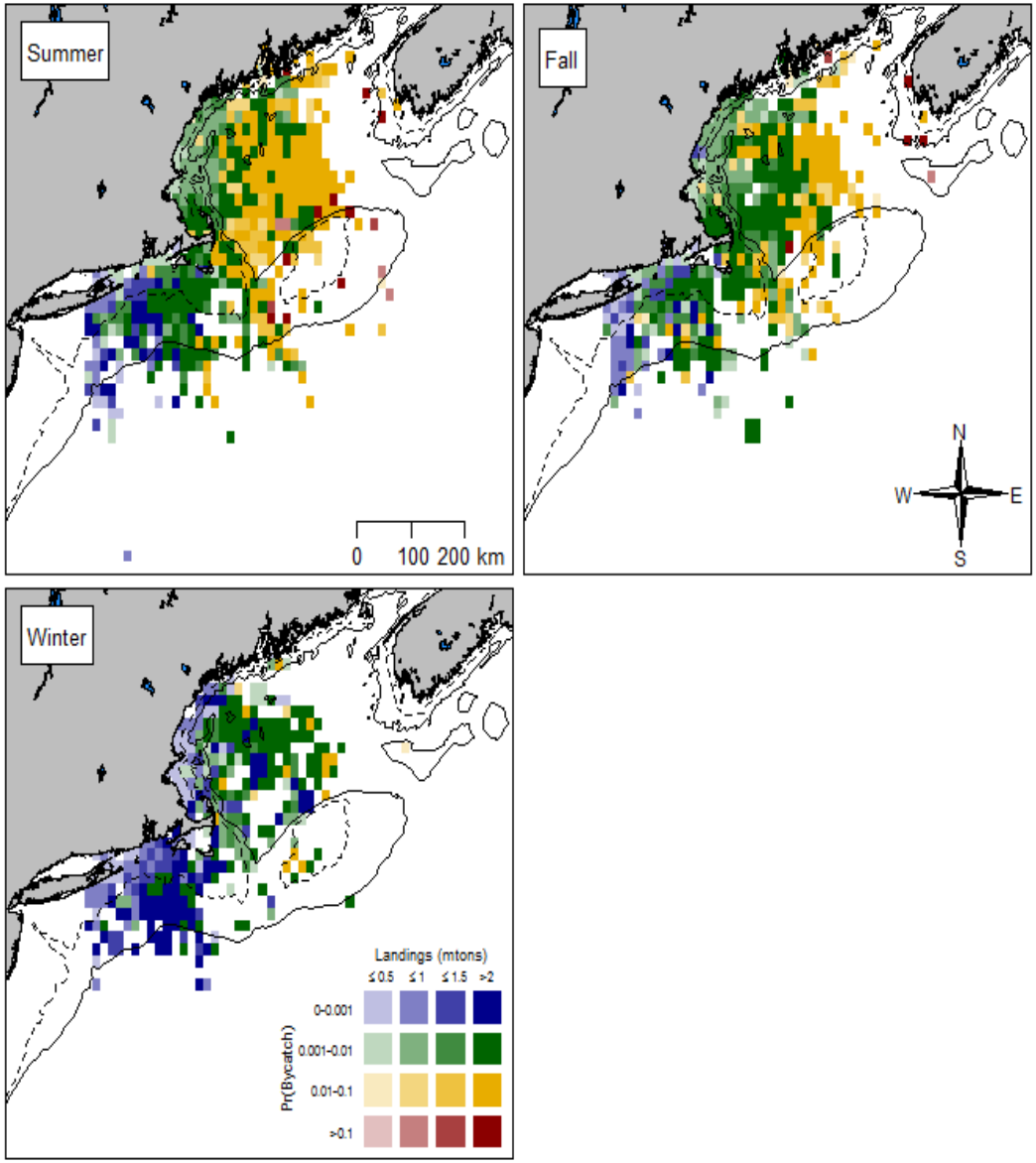


From Warden and Murray 2011. Reframing protected species interactions with commercial fishing gear: Moving toward estimating the unobservable *Fish. Res*. 110

Example 4: Bayesian estimates of great shearwaters

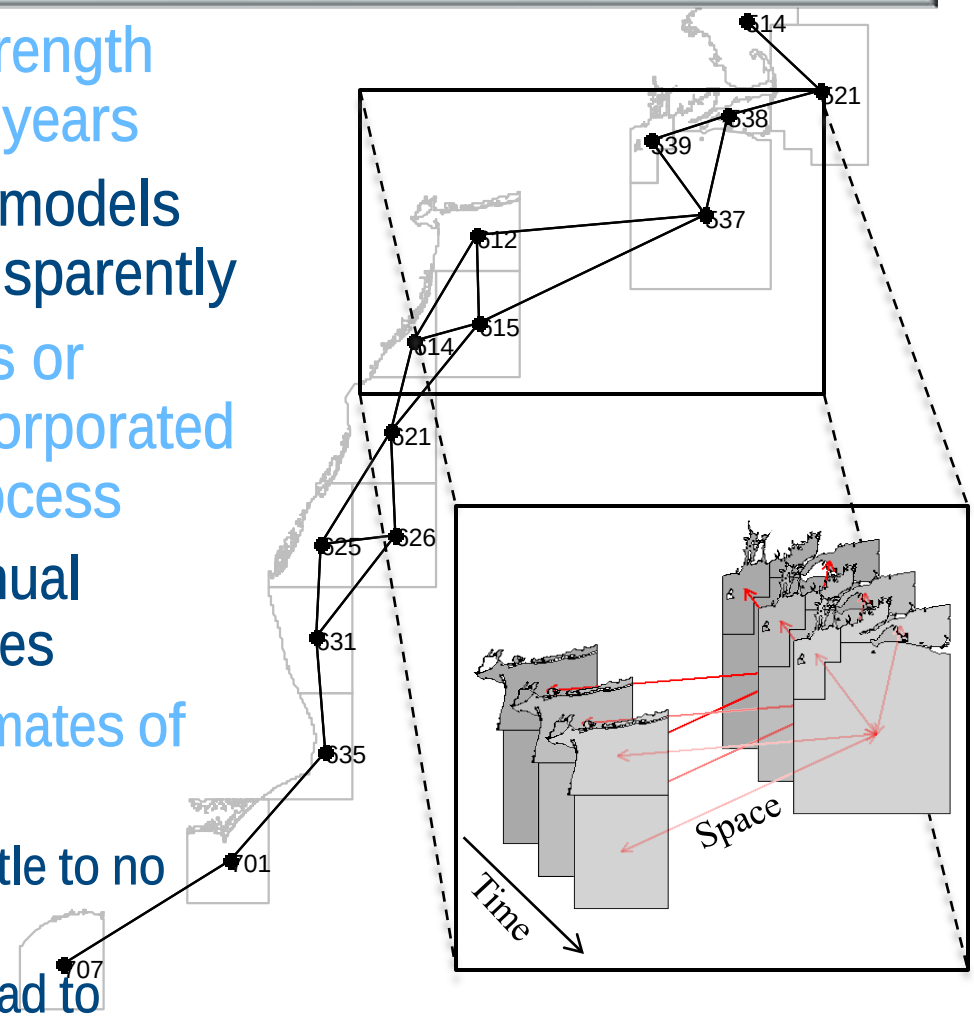
Hatch, JM. In review. Incidental mortality of great shearwaters (*Puffinus gravis*) in the US New England sink gillnet fishery from 1996-2011

