Juvenile habitat and spawning area recommendations for Omnibus Habitat Amendment 2

CLOSED AREA TECHNICAL TEAM

APRIL 2013

Membership and contibutors

- CATT members
  - David Stevenson
  - Laurel Smith
  - Sean Lucey
  - Dan Caless
  - Tim Cardiasmenos
  - Geret DePiper
  - William Whitmore
  - Evan Bing-Sawyer
  - Sally Roman
  - Dave Thomas
  - Michelle Bachman
  - Andrew Applegate (chair)
- Contributors
  - Owen Liu
  - Sarah Smith
  - Chris McGuire
  - Scott Galager
  - Sam Truesdell

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Table of management options and area estimates

			Description (slide)	Relevant maps (slide)	Georges Bank (nm^2)	Percent	Gulf of Maine (nm^2)	Percent
Habitat	Status quo			9	1,909	6.8%	937	3.7%
	Proposed			10	1,377	4.9%	686	2.7%
	DHRA				170	0.6%	484	1.9%
Groundfish	Year round	Opton 1	56	9	4,994	17.7%	1,285	5.1%
	Coasal area	Option 2	57	59	0	0.0%	4582	18.3%
	Juvenile habitat	Option 3	60	61 - 82	487	1.7%	6,859	27.4%
Spawning (seasonal)	Rolling clousres	Option 1	83		0	0.0%	12,743	50.9%
	Spawning hotspot areas	Option 2	84	86 - 106	449	1.6%	3,423	13.7%
	Modified rolling spawning closures	Option 3	107	108 - 110	0	0.0%	5,273	21.1%
	Western Gulf of Maine and Closed Area II	Option 4	111	9	2016	7.2%	883	3.5%
Total area					28,146		25,044	

Primary Goals of Groundfish Closed Area Management Adopted Nov 2012

1. Enhance groundfish fishery productivity

2. Maximize societal net benefits from the groundfish stocks while addressing current management needs

Objectives for Groundfish Closed Area Management

1. Improved spawning protection; including protection of localized spawning contingents or sub-populations of stocks

2. Improved protection of critical groundfish habitats

3. Improved refuge for critical life history stages

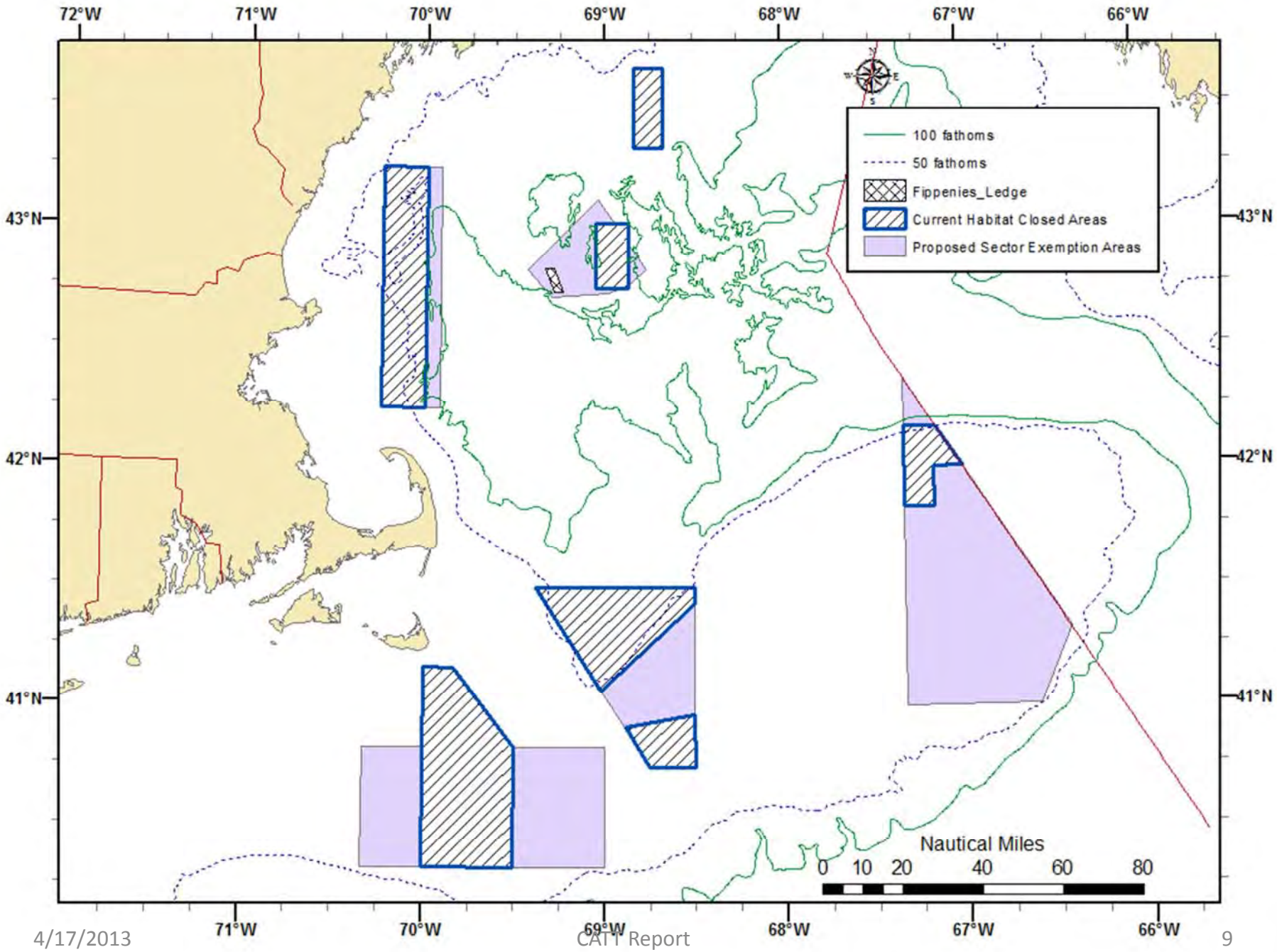
4. Improved access to both the use and non-use benefits arising from closed area management across gear types, fisheries, and groups. These benefits may arise from areas designed to address other three groundfish closed area objectives.

Closed Area Recommendations for Council

- Spawning closures should be narrowly defined spatially and temporally
- Spawning closures should be designed to be adaptive and responsive to variations in environmental conditions
- Spawning closures should include specific triggers that would allow areas to re-open to fishing
- Fishing by all gears and fleets catching groundfish should be prohibited in spawning closure areas

Closed Area Recommendations for Council

- CATT should analyze the efficacy of specific blocks of the rolling closure areas
- Groundfish spawning and habitat closures should include provisions for monitoring the resource conditions
- Monitoring of gears fishing in closed groundfish spawning and habitat areas should be required.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69°W
68°W
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66°W
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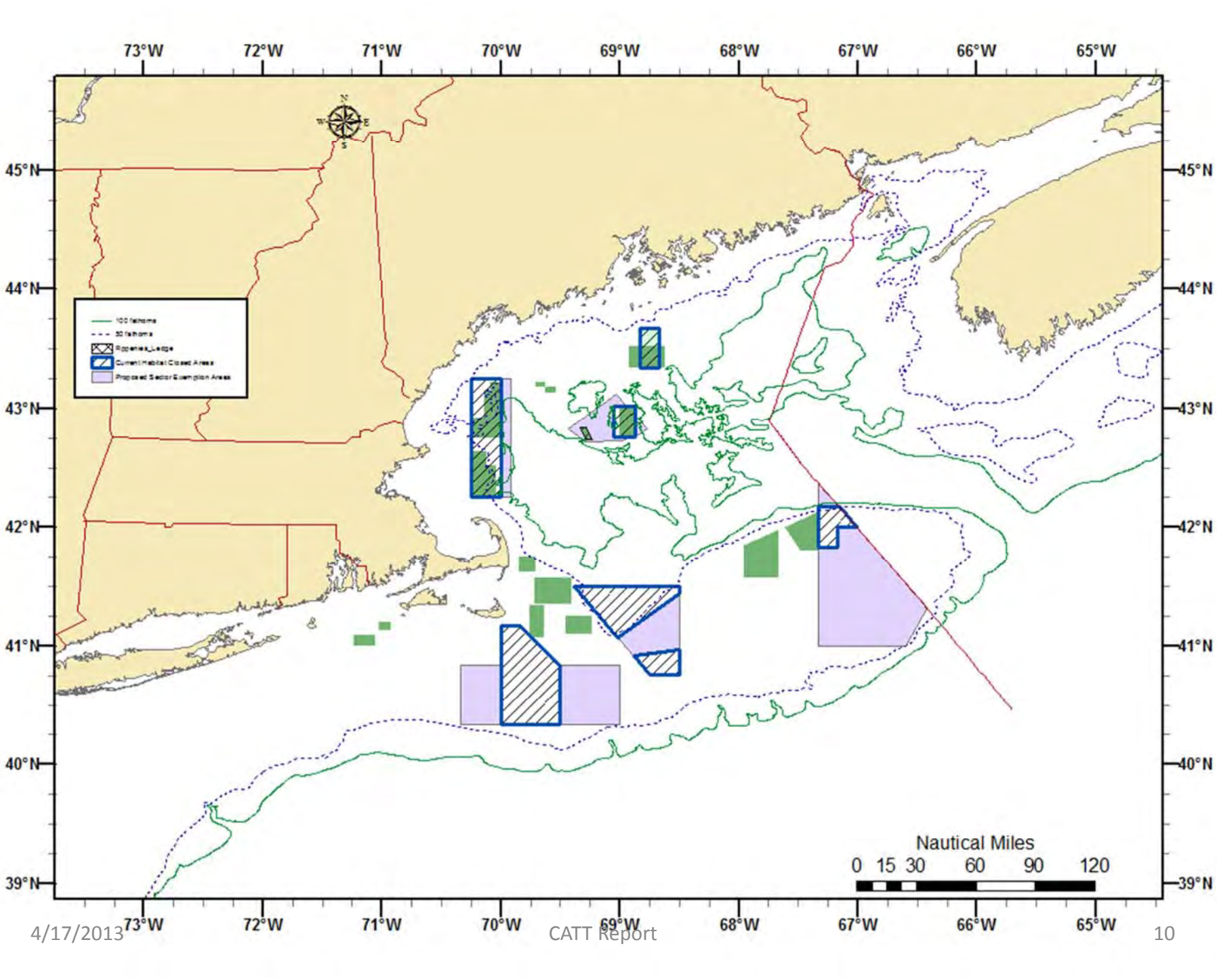
42°N
41°N
100 fathoms
50 fathoms
Fippenies_Ledge
Current Habitat Closed Areas
Proposed Sector Exemption Areas
Nautical Miles
0 10 20 40 60 80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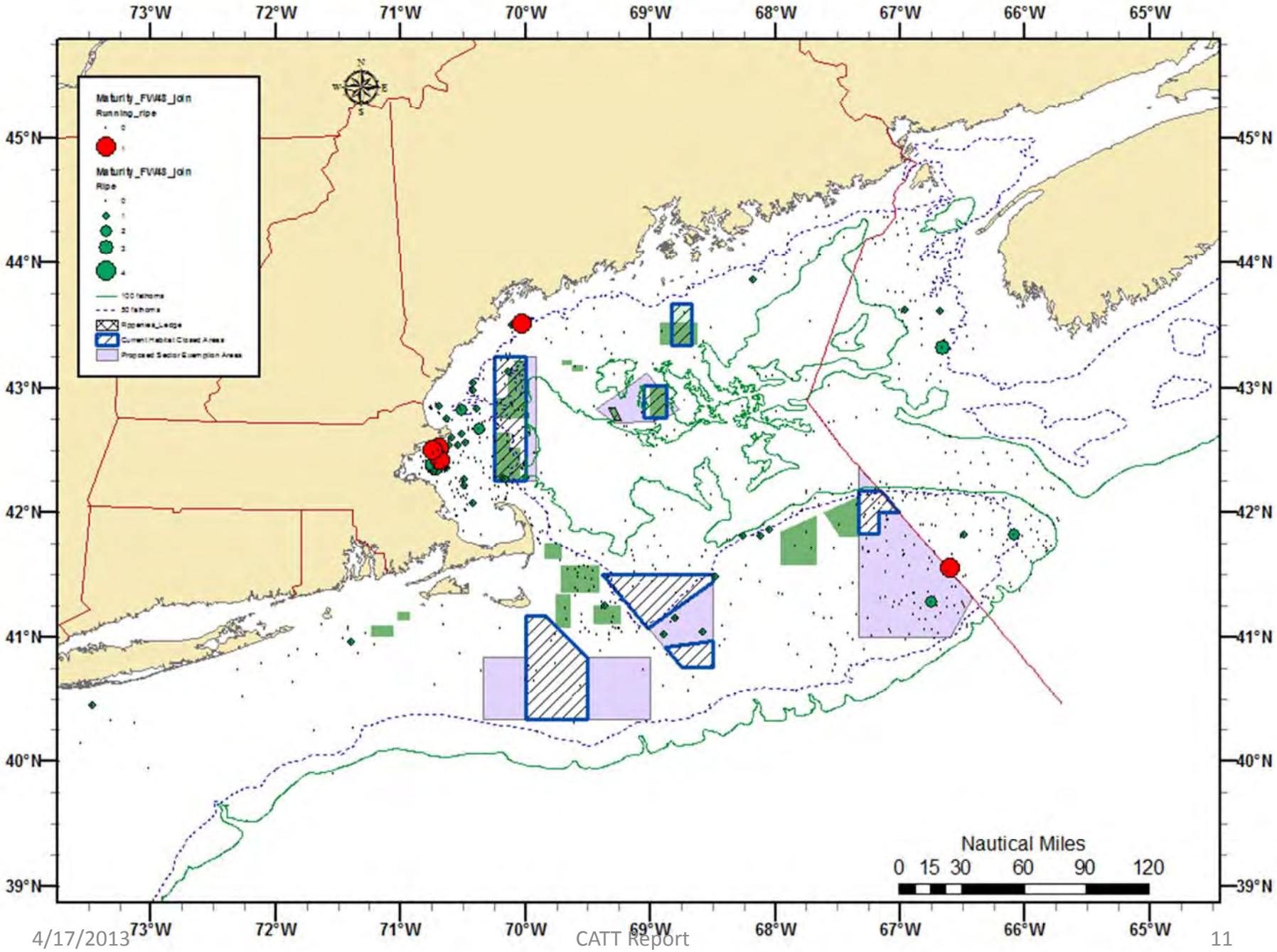
Ripenek_Ledge
Current Habitat Closed Areas
Proposed Sector Exemption Areas
Nautical Miles
0 15 30 60 90 120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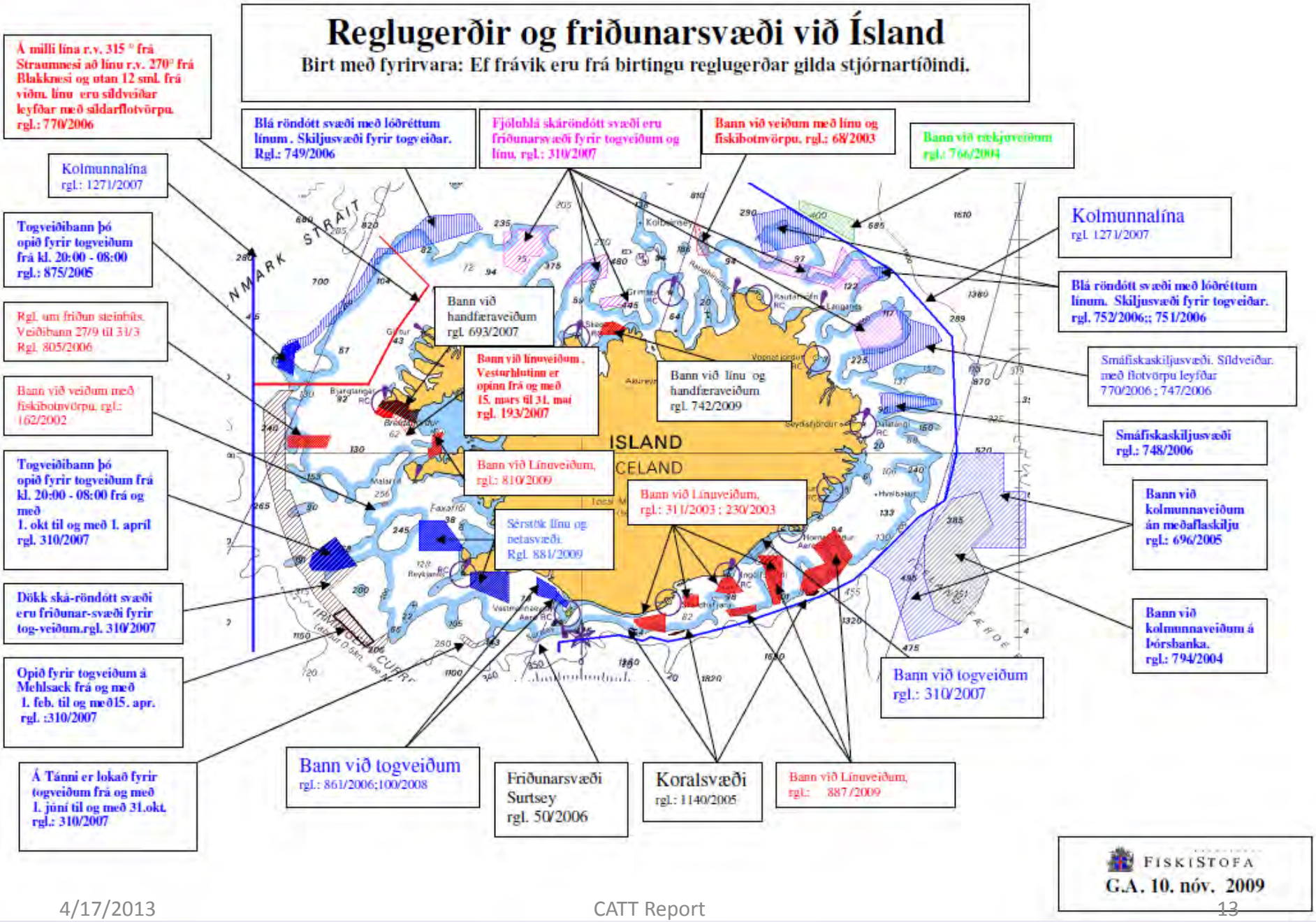
Current Habitat Closed Areas
Proposed Sector Exemption Areas
Nautical Miles
0 15 30 60 90 120