- Bayesian 2-part conditional hurdle model using zero-truncated Poisson and negative binomial distributions
- Generalized linear mixed-models
- Potential covariates: SST, depth, NAO with lags, latitude and longitude.



Comprehensive Estimates of Seabird Bycatch using Bayesian Hierarchical Methods

- Data-poor strata can borrow strength from neighboring areas and/or years
- Uncertainty in parameters and models are handled efficiently and transparently
- Information from prior analyses or assessments can be easily incorporated into the bycatch estimation process
  - Potential to smooth inter-annual variability in bycatch estimates
  - May help reduce bias in estimates of bycatch as a result of:
    - Poor coverage resulting in little to no observed bycatch events
    - Observing rare events that lead to volatile bycatch estimates through inflated scaling factors



Contributions to biological information

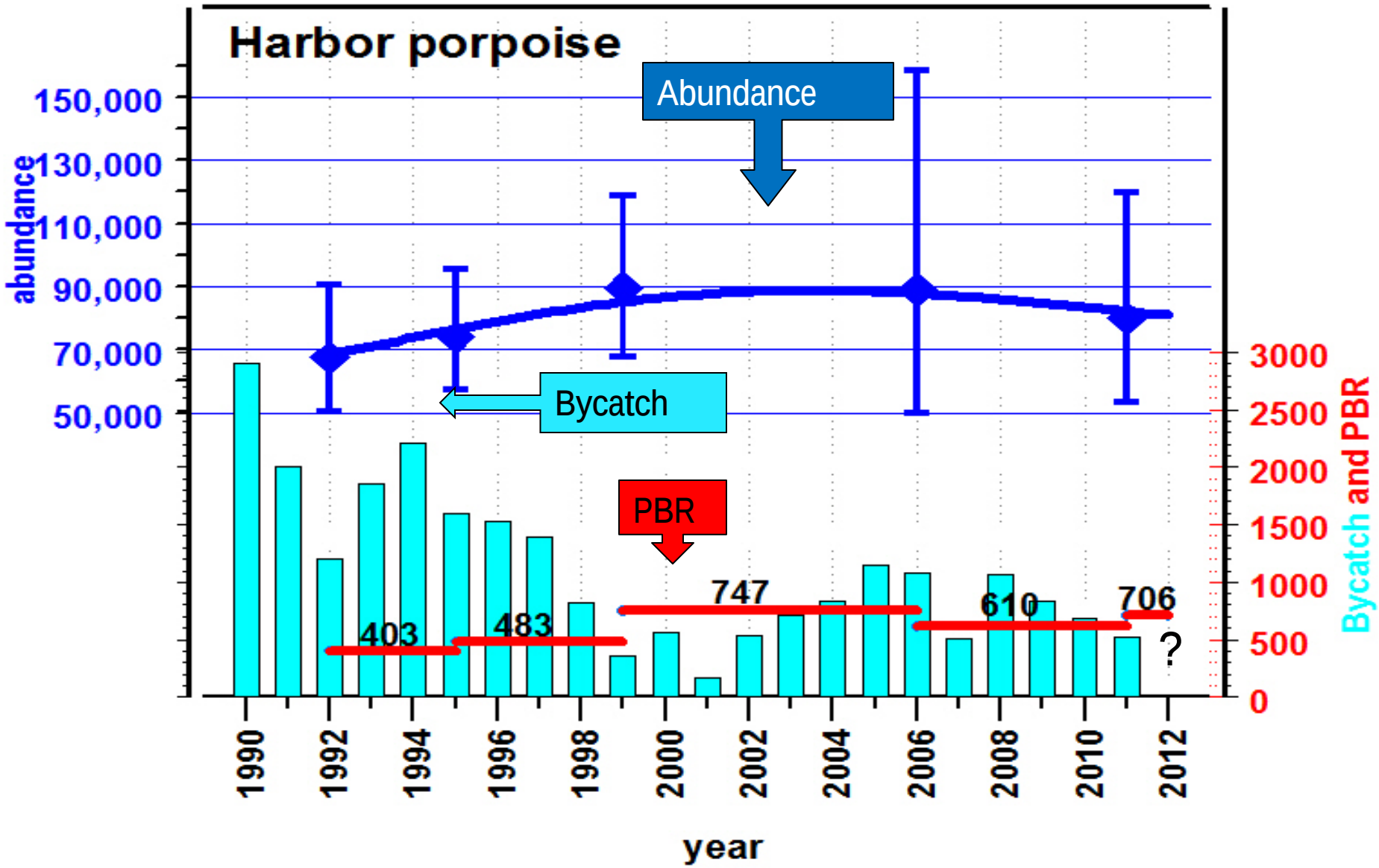
Basic biology & life history parameters
Stock structure
Food habits