Case studies

- Spatial management
- Temperate latitudes
- Quota-managed fisheries
- Purpose and objective
- Outcomes
- Lessons


Reglugerðir og friðunarsvæði við Ísland
Birt með fyrirvara: Ef frávik eru frá birtingu reglugerðar gilda stjórnartíðindi.
Á milli lína r.v. 315° frá Straumnesi að línu r.v. 270° frá Blakknesi og utan 12 sml. frá viðm. línu eru síldveiðar leyfðar með síldarflotvörpu. rgl.: 770/2006
Kolmunnalína rgl.: 1271/2007
Togveiðibann þó opið fyrir togveiðum frá kl. 20:00 - 08:00 rgl.: 875/2005
Rgl. um friðun steinbíts. Veiðibann 27/9 til 31/3 Rgl. 805/2006
Bann við veiðum með fiskibotnvörpu, rgl.: 162/2002
Togveiðibann þó opið fyrir togveiðum frá kl. 20:00 - 08:00 frá og með 1. okt til og með 1. apríl rgl. 310/2007
Dökk ská-röndótt svæði eru friðunar-svæði fyrir tog-veiðum.rgl. 310/2007
Opið fyrir togveiðum á Mehlsack frá og með 1. feb. til og með15. apr. rgl. :310/2007
Á Tánni er lokað fyrir togveiðum frá og með 1. júní til og með 31.okt. rgl.: 310/2007
Blá röndótt svæði með lóðréttum línum . Skiljusvæði fyrir togveiðar. Rgl.: 749/2006
Fjólublá skárröndótt svæði eru friðunarsvæði fyrir togveiðum og línu, rgl.: 310/2007
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Bann við netjaveiðum rgl.: 766/2004
Bann við handfæraveiðum rgl. 693/2007
Bann við línuveiðum , Vesturhlutinn er opinn frá og með 15. mars til 31. maí rgl. 193/2007
Bann við línu og handfæraveiðum rgl. 742/2009
Bann við Línuveiðum, rgl.: 810/2009
Bann við Línuveiðum, rgl.: 311/2003 ; 230/2003
Sérstök línu og netasvæði. Rgl. 881/2009
ISLAND
ICELAND
Kolmunnalína rgl. 1271/2007
Blá röndótt svæði með lóðréttum línum. Skiljusvæði fyrir togveiðar. rgl. 752/2006;; 751/2006
Smáfiskaskiljusvæði. Síldveiðar. með flotvörpu leyfðar 770/2006 ; 747/2006
Smáfiskaskiljusvæði rgl.: 748/2006
Bann við kolmunnaveiðum án meðaflaskilju rgl.: 696/2005
Bann við kolmunnaveiðum á Þórsbanka. rgl.: 794/2004
Bann við togveiðum rgl.: 310/2007
Bann við togveiðum rgl.: 861/2006;100/2008
Friðunarsvæði Surtsey rgl. 50/2006
Koralsvæði rgl.: 1140/2005
Bann við Línuveiðum, rgl.: 887/2009
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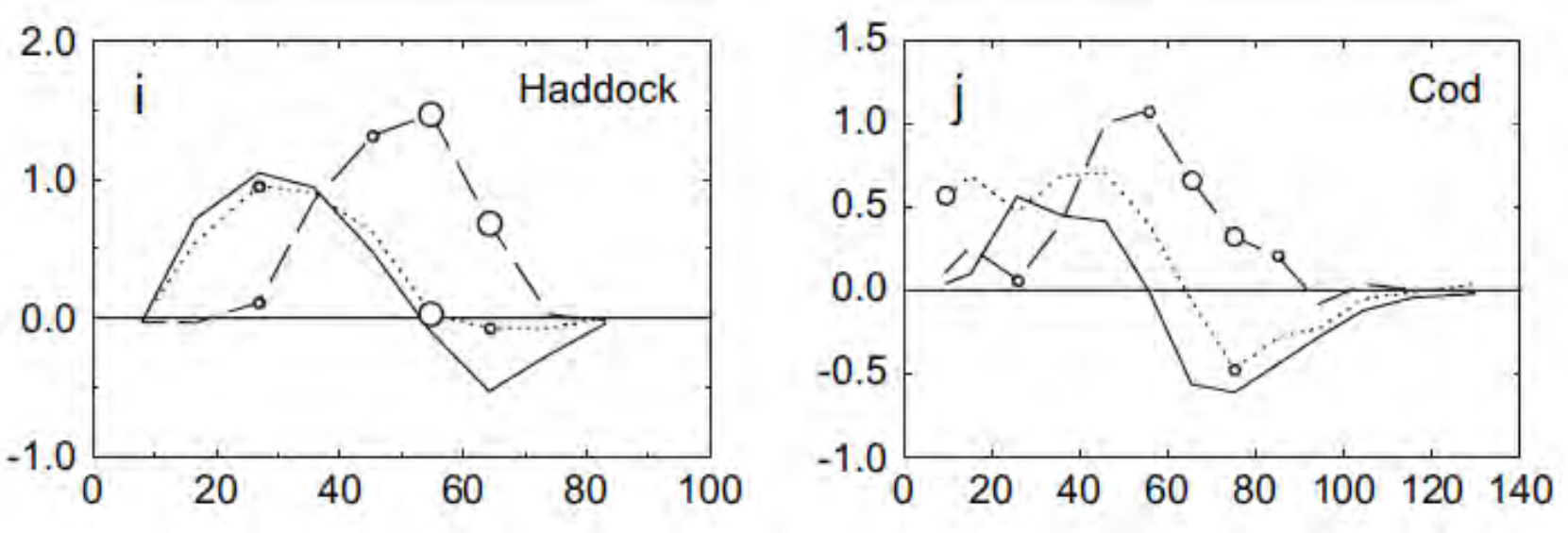
Iceland

- Purpose
  - Network of seasonal, year-round, and “real-time” closures, mostly to protect spawning and/or juvenile areas
- Outcome
  - For two areas closed year-round in 1993, significant and rapid increases relative to the open areas for larger size classes of cod and haddock were observed
  - One area was reopened in 1997, and effects were quickly reversed to pre-closure state
- Context
  - Closures instituted at a time of low SSB, and TAC was reduced 42% between 1992 and 1995
  - Combination of ITQs and spatial management network has contributed to the highest estimate of stock size in three decades

Cod and Haddock in Breiddalsgrunn



X-axis: Length(cm)

Y-axis: Difference between protected and reference areas (log fish/tow) before the closure (solid line), after the closure (dashed line) and after reopening (dotted line).

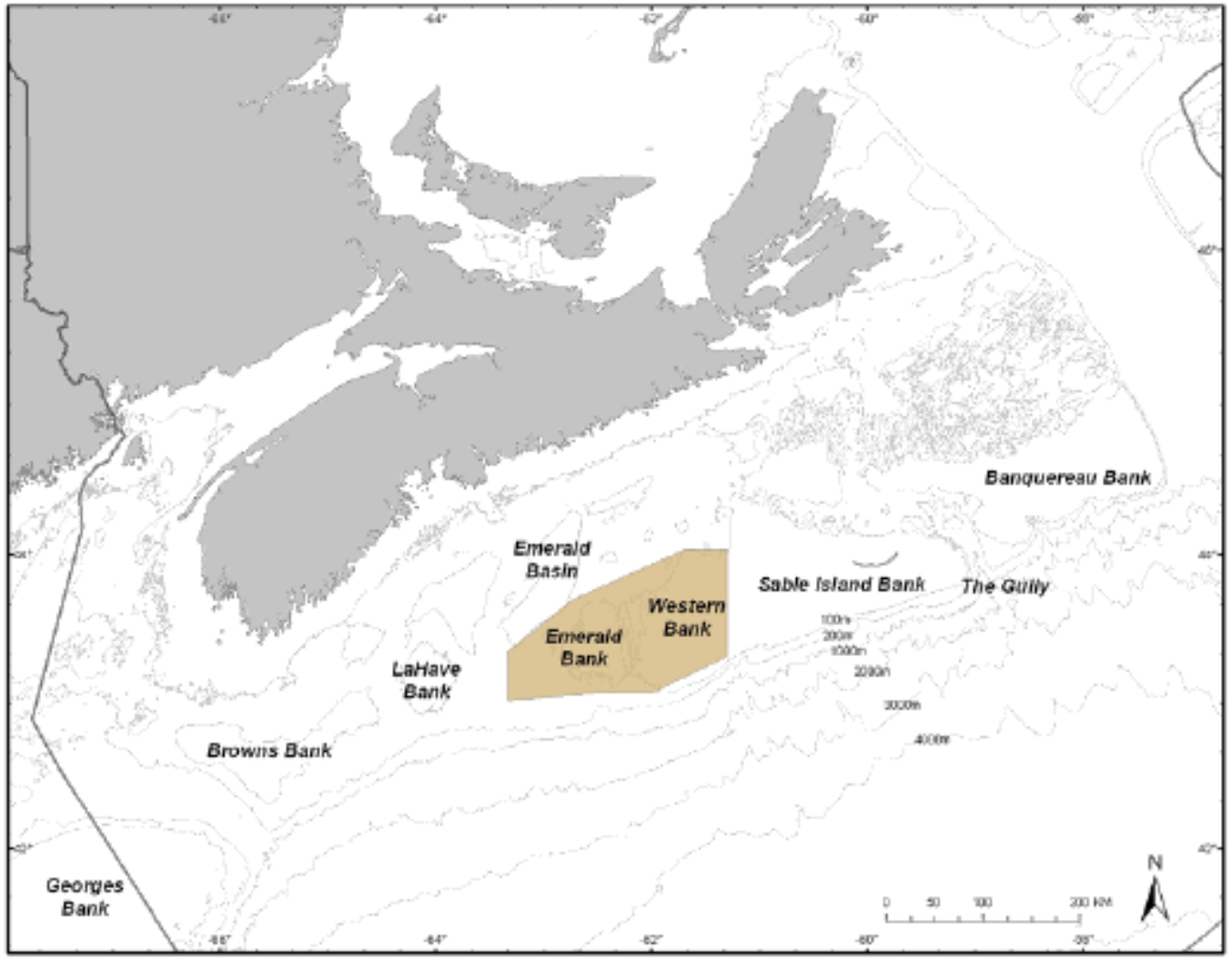
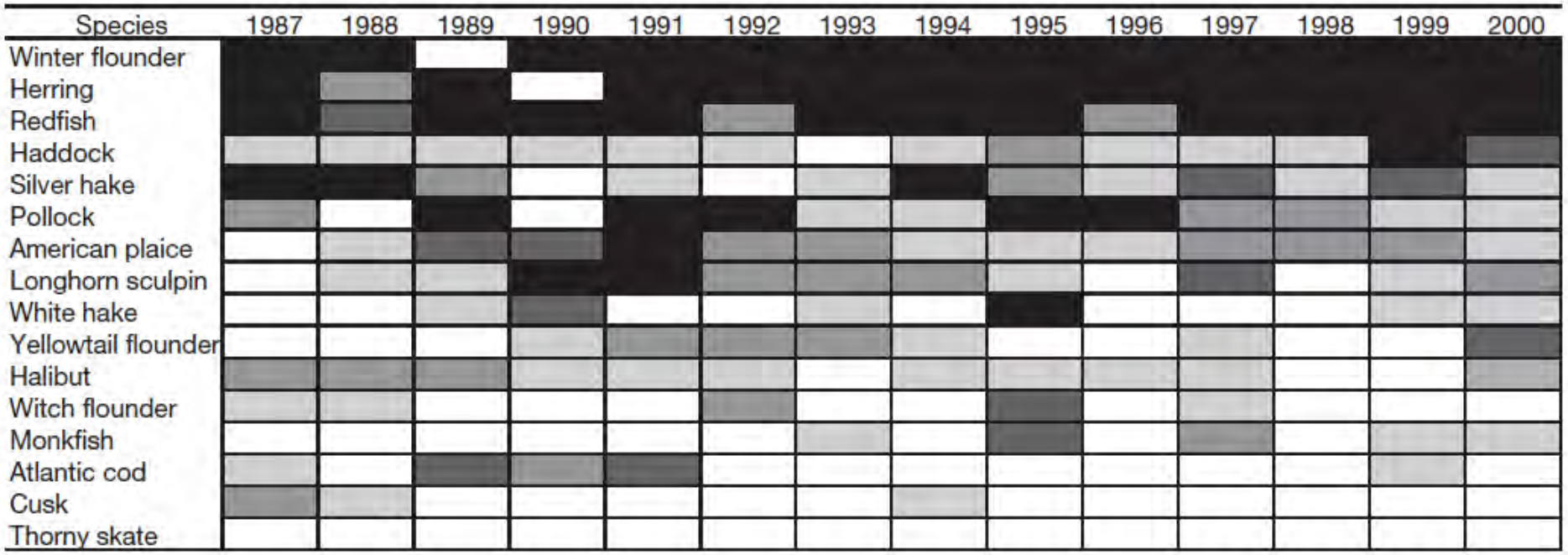


Figure 15. Haddock closed area on Emerald / Western Bank of the Scotian Shelf

Scotian Shelf

- Purpose
  - Emerald/Western Bank closed to mobile groundfish gear in 1987 to protect juvenile haddock from discarding
- Outcome
  - No effect on recruitment, and juvenile survival decreased, comparing before (1970-1986) and after (1987-1994) closure
  - Some species saw large increases, including herring, winter flounder, redfish
- Context
  - Whole area under moratorium for cod and haddock since 1994
  - Not fully closed (fixed gear, scallop dredging) and only a single closed area
  - Species “center of abundance” shift
  - Overall stock productivity declines

Species abundance anomalies in the closed area



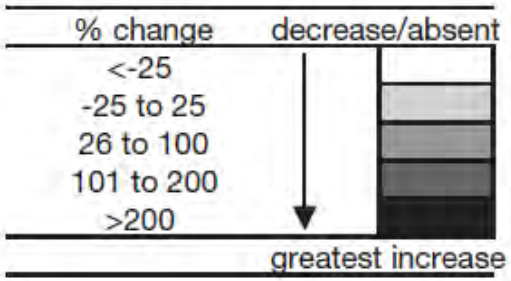
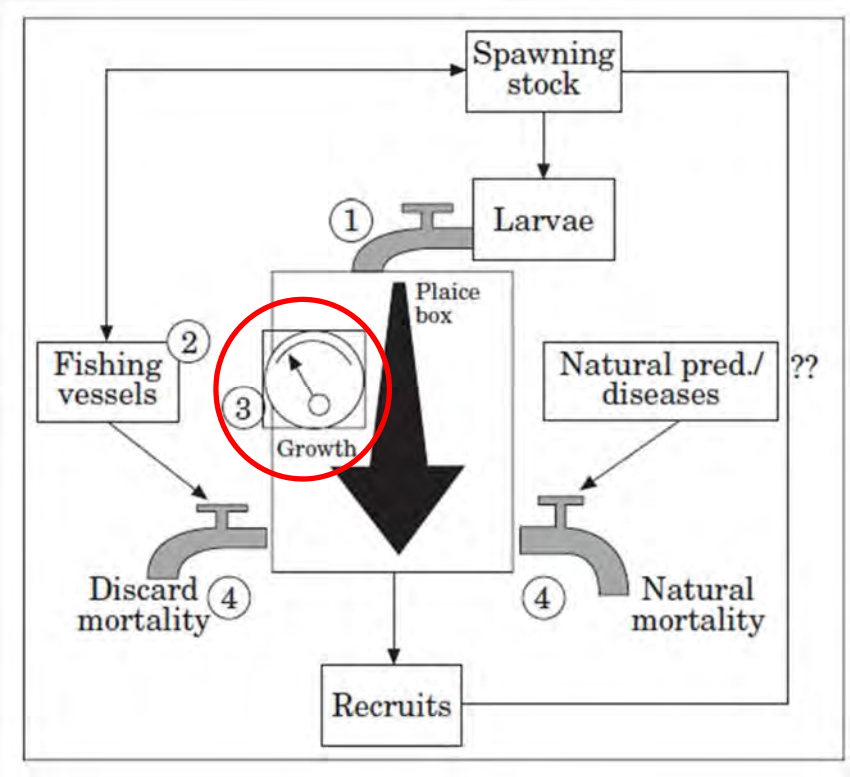
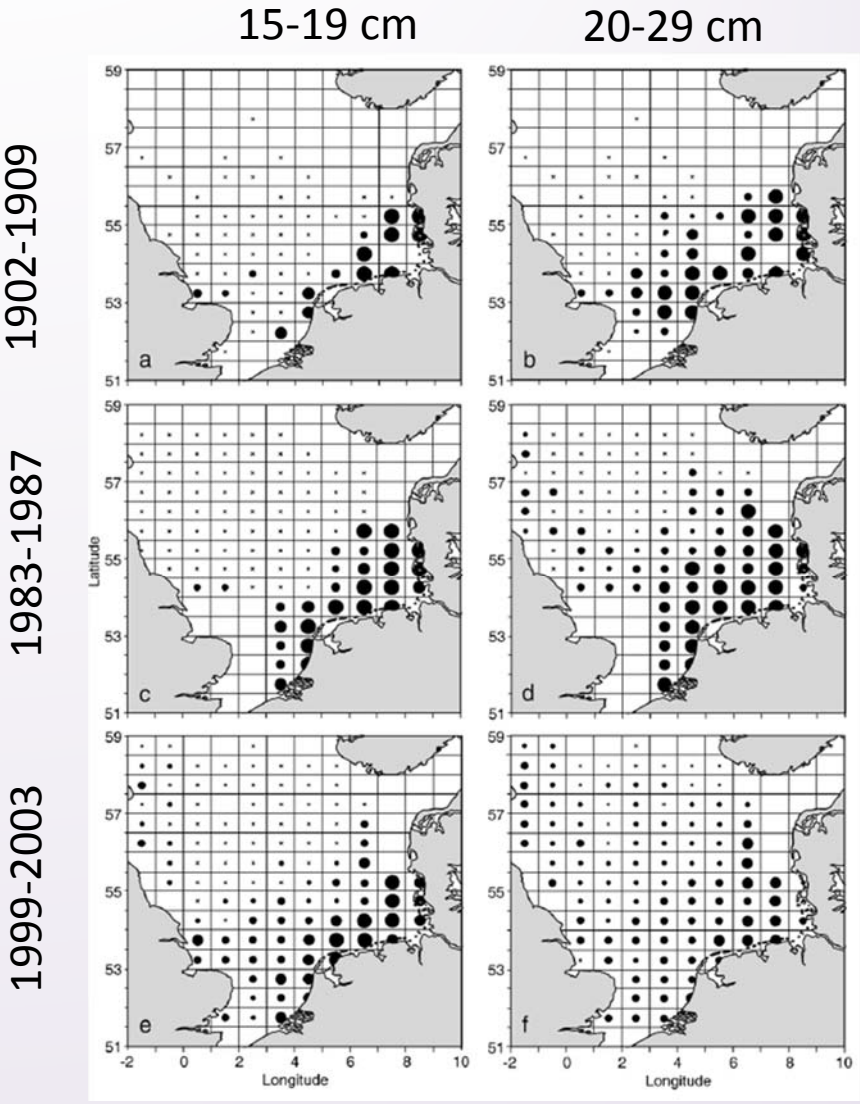


Fig. 5. Species abundance anomalies (relative to the 1970 to 1986 average) in the closed area for 8 species that generally increased relative to their abundance since closure and 8 additional common species that exhibited decreasing or variable trends. Magnitude of the change shown in key


Spawning stock
1
Larvae
Plaice box
2
Fishing vessels
3
Growth
Natural pred./ diseases
??
Discard mortality
4
4
Natural mortality
Recruits


15-19 cm
20-29 cm
1902-1909
1983-1987
1999-2003
Latitude
Longitude
a
b
c
d
e
f

The Plaice Box

- Purpose
  - Area closed in SE North Sea in 1989 to reduce discards of undersized European plaice on their nursery grounds
- Outcome
  - Abundance of marketable size classes increased
  - Increase in abundance of non-target species
  - Overall yield and SSB have decreased substantially
- Context
  - Only closed to the largest boats (>300 hp), and 1989-1994 only closed seasonally
  - Single closure, not part of network
  - Overall decreased growth rate of plaice
  - Spatial shift in stock, in response to elevated water temperatures

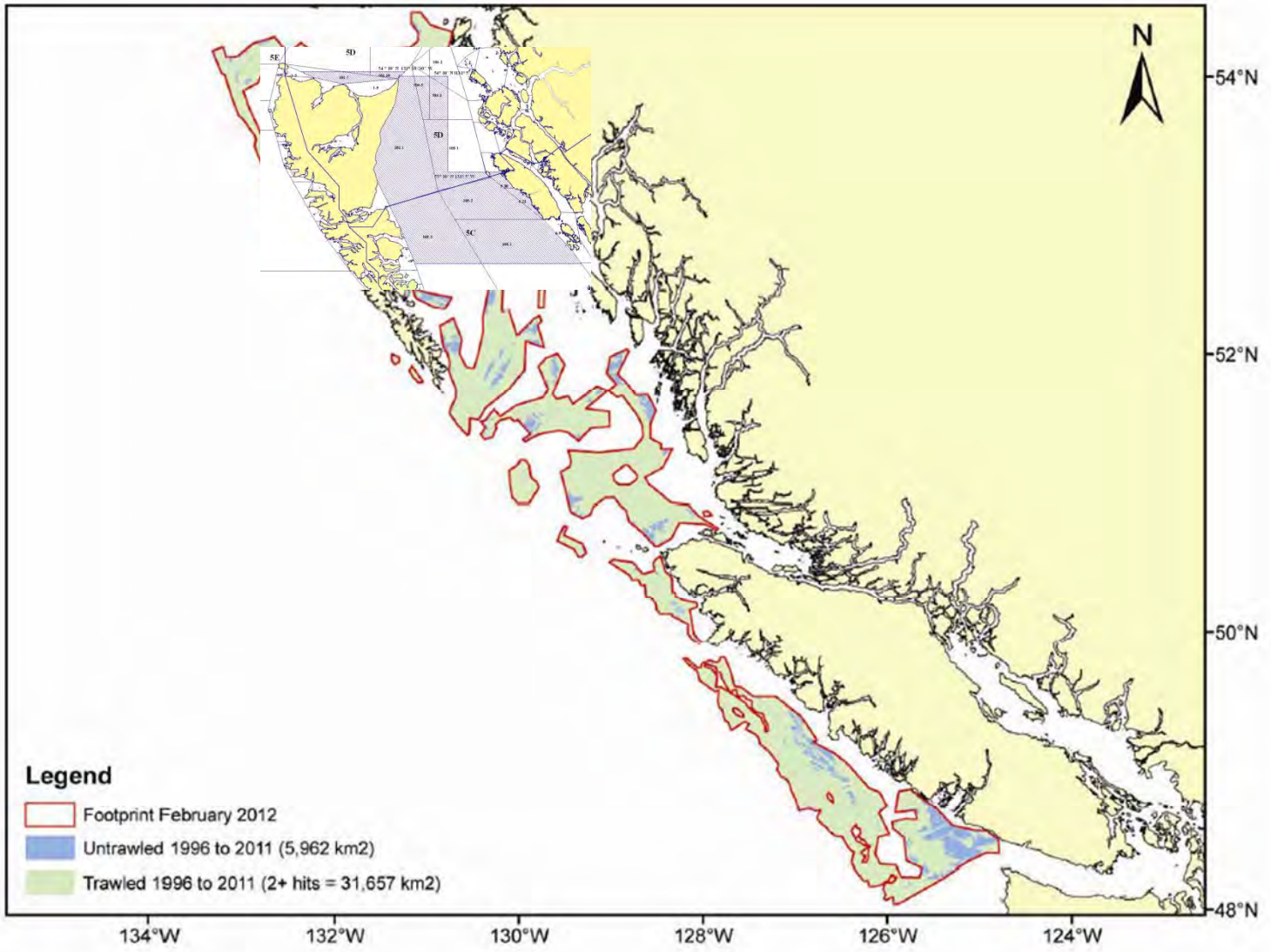


Figure 2. Trawled and untrawled areas within Option A groundfish bottom trawl boundaries.