Use of fishery dependent data in management

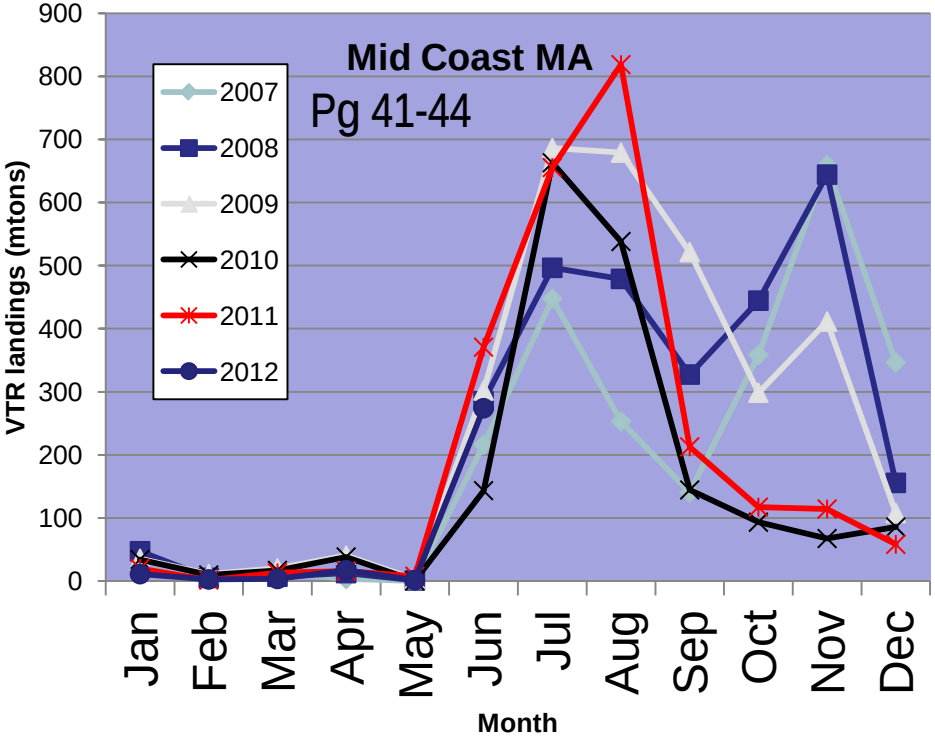
1. Provide input to management bodies
2. Identify “hot” spots, i.e., areas of concern
3. Identify potential mitigation options
4. Estimate predicted bycatch under scenarios of potential mitigation options
5. Monitor compliance of mitigation options
6. Quantify population level impact of takes

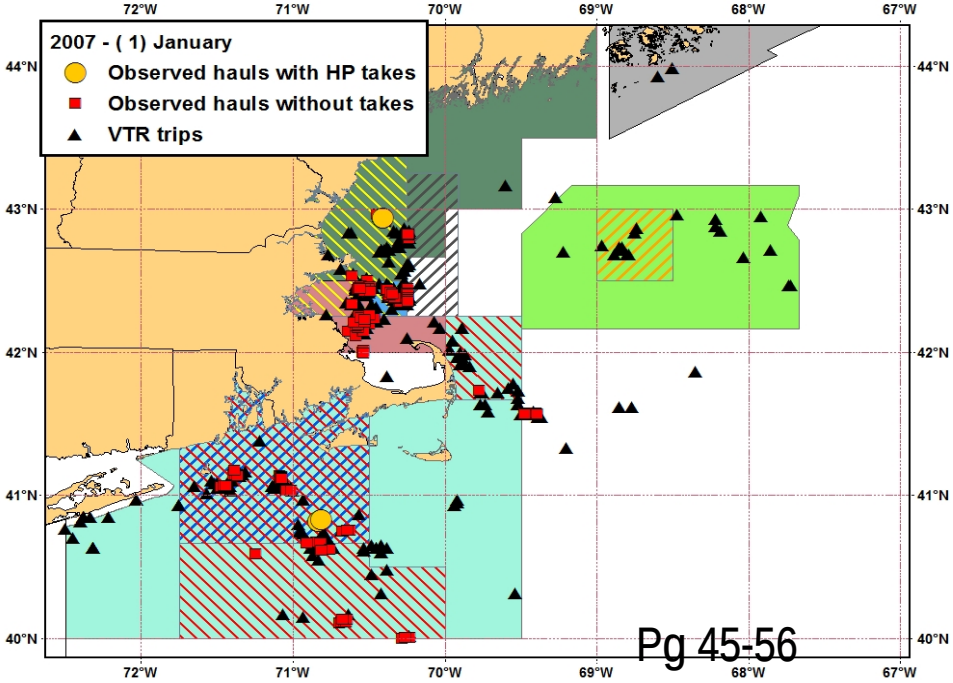
Example 1: Harbor Porpoise Take Reduction Team