British Columbia

- Purpose
  - "Freezing the footprint" of the groundfish trawl fishery, primarily to protect coral and sponge areas and to reduce habitat impacts, including representative habitats of all types, through an agreement between industry and conservation groups
  - Many other closures, including 164 inshore Rockfish Conservation Areas, seasonal spawning closures, and traditional First Nations fishing areas
- Context
  - ITQs since 1997, after a period of continual TAC overruns, large amounts of discarding
  - 100% at-sea and dockside monitoring
  - Sponge and coral bycatch limits and allocation
  - Besides a couple of rockfish species, most species in B.C. are not overfished

Summary

- Purpose of closures
  - Protection of juveniles, usually from discarding, not juvenile habitats per se
  - Seasonal spawning closures
  - Closures protecting vulnerable, unique, or representative habitats
- Outcomes
  - Some closures did not lead to stock rebuilding
  - In almost all cases, saw increases for marketable sizes of target species in year-round closures
  - In all cases, ancillary effects on other, non-target species
- Context
  - Areas with a network of spawning and juvenile areas (Iceland) seemed to perform better than single areas (Plaice box, Scotian Shelf)
  - Factors outside of closed areas were identified as important in evaluation, especially changing stock productivity (e.g. growth) and changing environmental factors leading to species shifts

Literature review

- Groundfish spawning in NE waters
  - General and vague, except for some specific cases for cod research

Summary of identified spawning locations

	Identified Spawning Locations	Habitat Area Location/Characteristics	Spawning Notes	Habitat Notes
Cod	Gulf of Maine: Ames Study Areas (Ames 2004). Ipswich Bay (specific spawning aggregation at Whaleback feature)(Siceloff and Howell 2012). Cape Cod Bay, western Maine coast, Jeffries Ledge and Northern Mass. Bay (Deese 2005 and Dean et al. 2012). Georges Bank: concentrated in the Northeast area (mostly gravel and complex relief levels)(Berlinsky 2009).	Juveniles (age 0-1) prefer gravel substrates with lower bathymetric relief (Gregory et al. 1997) Older and larger cod would move to coarse substrates with higher bathymetric relief, such as humps and ridges (Gregory et al. 1997). Ipswich Bay, Mass. Bay and Cape Cod Bay (Howe et al 2002). Spread across Georges Bank in early summer, constant concentration in NE Georges Bank (Lough 2010).	Spring spawning in northern GOM (Berlinsky 2009). Fall spawning in inshore areas from Cape Cod to Nantucket Shoal (Deese 2005). Winter spawning in southern GOM and Coxes Ledge (Deese 2005). Spring and winter spawning in western GOM (Berlinsky 2009). Peak Georges Bank spawning activity occurs in February-March (Lough 2010)	Age 0 cod prefer shallower depths (<90') and move to deeper waters both in autumn and as they grow older (Howe et al. 2002) Young juveniles would hide in cobble to avoid predators, and would partially remain after the threat was removed (Gotceitas and Brown, 1993).
Haddock	Georges Bank: Concentrated in Eastern and Northeastern areas (Overholtz 1987).	Spread throughout Georges Bank	Peak spawning in Georges Bank from late March-early April (Overholtz 1987) Ideal temperatures from 4-7°C at depths from 28-110' (Overholtz 1987)	As pelagic juveniles grow, they move deeper in the water column (Lough and Potter 1994).
Yellowtail Flounder		Eastern Georges Bank, specifically within Closed Area II. (Pereira et al 2012)		Occupied area in Georges Bank doubled from ~4000 to ~8000 km^2 when abundance increased (Pereira et al 2012)
Winter Flounder	Plymouth Bay (minor activity in Plymouth Estuary) (DeCelles and Cadrin 2010)		Peak spawning in March-May in the Plymouth Bay (DeCelles and Cadrin 2010)	

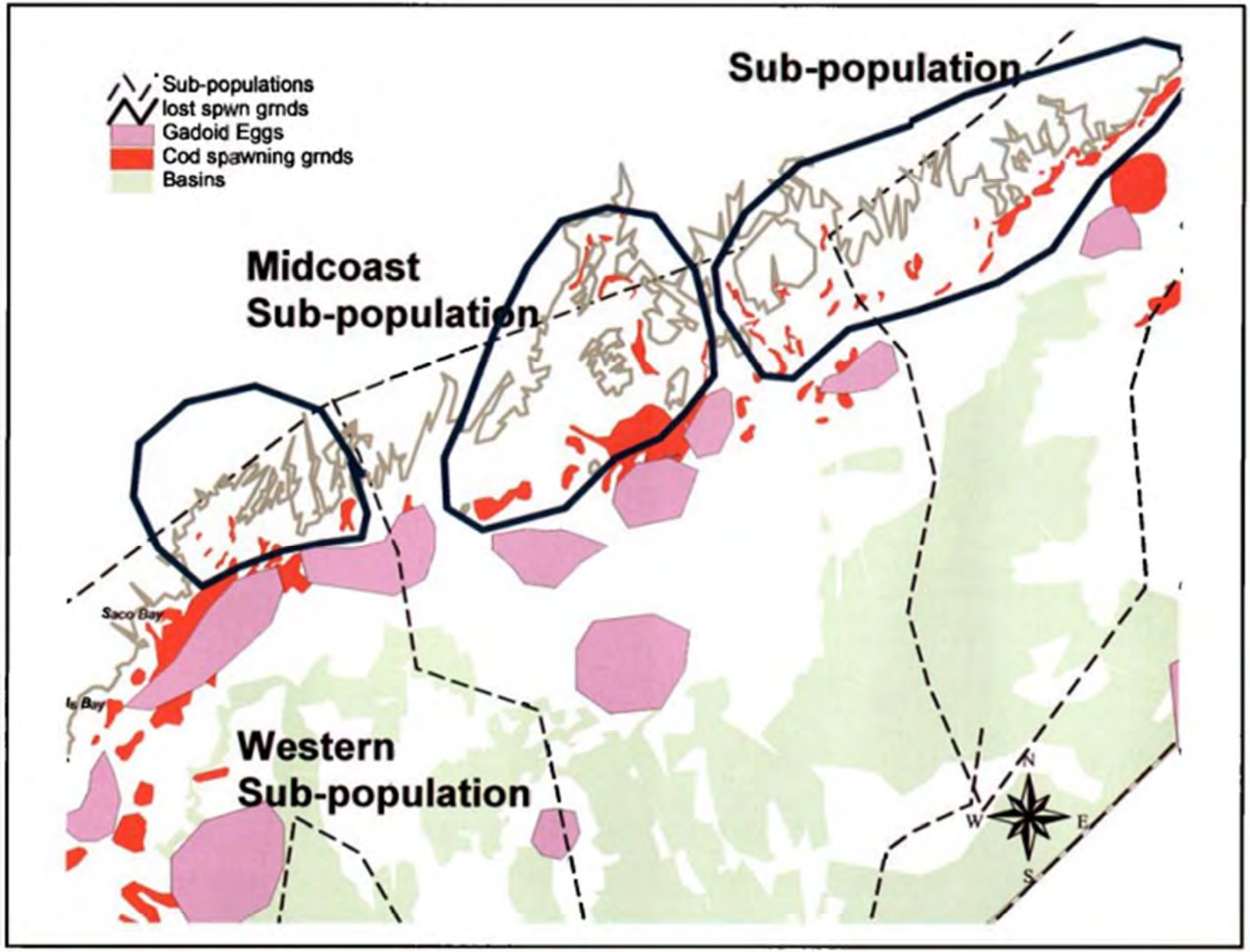


Figure 1. Map of indicated cod spawning areas. Circled areas indicate former spawning grounds that are no longer active. Ames, 2004.

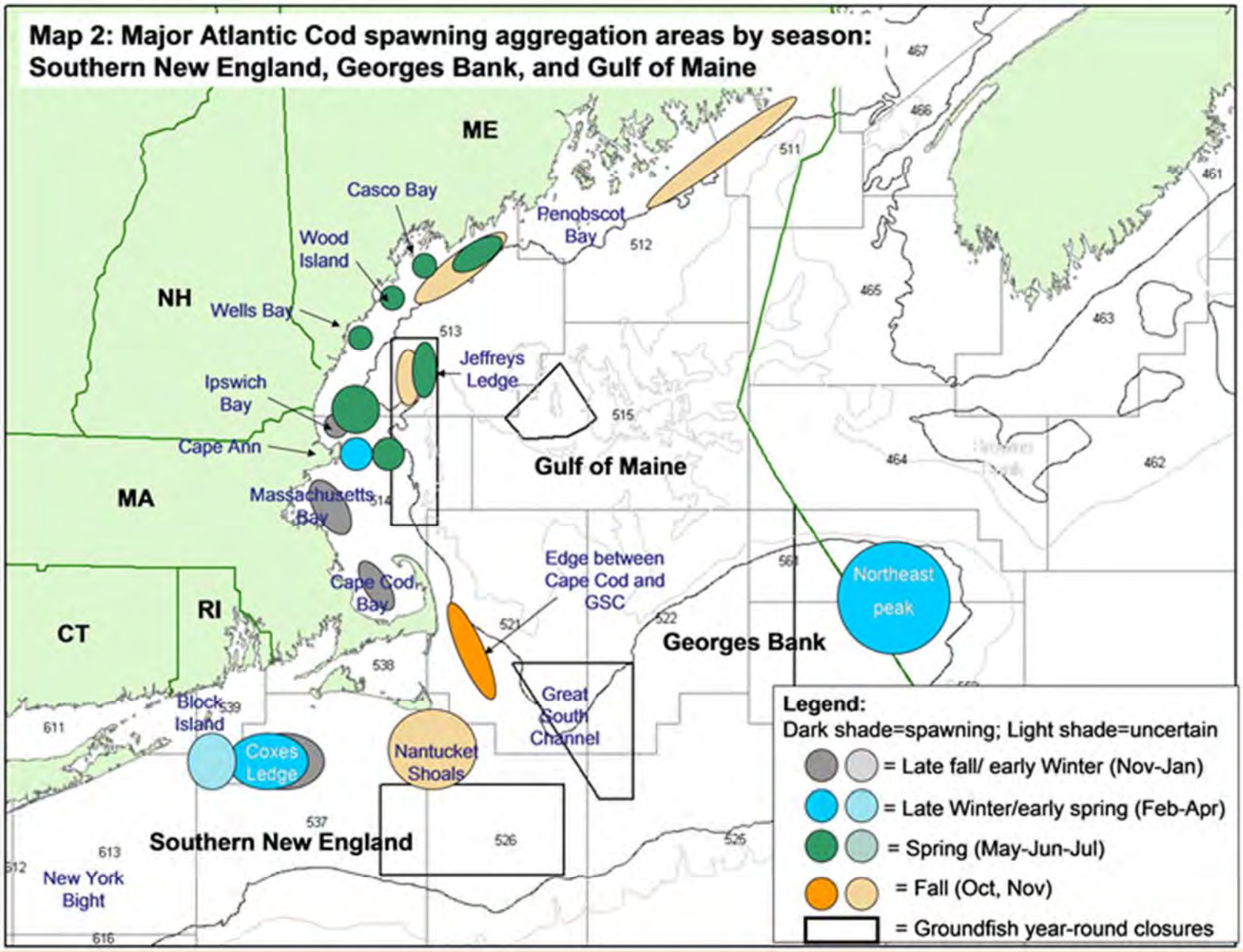


Figure 1. Summary of cod spawning areas. Deese, 2005.

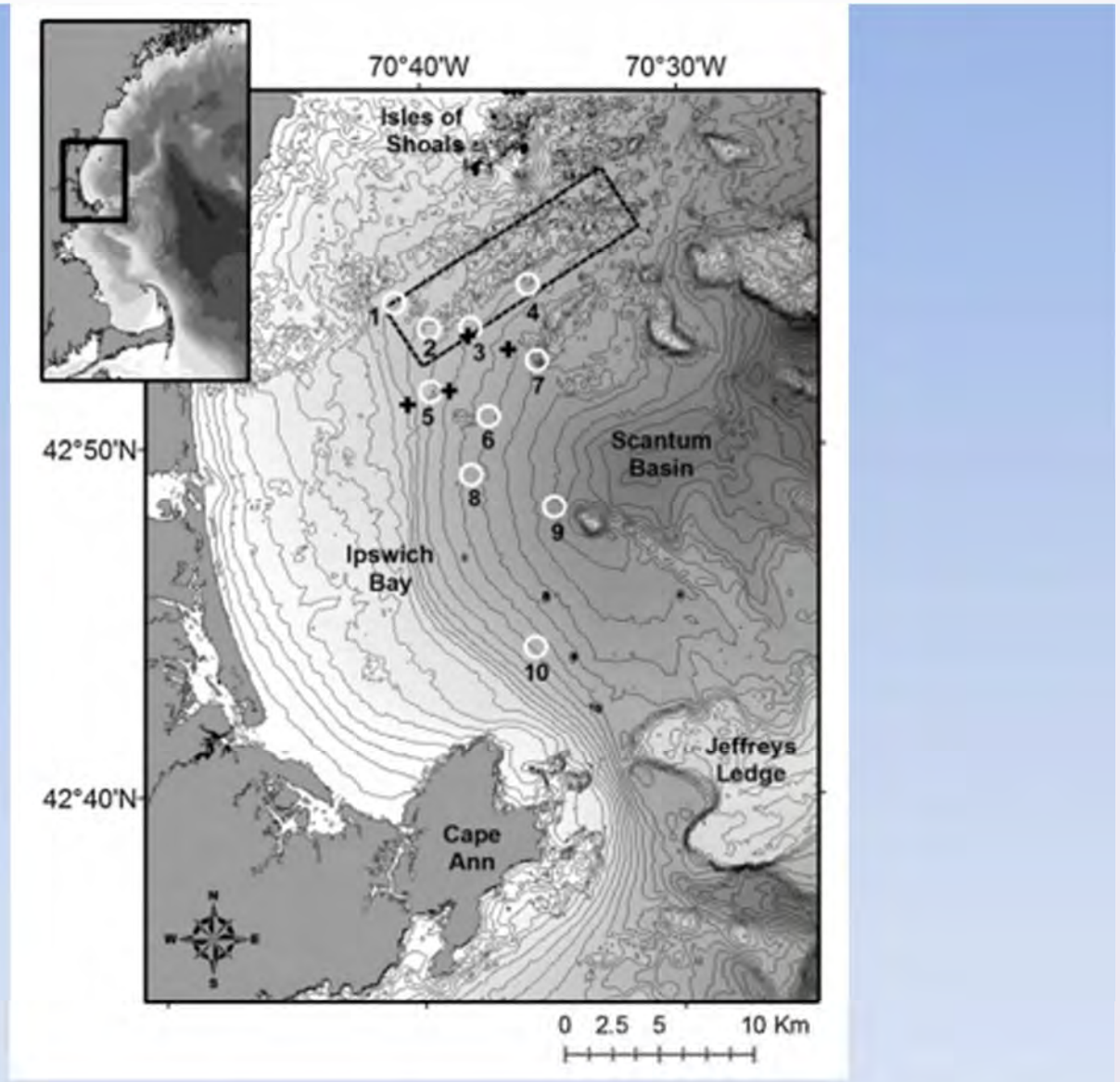


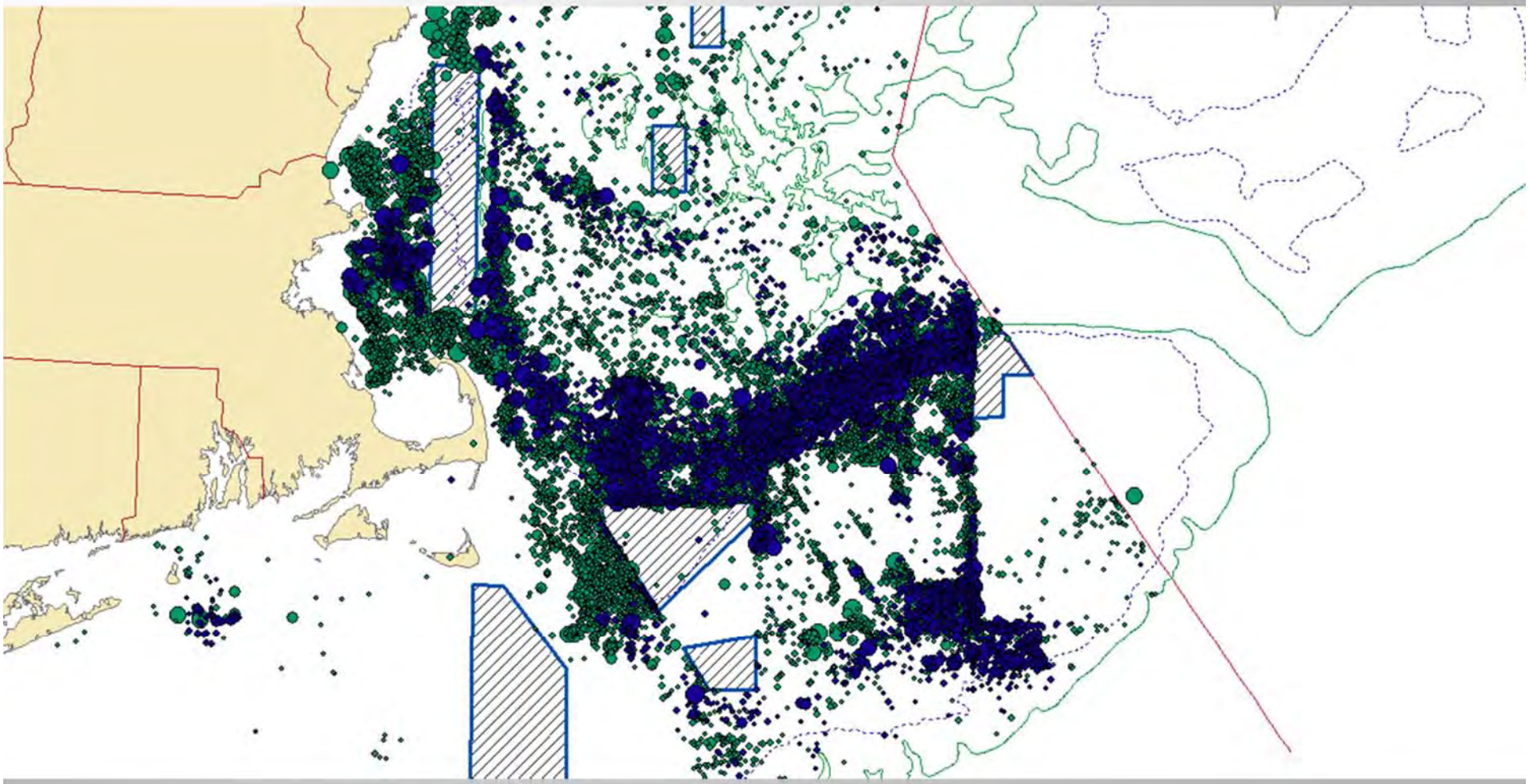
Figure 1. Bathymetric map of Ipswich Bay. Black dotted rectangle highlights the elevated bathymetric feature "Whaleback". Siceloff and Howell, 2012.

Tagging data

- Difficult/impossible to access
  - Unix firewall; foreign SQL system
  - Institutional ownership
  - Not effort adjusted – probability of closed area returns

Sea sampling data

- More data and greater temporal resolution
- Missing information about aggregations of juveniles and large spawners in rolling and year round closed areas
- Might be used to refine the timing of seasonal spawning closures and some boundaries
- Follow same hotspot procedure used by the CATT
- Groundfish Committee or Council meeting.



Habcam Imagery

- High resolution data
- Species identification and size estimates
- Habitat and species association

Juvenile habitat association

- GAMs based hurdle model
- Gulf of Maine cod, Georges Bank cod, Georges Bank yellowtail flounder
- Proof of concept; demonstration
- Application of a lobster habitat association model
- Sam Truesdell, U. Maine Orono
- Identifies physical features that are associated with above average survey catches (not hotspots)
- Predicted values and residual maps

Final variables in GB cod presence/absence model – explained 31.8% deviance, reasonable diagnostics

Variable	Direction of relationship
Purpose code	
Season	Fewer cod in spring
Sediment coarseness	Positive linear relationship
Shear stress (marginal)	Expected abundance decreased with increasing shear stress between values of 1 and 3
Zenith (marginal)	Slightly positive linear effect, indicates increase in catches at night
Temperature	Bottom temperature to have a highly negative almost linear effect
Depth	Depth to have a positive effect between approximately 5 to 35 meters and then a strong negative effect between depths of about 35 to 80 meters

Final variables in GB cod conditional presence model – 6.1% of deviance, mixed diagnostics

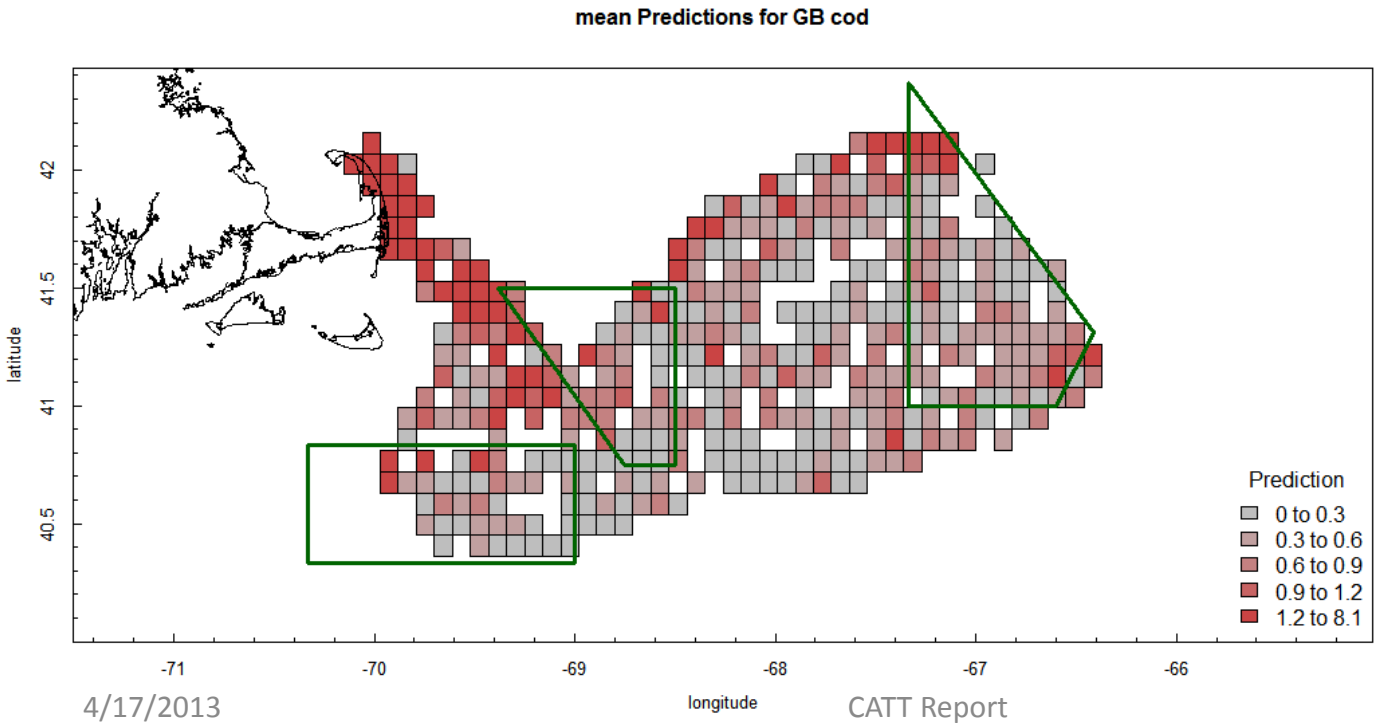
Variable	Direction of relationship
Shear stress (marginal)	Negative and linear, so expected abundance decreased with increasing shear stress, but the residuals show much scatter around the trend line

Georges Bank cod

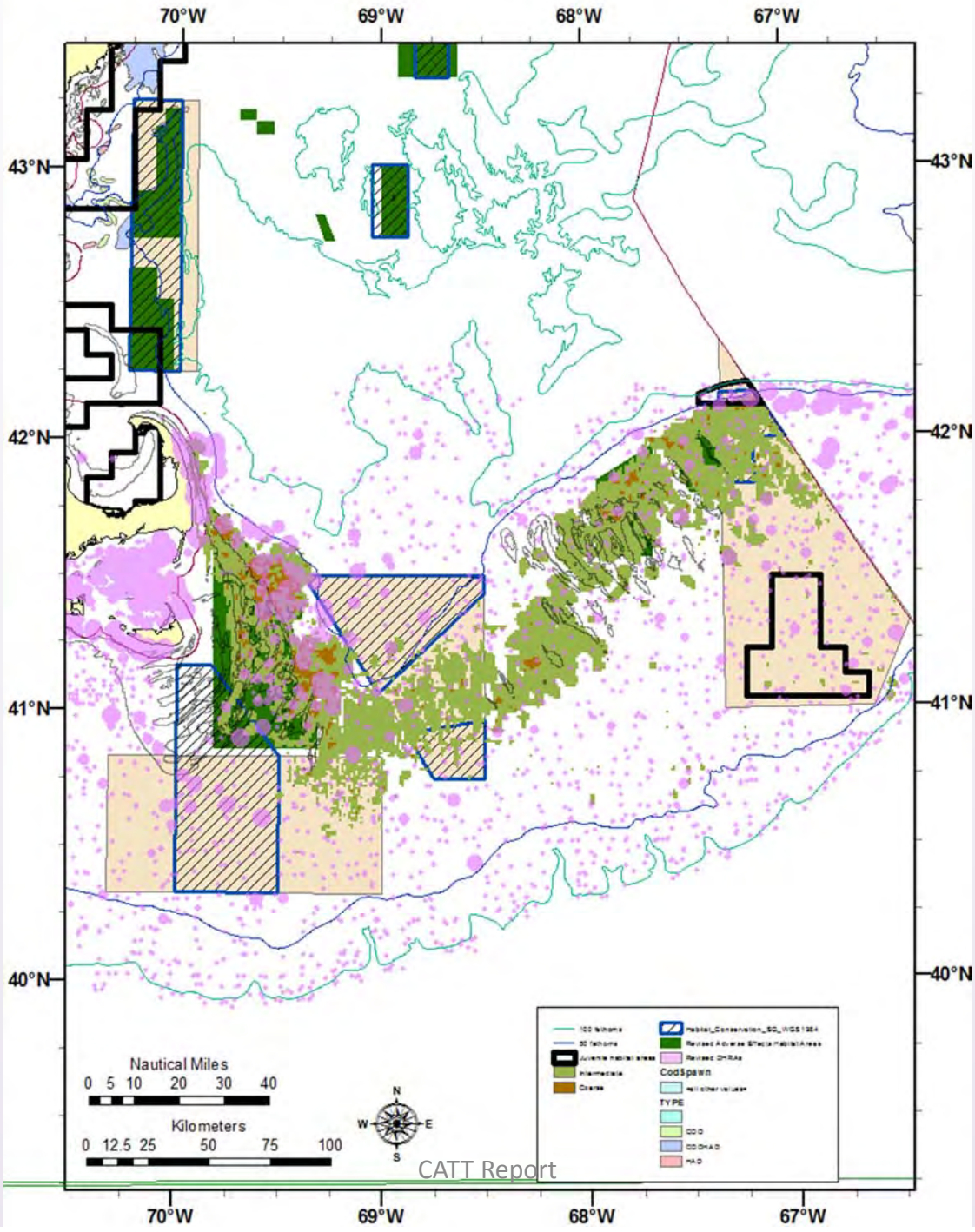
The general saturated model for Georges Bank cod was:

$$\hat{J} = SEA + PC + SBF + SD + s(SC) + s(STR) + s(T) + s(Z) + s(D)$$

Where SEA is season, PC is purpose code (survey type), SBF is seabed form, SD is dominant sediment type, SC is sediment coarseness, STR is shear stress, T is temperature, Z is zenith angle at tow-time, and D is depth. $\hat{J}$, the expected value of the response, was zero or one for the presence-absence model and the logged measured juvenile abundance for the conditional presence model.