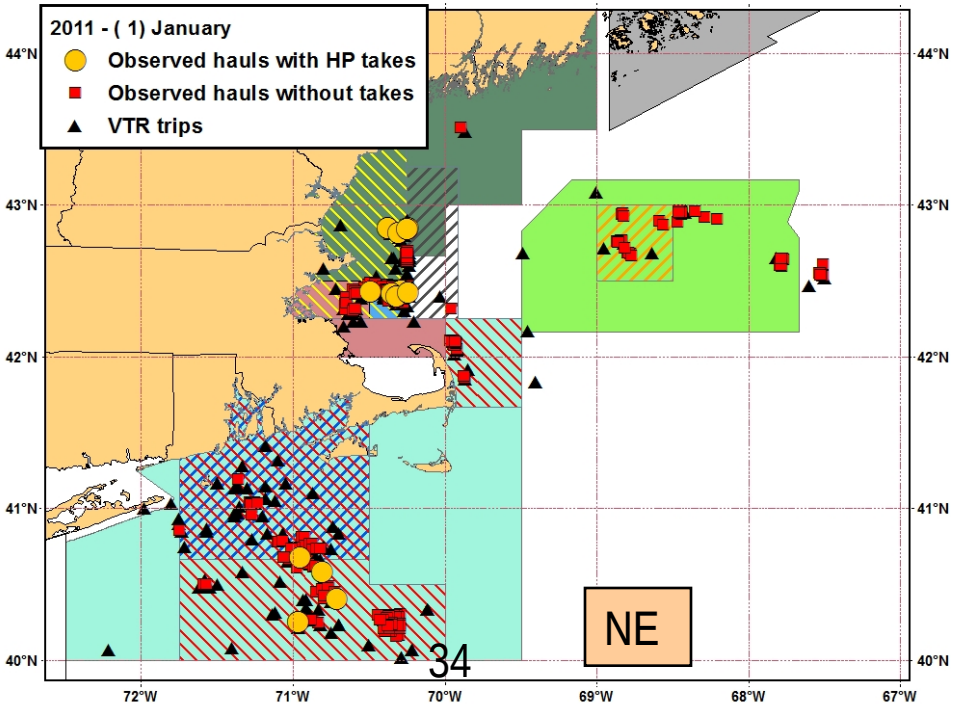
Provide basic background information



General information on when and where bycatch occurs relative to fishing effort





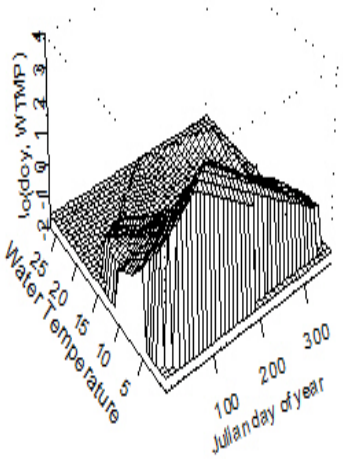


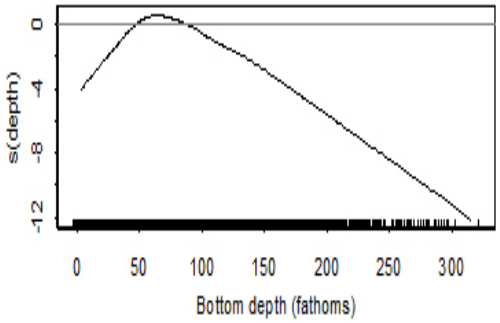
2009. Palka et al. Summary of harbor porpoise bycatch and levels of compliance in the Northeast and mid-Atlantic gillnet fisheries after the implementation of the Take Reduction Plan: 1 Jan 1999 – 31 May 2007

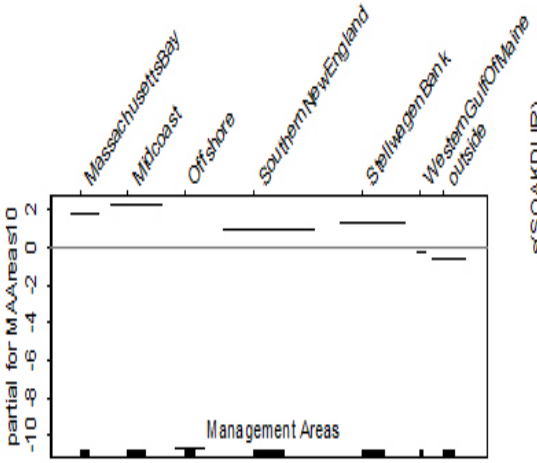
General information on gear characteristics with highest bycatch

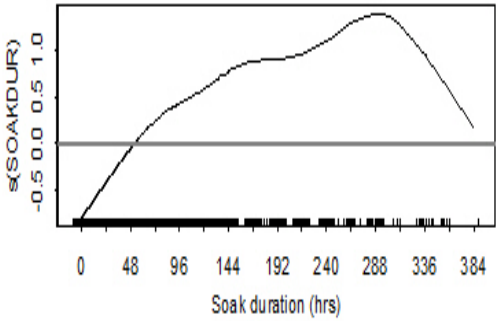
Highest bycatch rates
in Gulf of Maine
during 2007 – May 2012:

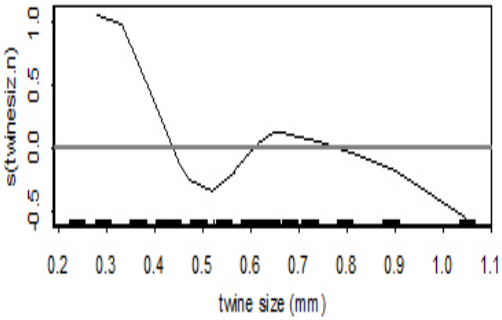
- November - May
- 50 – 100 fathoms deep
- colder waters
- Mid-Coast Management Area
- long soak durations
- smaller twine sizes











Results for Generalized Additive Modeling of Observed bycatch rate

NE pgs 28 & 65

NOAA FISHERIES

Expected consequence of a potential mitigation measure

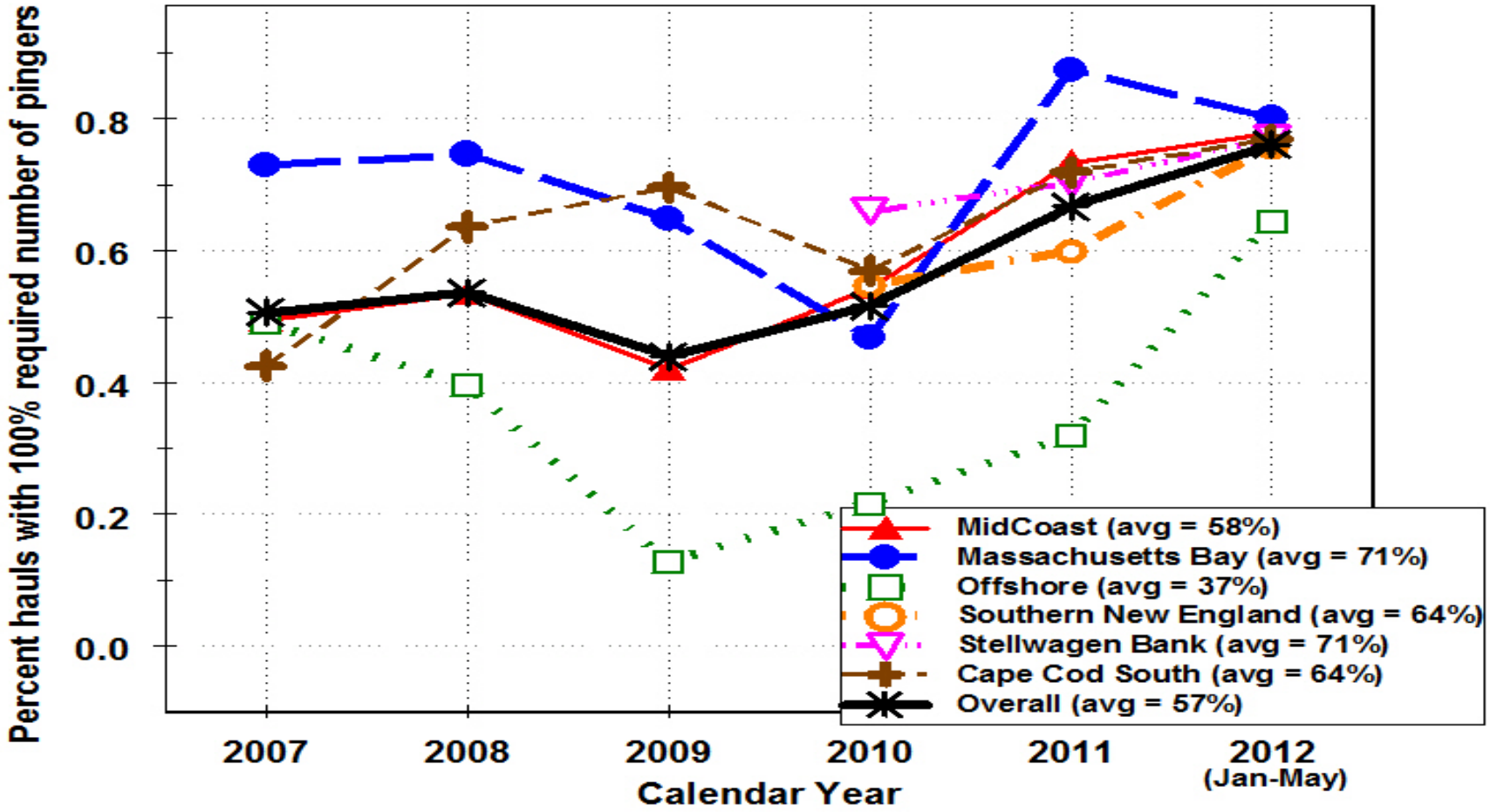
Palka, D. & Orphanides, C. 2008. Predicted bycatch of harbor porpoises under various alternatives to reduce bycatch in the US Northeast and mid-Atlantic gillnet fisheries. Northeast Fisheries Science Center Reference Document 08-14

- Use observer data to simulate potential measure
- Use commercial data to reflect the potential measure
- Estimate predicted bycatch under potential measure
- Compare with actual and targeted bycatch

Time/Area	2005 Actual bycatch estimates	Alternative 1. Closures		Alternative 2. Pingers	
		Min	Max	Min	Max
Winter NE	306	147	248	57	101
Summer NE	52	44	44	44	44
Fall NE	272	47	111	50	87
NORTHEAST SUBTOTAL	630	238	403	151	232

Compliance with pinger regulations

- Pinger usage dropped in 2009 and 2010, increased in 2012 (Jan-May) to avg of 76%



Annual updates

Summary of 2013 pinger functionality for a limited number of NEFOP-observed hauls within times and areas where pingers were required by the 2010 harbor porpoise take reduction team plan.

From: Hatch, J. & Orphanides, C. in review. Estimates of cetacean and pinniped bycatch in the 2013 New England sink and mid-Atlantic gillnet fisheries.

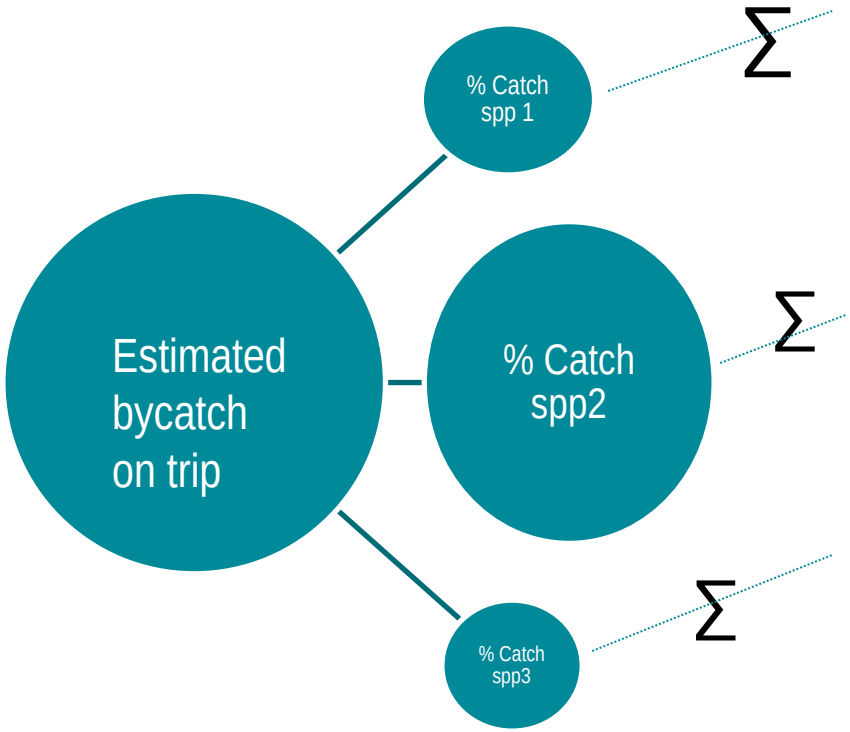
Season 2013	Obs # hauls	Lost	Not working	Working	Unknown	Total tested	% working
Jan-May	175	47	78	2354	3	2482	95
Sep-Dec	15	0	0	159	16	175	100
Total	190	47	78	2513	19	2657	95