Grain size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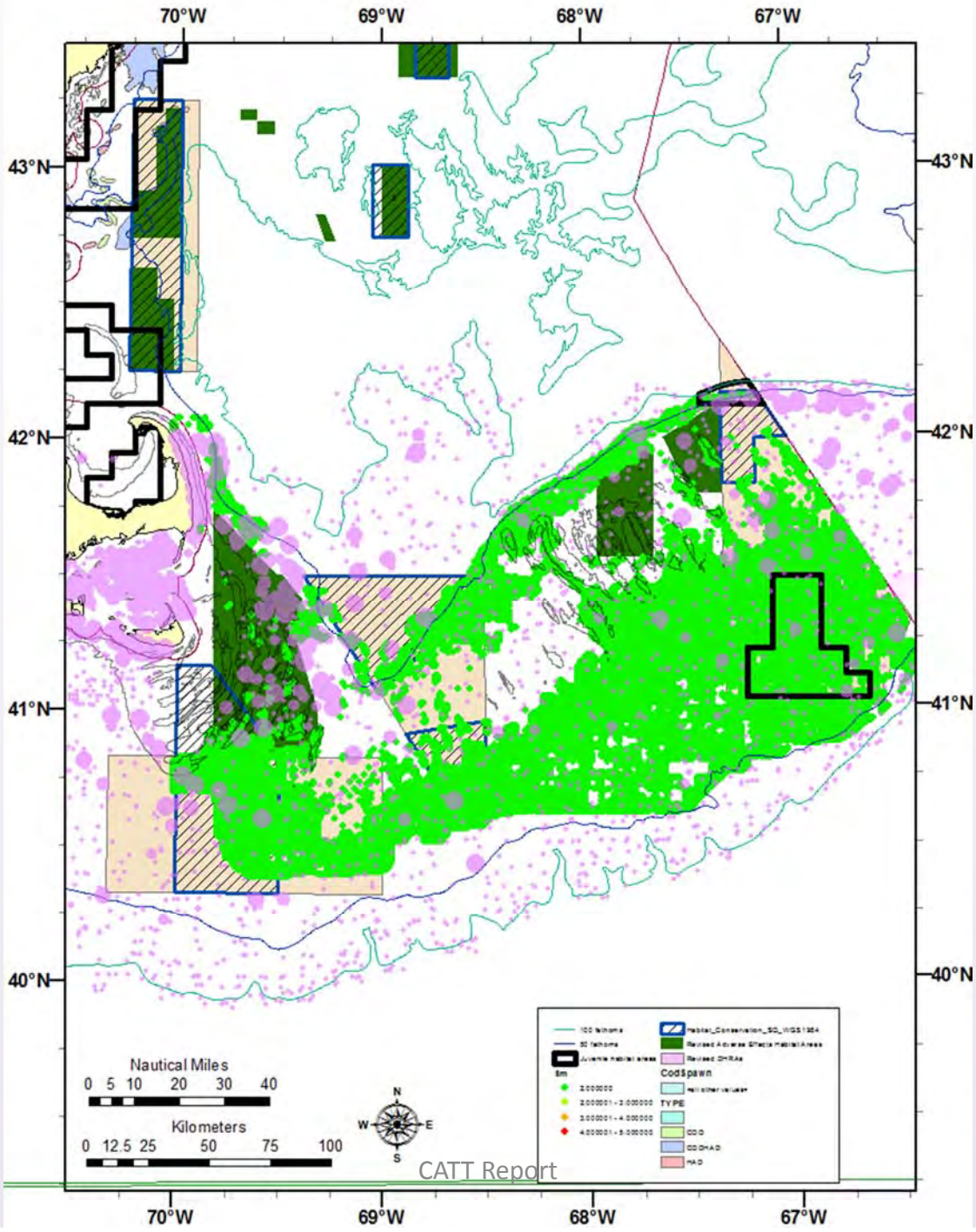
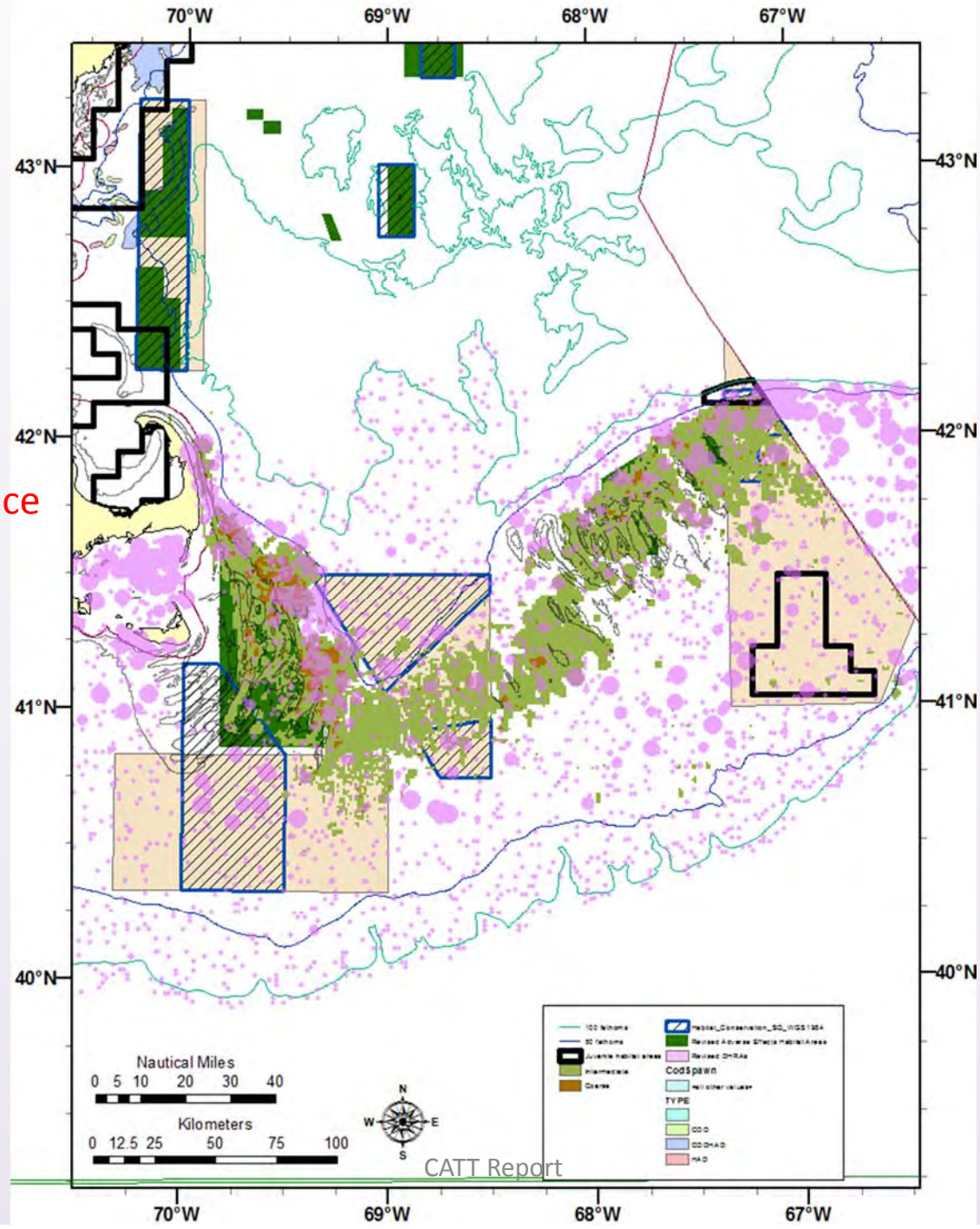
42°N
41°N
40°N
Nautical Miles
0 5 10 20 30 40
Kilometers
0 12.5 25 50 75 100
N
W
E
S
Cod Spawn
TYPE

Shear stress



Grain size
72-81 cod abundance



Final variables in GOM cod presence/absence model – explained 20.7% deviance, mixed diagnostics

Variable	Direction of relationship
Sediment type	Mud had a very negative effect and the smallest and extra-large sand categories also had a negative effect though they were weaker.
Seabed form	The “high flat” and “high slope” seabed form categories had a strong positive effect.
Temperature	Highly significant, negative effect on abundance. Temperature effect shows a sharp decline at values less than about five, followed by a more gradual decline between 5 and 11 degrees, then a steeper decline again at temperatures higher than 11 (though there is relatively less data at these higher temperatures)
Depth	Highly significant, negative effect on abundance. On average, abundance is highest at depths between approximately 0 and 80 meters, then declines rapidly after that.

Final variables in GOM cod conditional presence model – 11.3% of deviance, mixed diagnostics

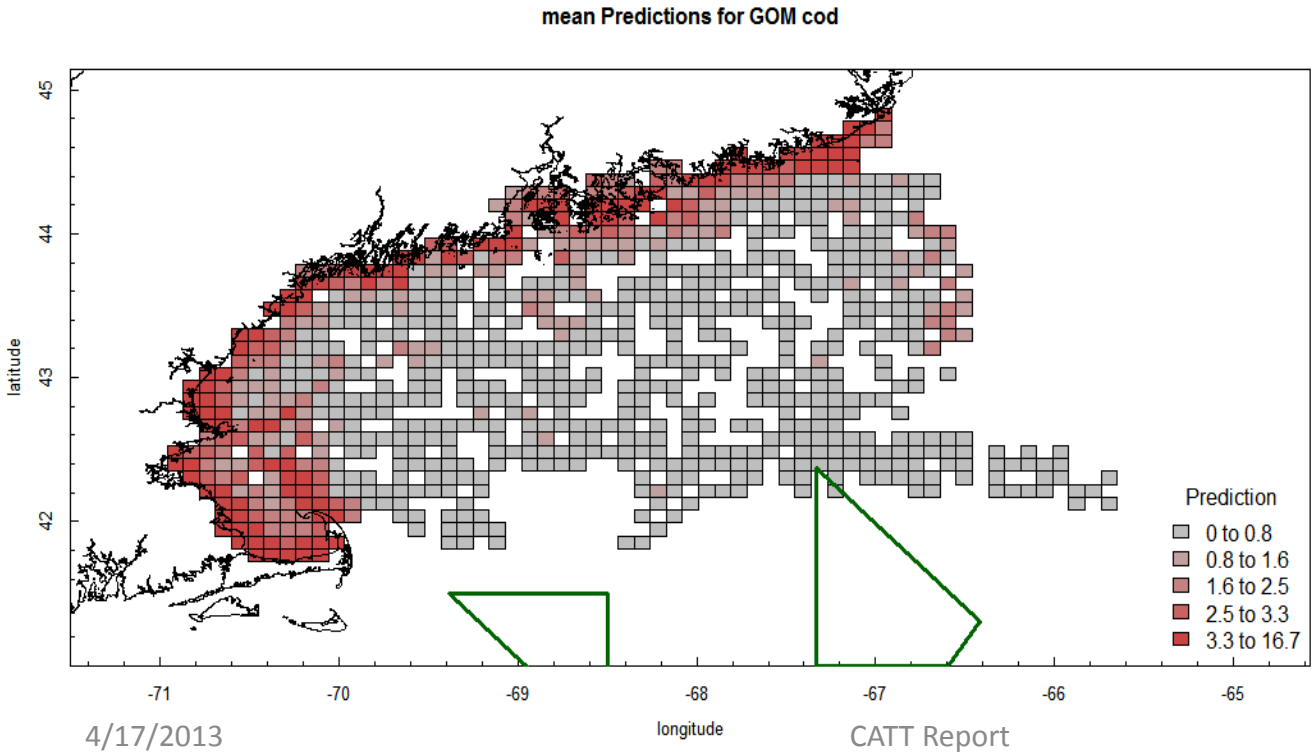
Variable	Direction of relationship
Purpose code	
Season	Spring had a highly significant, positive effect.
Sediment type	Mud had a negative effect on measured juvenile abundance, while large sand had a positive, marginally significant effect
Zenith	Significant effect but relationship unclear
Temperature	Abundance increased slightly with temperature from 0 to 10 degrees, then showed a marked decline, though there were only very few data points above 10 degrees.
Depth	The depth effect was slightly negative and linear.

Gulf of Maine cod

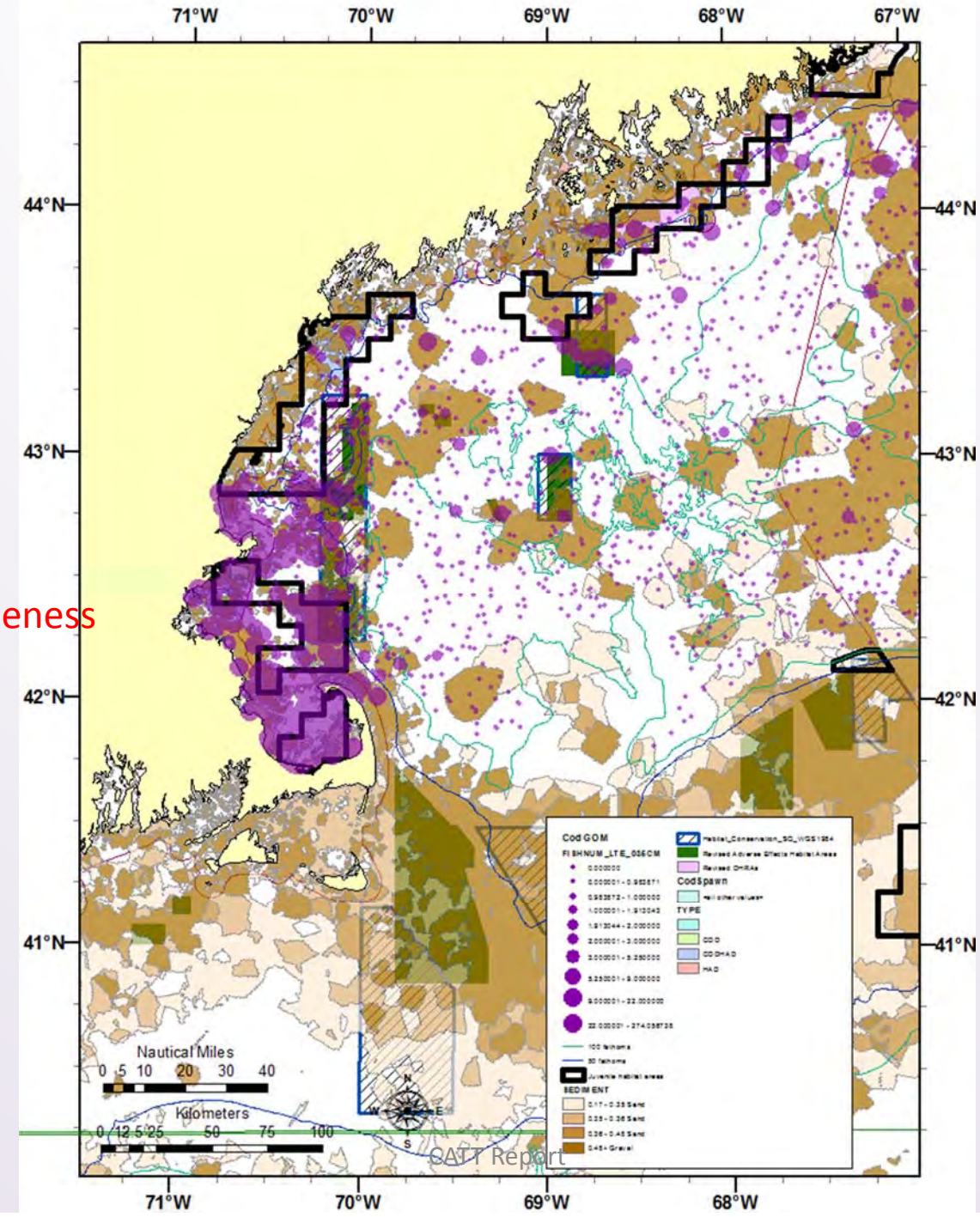
The general saturated model for Gulf of Maine cod was:

$$\hat{J} = SEA + PC + SBF + SED + s(T) + s(Z) + s(D)$$

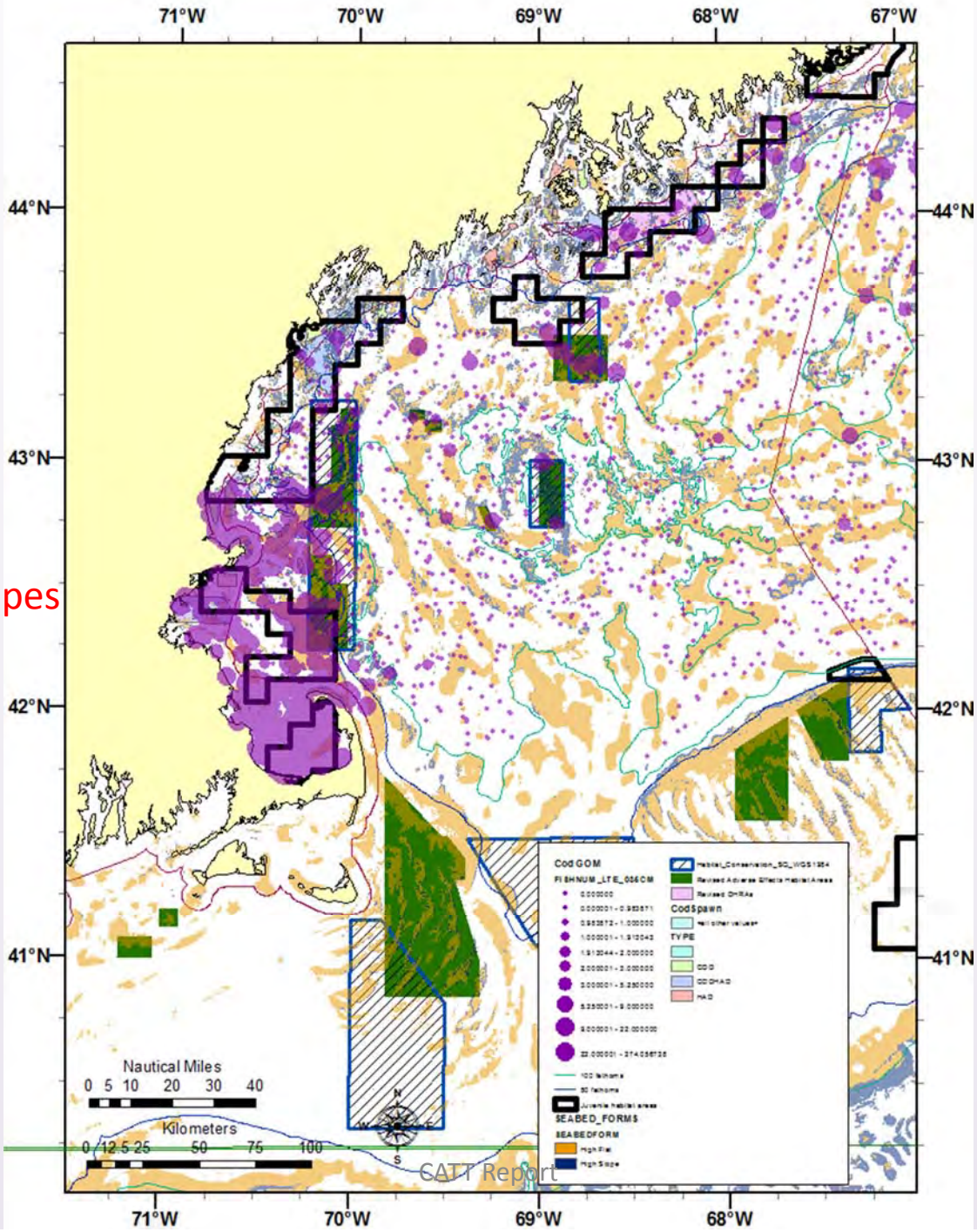
Where SEA is season, PC is purpose code (survey type), SBF is seabed form, SED is sediment type, T is temperature, Z is zenith angle at tow-time, and D is depth. $\hat{J}$, the expected value of the response, was zero or one for the presence-absence model and the logged measured juvenile abundance for the count model.



Sediment coarseness



High flats and slopes



GB yellowtail presence/absence – explained 23.3% deviance, poor diagnostics

Variable	Direction of relationship
Purpose code	
Season	Many more yellowtail in spring
Seabed form (marginal)	More yellowtail on high flats
Sediment coarseness (marginal)	Significant term but spline relationship questionable. Sediment coarseness increased slightly across values less than about 2.2 and decreased slightly at values larger than about 2.5 but these effects were small.
Zenith angle	Had a highly significant, positive, almost linear effect indicating that more yellowtail are caught at night
Depth (marginal)	Significant term but spline relationship questionable. Estimated abundance increased slightly with depth until about 85 meters, after which it declined.

GB yellowtail conditional presence – 52.9% of deviance, reasonable diagnostics

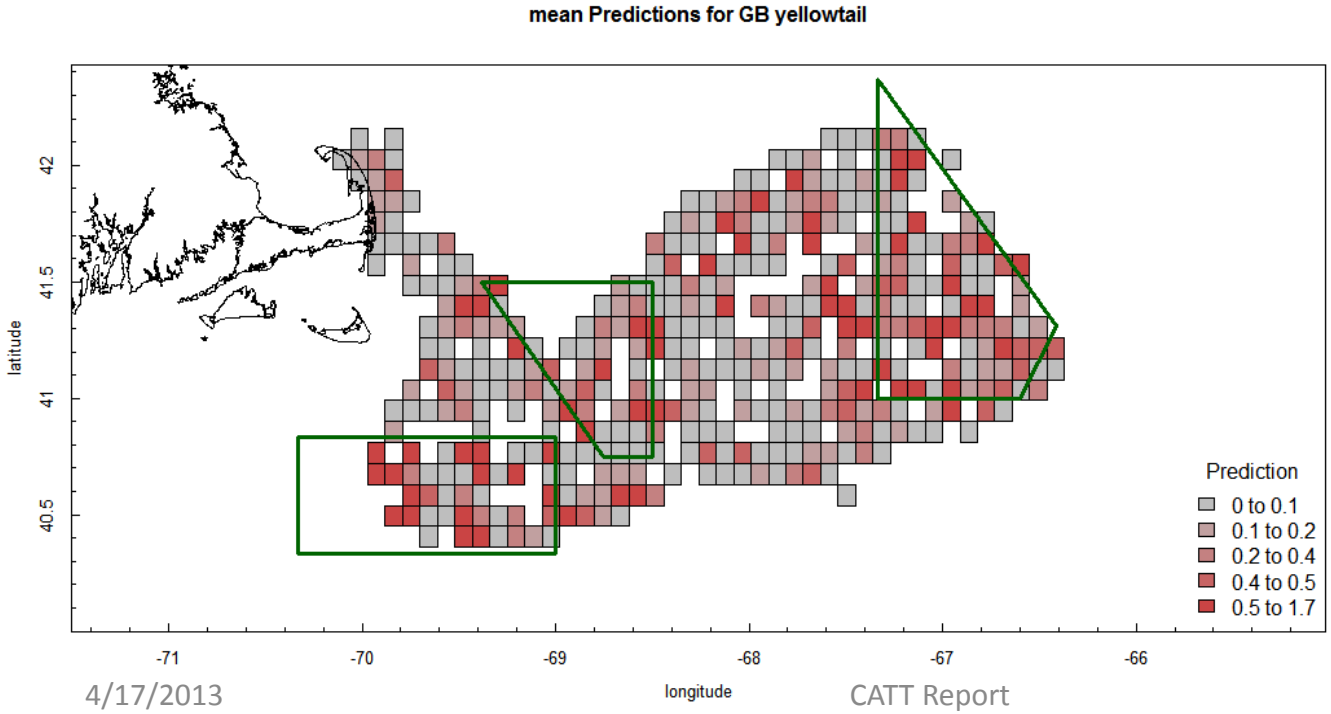
Variable	Direction of relationship
Purpose code	
Sediment coarseness (marginal)	Complicated spline relationship
Temperature (marginal)	The temperature effect was positive between 4 and 7 degrees where most of the data lay, and then declined at higher values.
Depth	The depth effect was negative and linear

Georges Bank yellowtail flounder

The general saturated model for Georges Bank yellowtail was:

$$\hat{J} = SEA + PC + SBF + SD + s(SC) + s(STR) + s(T) + s(Z) + s(D)$$

Where SEA is season, PC is purpose code (survey type), SBF is seabed form, SD is dominant sediment type, SC is sediment coarseness, STR is shear stress, T is temperature, Z is zenith angle at tow-time, and D is depth. $\hat{J}$, the expected value of the response, was zero or one for the presence-absence model and the logged measured juvenile abundance for the conditional presence model.



High flats and depth

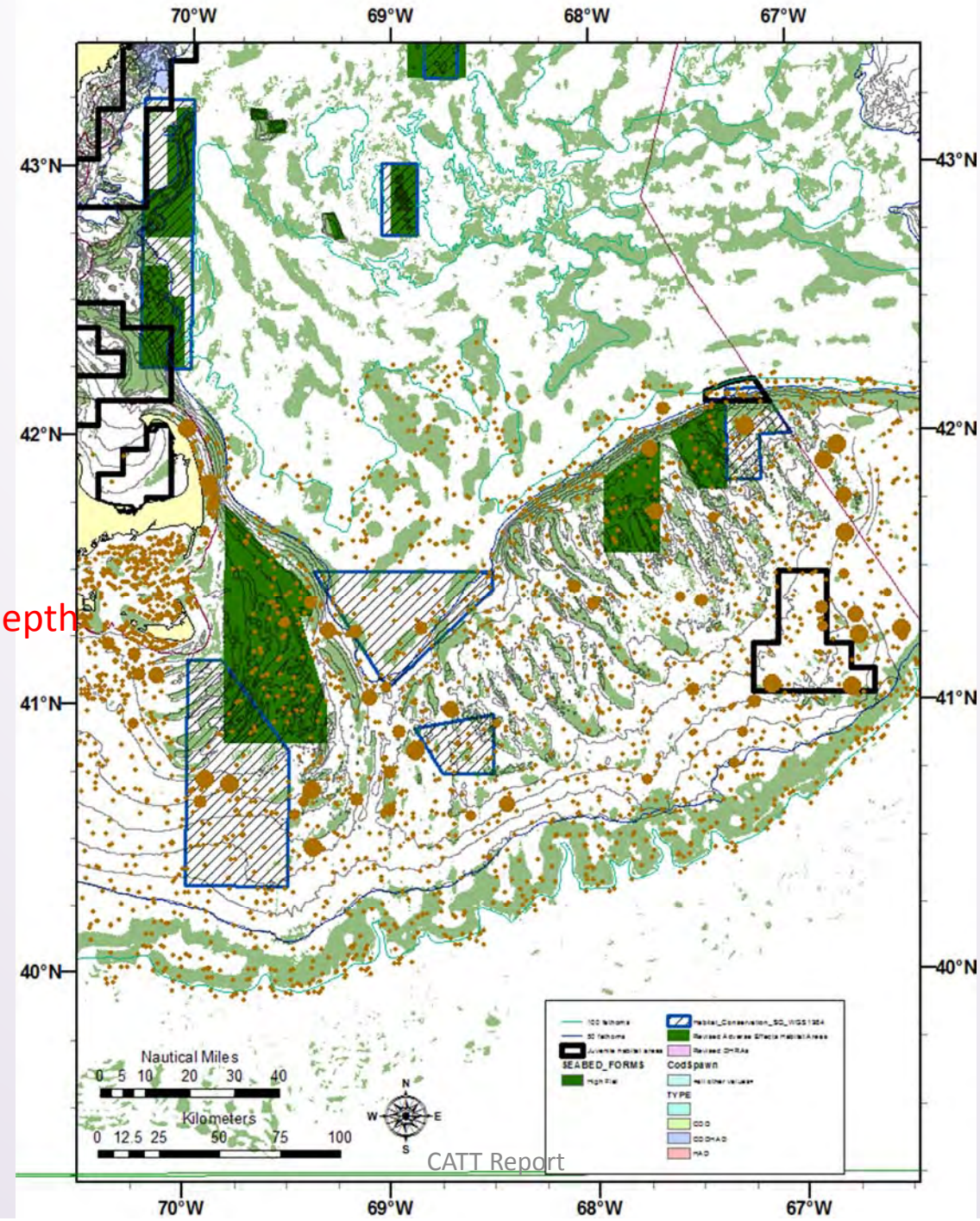
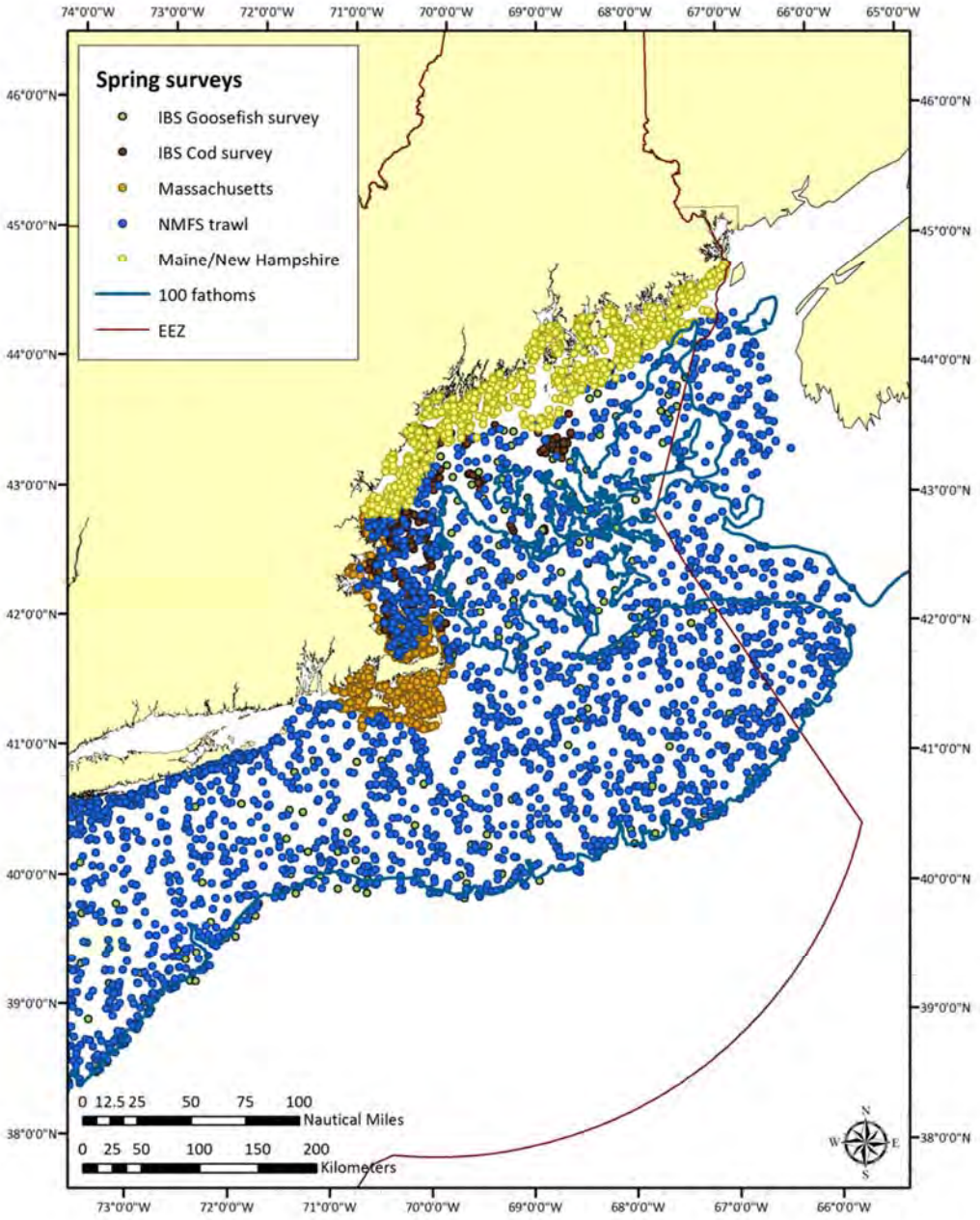