Example 2: Loggerhead Bycatch Management Needs

1. Bycatch estimates form the basis of Incidental Take Statements (ITS) in Section 7 Consultations on the Fishery
2. The spatial and temporal distribution of bycatch hotspots, as well as factors correlated with high bycatch rates, inform conservation engineering
3. The magnitude of interactions and Adult Equivalents (AE) removals are used in population assessment tools

Reporting turtle bycatch by fishery

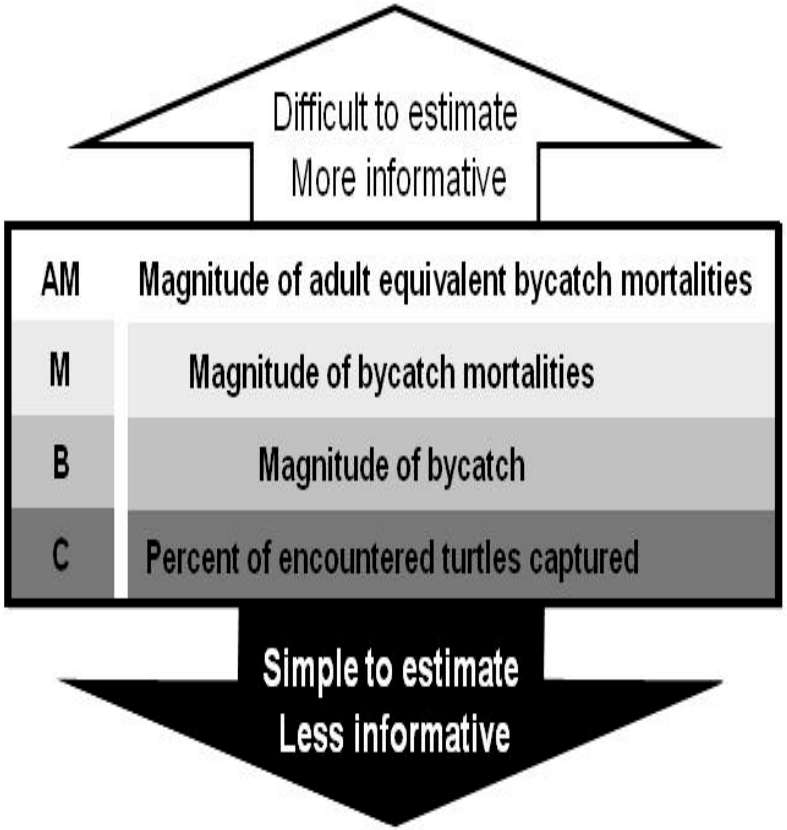
- Total estimated turtle bycatch on a trip proportioned across landed catch reported on VTR



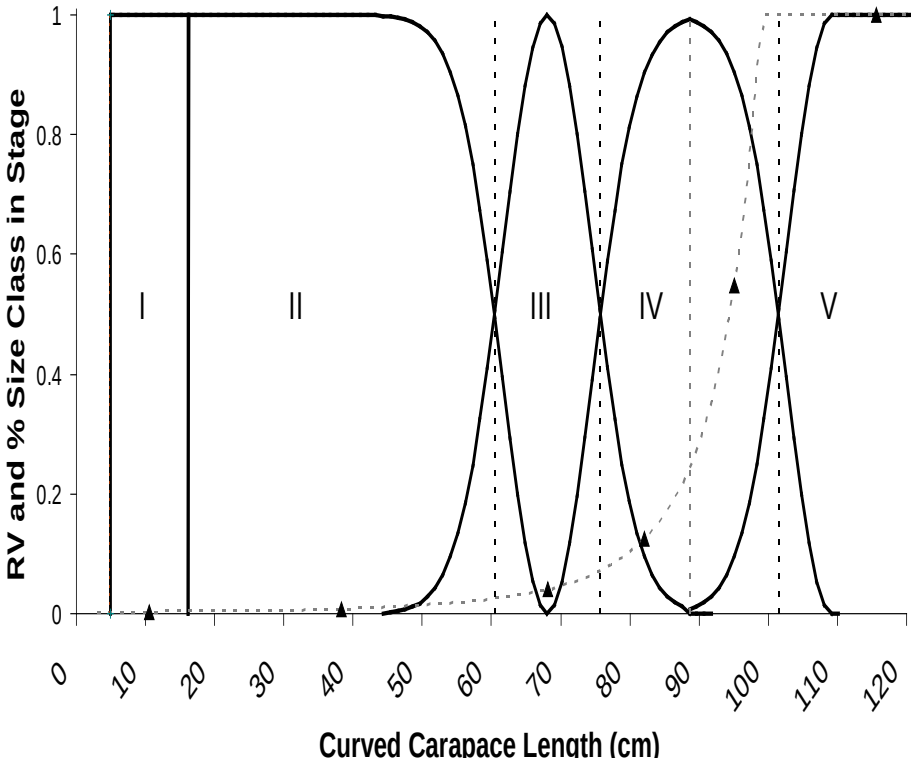
Managed Species[3]	Avg ton observed landed	Estimated Loggerheads							
		2007	2008	2009	2010	2011	Mean	CV	95% CI
Monkfish	196	23	44	7	23	39	27	0.28	16-41
Skates	218	6	10	6	30	30	16	0.30	9-23
Spiny dogfish	43	2	2	4	7	11	5	0.37	2-8
Smooth dogfish	18	9	11	14	23	26	17	0.54	6-32
Bluefish	49	14	7	22	22	7	14	0.46	6-26
Summer flounder	2	0	0	0	0	1	0	0.38	0-0
Croaker	55	18	3	2	2	4	6	0.43	2-10
Spanish mackerel	5	0	0	1	1	1	1	0.73	0-1
King mackerel	1	1	0	0	1	1	1	0.53	0-1
Sandbar shark	0	1	1	0	0	0	0	0.65	0-1
Black-tipped shark	0	1	2	0	1	0	1	0.41	0-1
Thresher shark	0	0	0	0	1	0	0	0.48	0-0
Sharpnose shark	0	0	1	0	1	0	0	0.43	0-1
Black drum	0	0	1	0	1	0	0	0.54	0-1
Total		75	82	55	113	120	89		

From Murray 2013. Estimated loggerhead and unidentified hard-shelled turtle interactions in mid-Atlantic gillnet gear, 2007-2011*NOAA Tech Memo*. 225

Adult Equivalent interactions as part of evaluating population impacts



From Haas, HL. 2010. *Mar. & Coastal Fish. 2*



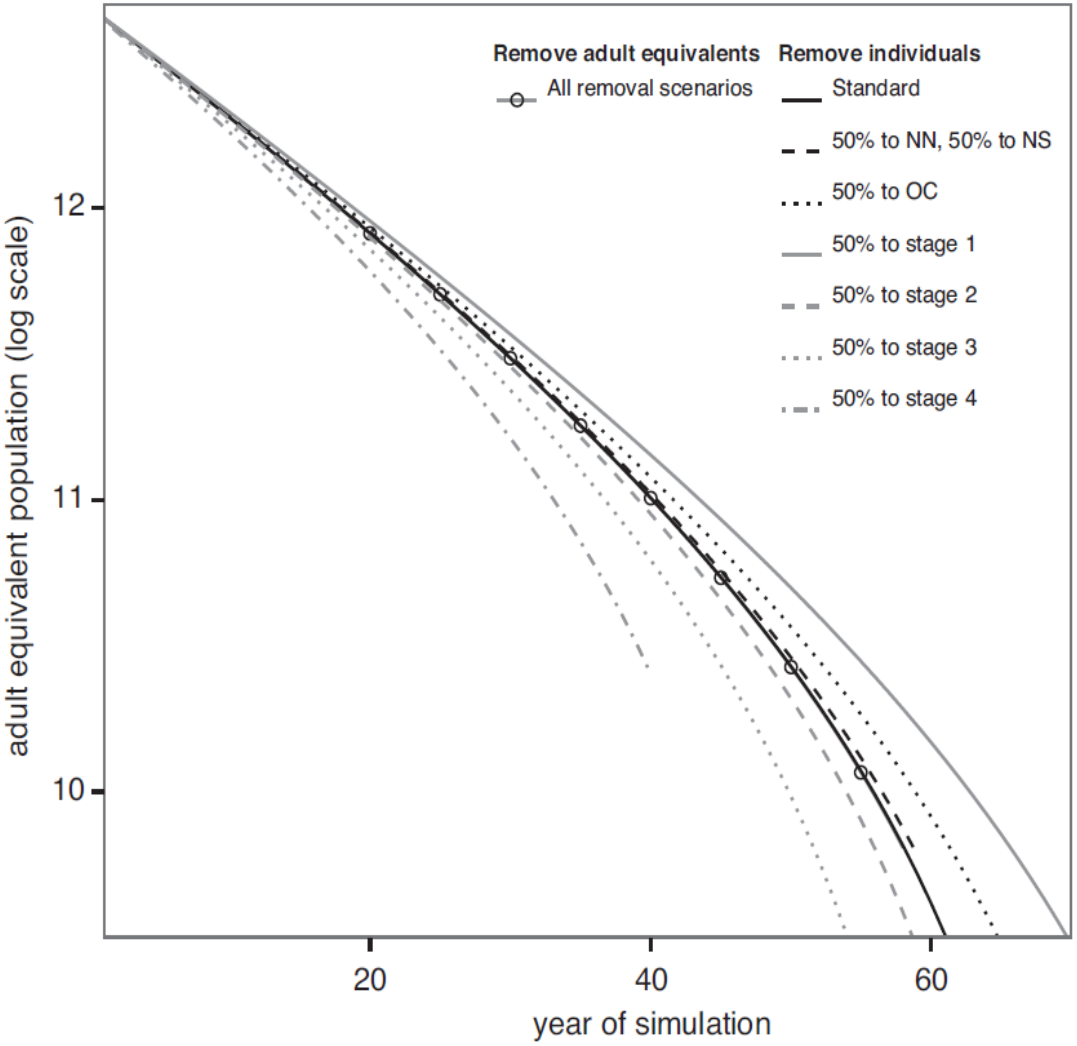
From Murray, KT. 2011. *Fish. Res*. 107

Turtle bycatch analyses feed into…

Population Assessments

This work emphasizes the importance of managing and monitoring Incidental Take Statements in terms of turtle adult equivalents rather than individuals, because it is a more reliable indicator of the impact of bycatch removals from the population

From Warden M. 2015. A spatially explicit population model of simulated fisheries impact on loggerhead se turtles in the NW Atlantic Ocean *Ecol Mod. 299*



Turtle bycatch analyses feed into NEFSC gear research

Problem Identification All

Bycatch analysis to describe interaction and spatial and temporal extent of the bycatch problem

Gear Design

Development of pilot study to test feasibility of gear modification

Test experimental gear in commercial fishery

Experimental fishery

NEFSC provides scientific information to GARFO

GARFO decision making

We plan to work with industry to the full extent possible throughout the entire documentation, design, and testing phases. We believe that working with industry when possible is beneficial because it allows us to gain knowledge about the fishing industry and increases the likelihood of industry acceptance and compliance. Without industry involvement in all phases, any bycatch reduction technology (BRT) could be met with skepticism by the industry, which could lead to non-compliance, political intrusion, and non-acceptance of any proposed BRT.

Modified gear designs are determined with input from the industry. Their support is considered crucial for successful implementation of a gear modification.

Test the experimental gear on commercial vessels, using commercial gear and commercial fishing practices and use a robust statistical design to evaluate the effectiveness of the gear modification.
Test for both difference in target catch and protected species catch.
Test across appropriate strata (such as time, area, or fishing strata).
Test with enough trials to detect a difference (alpha=0.05) if a difference exists.

Observers are placed on commercial vessels operating in the commercial fishery and collect quantitative data on the gear modification that is used to assess the effectiveness of the gear modification.

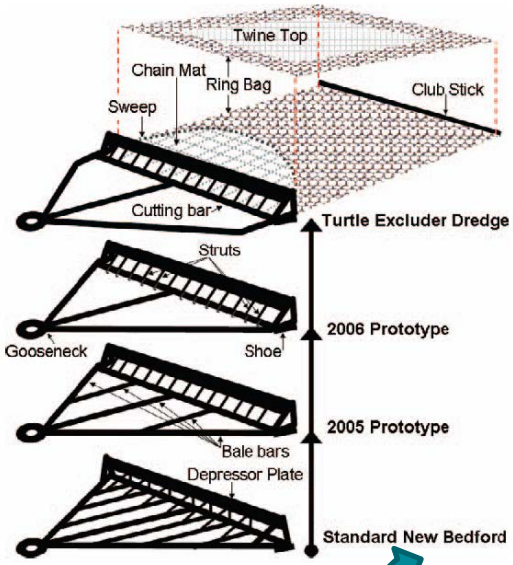
http://www.nefsc.noaa.gov/read/protspp/PR_gear_research

Key to color coding

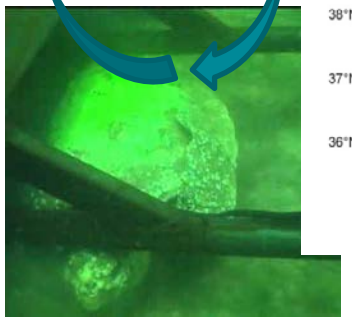
NMFS GARFO	NMFS NEFSC	Fishing Industry

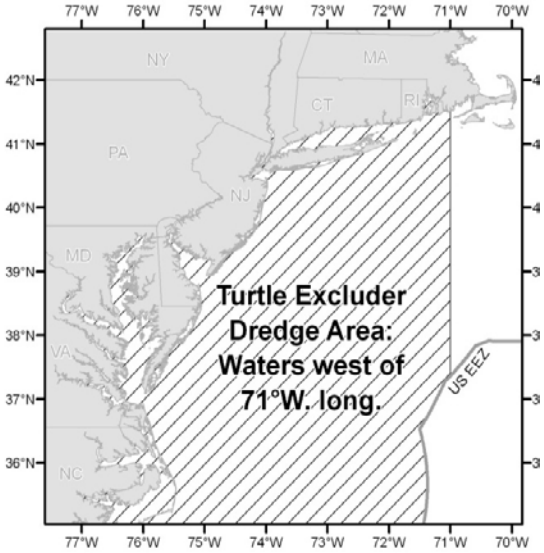
Conservation Engineering Success Story

Bycatch analysis



With industry, design, field test, modify design, field test again, use carcasses to test gear, finally evolve into efficient mitigation measure that still fishes the target species





Rulemaking

Collaborations

- Fisheries Related Organizations
  - Fishery Management Councils
  - Marine Fisheries Commissions
  - Individual State Fishery Programs
  - Industry organizations, such as Sector Managers
  - Fishers, especially related to gear research
- Lots of scientists at universities and other NMFS centers, as mentioned earlier

Reviews/Transparency

- Journal papers are peer-reviewed
- Marine mammal bycatch reviewed by ASRG
- Reviews received from
  - Take Reduction Teams
  - Fishery management teams
  - NOAA Fisheries Service regional offices
- Observer data available to the public except for confidential information

Strengths

- Bycatch estimates
  - Rich observer and commercial data sets available
  - Robust methods developed to estimate bycatch and investigate bycatch rate patterns
  - Demographic information incorporated to evaluate population impacts on turtles
- Management needs
  - Provide basic information for a variety of species on a routine basis
  - Identify gear characteristics and fishing practices that can be used as mitigation options
  - Evaluate mitigation effectiveness using observer data

Challenges

- Bycatch analyses
  - Commercial effort data (in particular VTR gillnet) are inaccurate and some fields cannot be used in bycatch analyses
  - Proposed shift to electronic monitoring to replace observers would have negative impacts on reported protected species bycatch and biological data collection
  - Most observer data come from the fish and turtle allocation schemes, and there are insufficient funds for observer coverage to monitor some marine mammal issues, particularly in times and areas that do not overlap with fish concerns
  - Difficult estimating very rare events, especially if mitigation measure works well or if there is low observer coverage
  - Too many species to estimate every year and evaluate compliance of mitigation measures
  - Could better incorporate demographic and ecological data into estimates or interpretation of the estimates

Challenges

- Biological data
  - Need more basic information on demography and foraging patterns of many species
- Management needs
  - No biological reference points for turtles to evaluate impact of bycatch
  - Need additional mitigation measures that are easy to monitor and comply to
  - Need to project bycatch under changing environmental conditions and fishing habits
  - Need to incorporate bycatch into ecosystem models

Solutions/Recommendations

- Bycatch analyses/Management needs
  - Continue improving fishery dependent data through the Fishery Dependent Data Committee, including improvements to VTR data form
  - Ensure that core protected species bycatch data and biological samples continue to be collected if/when a shift to electronic monitoring occurs
  - Investigate the use of other monitoring tools, such as stranding data, pilot fleets, or experimental studies, to evaluate bycatch if observers are insufficient
  - Investigate the efficiency and accuracy of conducting multi-taxa and/or multi-gear type bycatch estimation analyses.
  - Evaluate need and biological importance of estimating marine mammal bycatch every year
  - Develop tools that could more automatically evaluate compliance of at least some of the regulations/mitigation measures

Solutions/Recommendations

- Bycatch analyses/Management needs (cont…)
  - More fully utilize the biological data collected from the bycatch, including stable isotope/fatty acid analyses, to learn more about the population impacts of bycatch and co-occurrence with target fish species
  - Establish biological reference points for turtles or tools to assess impact of bycatch on population
  - Collaborate with Social Sciences Branch to investigate predictive models of fishing behavior
  - Collaborate with Ecosystems group to investigate methods to incorporate bycatch into ecosystem models