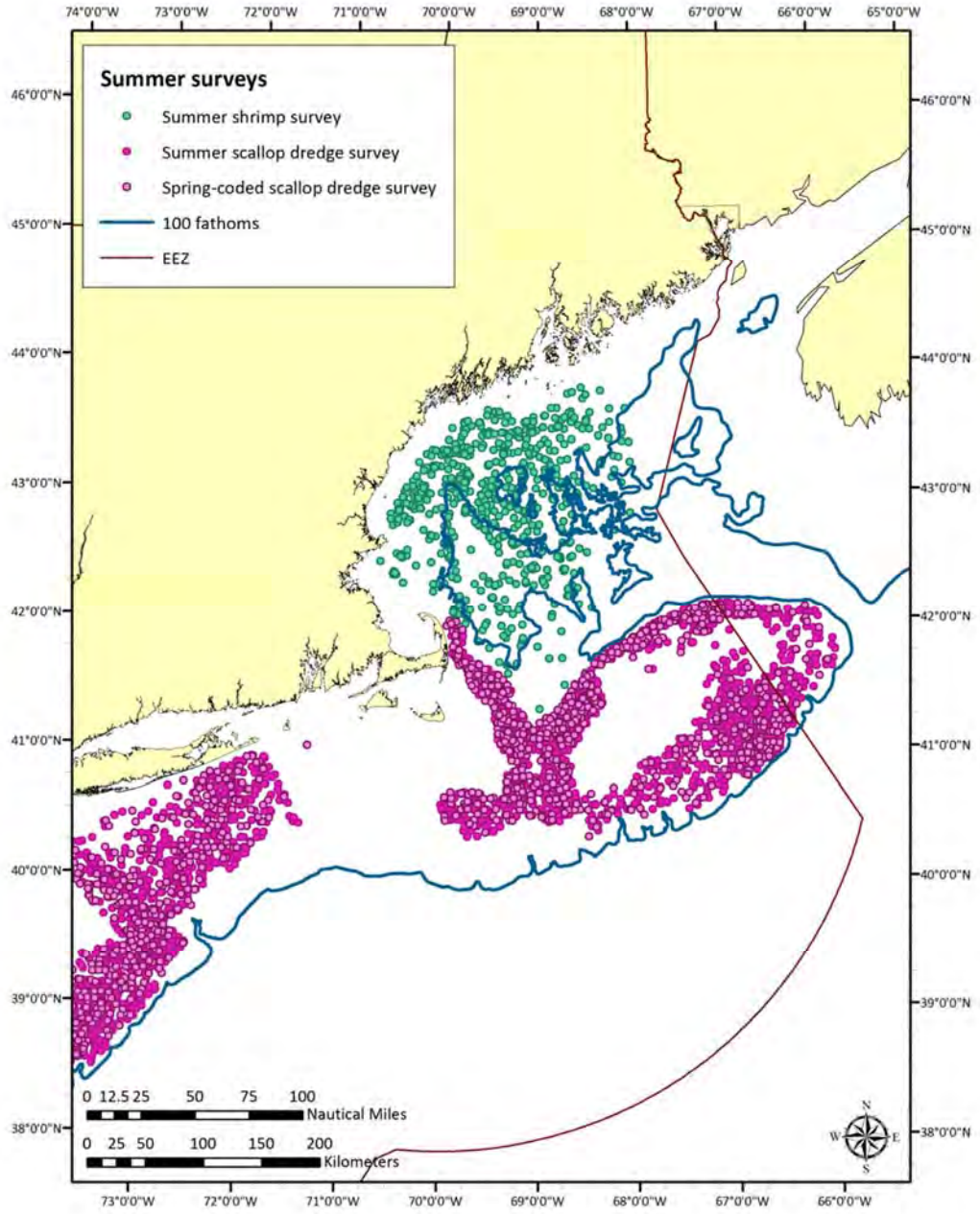
Table 2: Summary of parameter effects for all models. +/++ = positive/very positive effect; -/-- = negative/very negative; ~ = complicated spline relationship; 0 = significant term but spline relationship questionable. Dominant sediment not significant for GB cod or GB YTF, so not shown.

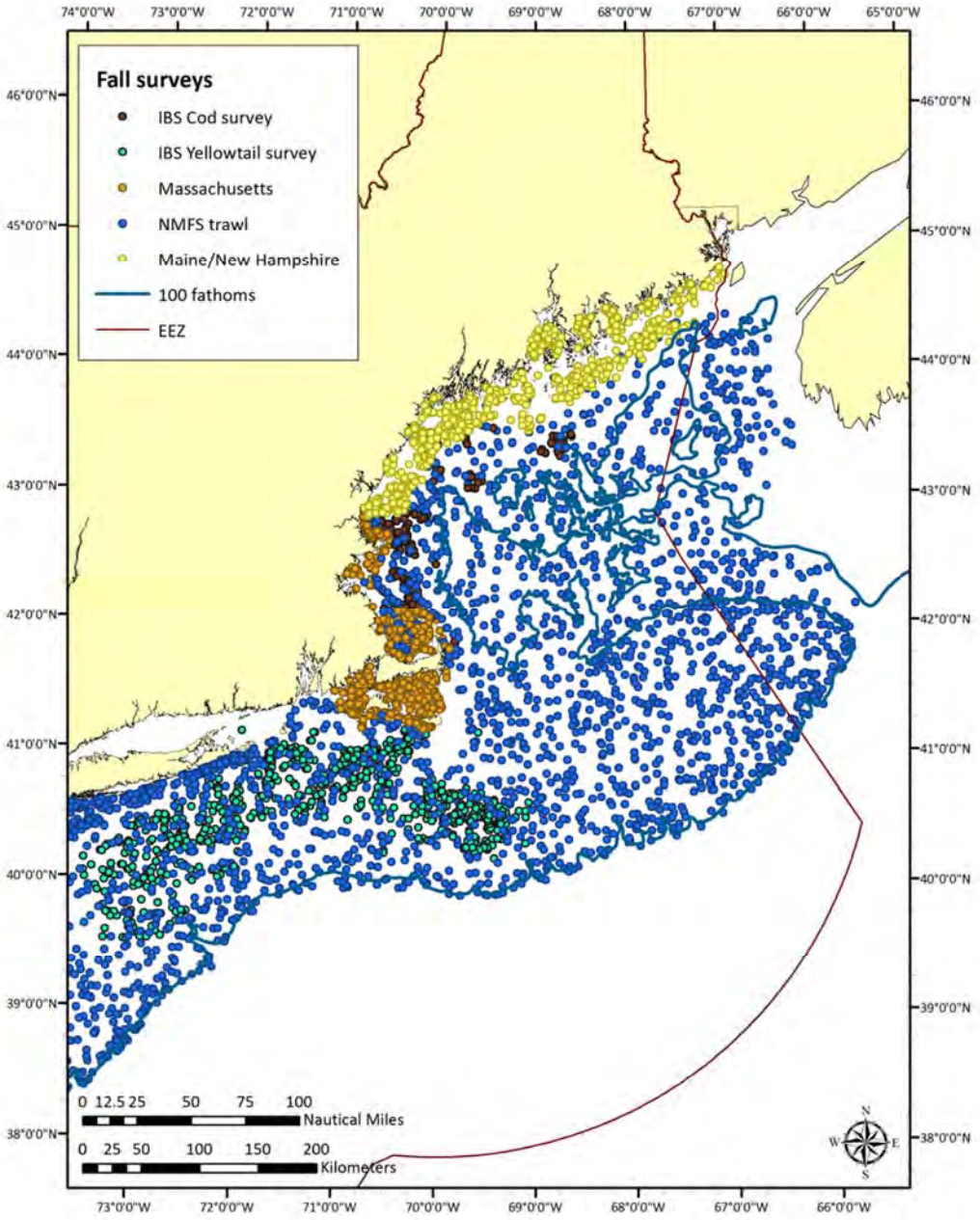
Variable	(Relative to)	GB Cod		GOM Cod		GB Yellowtail	
		P/A	P	P/A	P	P/A	P
DEPTH		— —		— —	—	0	— —
TEMPERATURE		— —		— —	~		~
ZENITH		+			0	+ +	
Sed Coarseness		+ +		NA		0	~
Shear Stress		—	—	NA			
Season – Spring	Fall	— —			+ +	+ +	
SB Form – High Flat	Depression			+ +		+	
SB Form – High Slope	Depression			+ +			
SB Form – Low Slope	Depression						
SB Form – Mid Flat	Depression						
SB Form – Side Slope	Depression						
Sediment – SandXL	Gravel	NA		—			NA
Sediment – SandLarge	Gravel	NA			+		NA
Sediment – SandMed	Gravel	NA					NA
Sediment – SandSmall	Gravel	NA		—			NA
Sediment – Silt/Mud	Gravel	NA		— —	—		NA

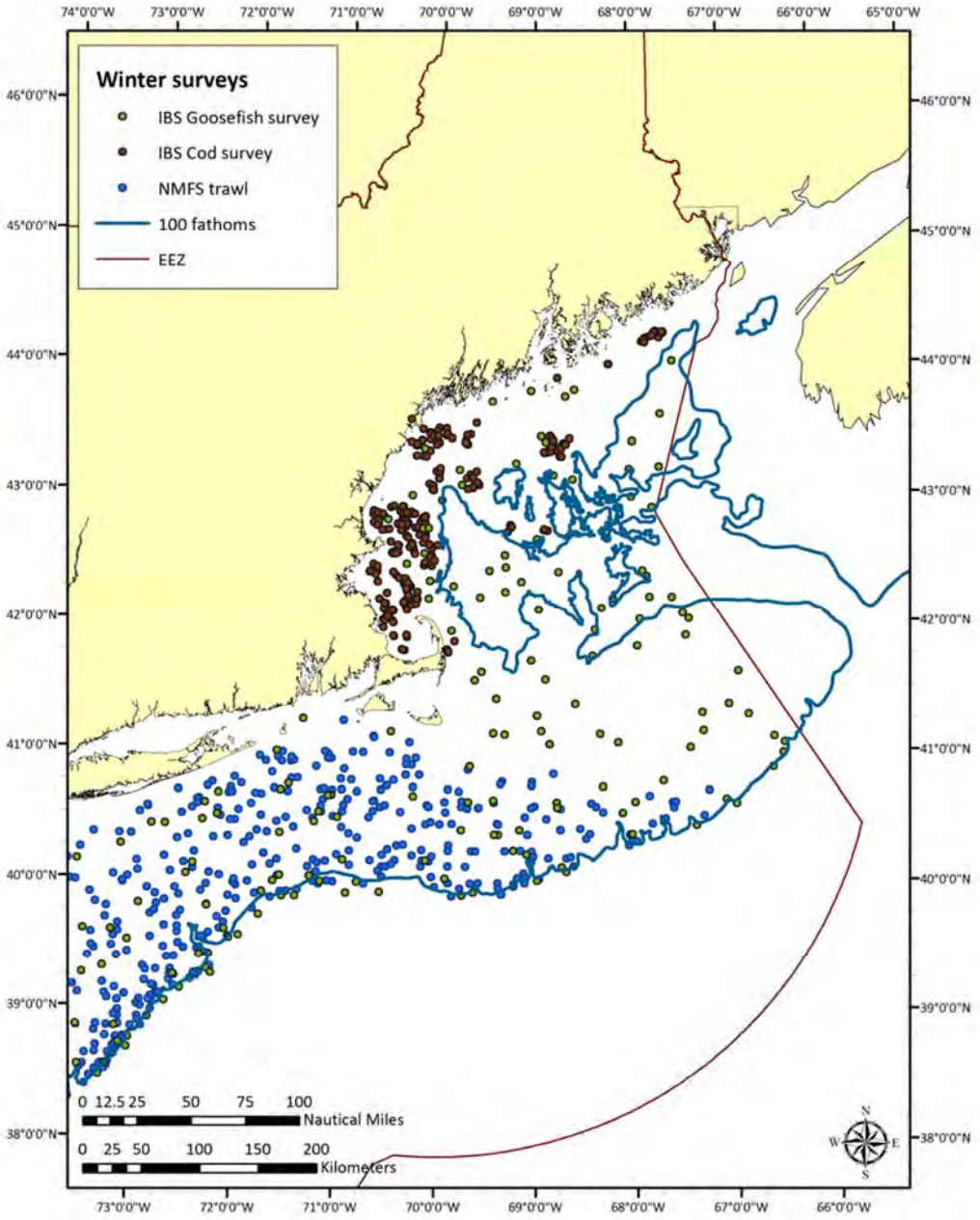
‘Hotspot’ analysis

Survey	Spring	Summer	Fall	Winter
NMFS trawl	2002-2012 Mar-Apr		2002-2011 Sep-Oct	2002-2007 Feb
NMFS shrimp		2002-2007 Jul-Aug		
NMFS dredge	2002-2012 Jul-Aug May-Jun			
MA DMF trawl	2002-2012 May		2002-2011 Sep	
MENH trawl	2002-2012		2002-2012	
IBS cod	2003-2007 Feb-May		2003-2006 Nov-Dec	2004-2007 Jan-Mar
IBS yellowtail flounder			2003-2005 Oct	
IBS goosefish	2001, 2004 Feb-May			2009 Feb-Apr


Spring surveys
IBS Goosefish survey
IBS Cod survey
Massachusetts
NMFS trawl
Maine/New Hampshire
100 fathoms
EEZ
74°0'0"W
73°0'0"W
72°0'0"W
71°0'0"W
70°0'0"W
69°0'0"W
68°0'0"W
67°0'0"W
66°0'0"W
65°0'0"W
46°0'0"N
45°0'0"N
44°0'0"N
43°0'0"N
42°0'0"N
41°0'0"N
40°0'0"N
39°0'0"N
38°0'0"N
0 12.5 25 50 75 100
Nautical Miles
0 25 50 100 150 200
Kilometers
N
W
E
S


Summer surveys
Summer shrimp survey
Summer scallop dredge survey
Spring-coded scallop dredge survey
100 fathoms
EEZ
74°0'0"W
73°0'0"W
72°0'0"W
71°0'0"W
70°0'0"W
69°0'0"W
68°0'0"W
67°0'0"W
66°0'0"W
65°0'0"W
46°0'0"N
45°0'0"N
44°0'0"N
43°0'0"N
42°0'0"N
41°0'0"N
40°0'0"N
39°0'0"N
38°0'0"N
0 12.5 25 50 75 100
Nautical Miles
0 25 50 100 150 200
Kilometers
N
W
E
S


Fall surveys
IBS Cod survey
IBS Yellowtail survey
Massachusetts
NMFS trawl
Maine/New Hampshire
100 fathoms
EEZ
74°0'0"W
73°0'0"W
72°0'0"W
71°0'0"W
70°0'0"W
69°0'0"W
68°0'0"W
67°0'0"W
66°0'0"W
65°0'0"W
46°0'0"N
45°0'0"N
44°0'0"N
43°0'0"N
42°0'0"N
41°0'0"N
40°0'0"N
39°0'0"N
38°0'0"N
0 12.5 25 50 75 100
Nautical Miles
0 25 50 100 150 200
Kilometers
N
W
E
S


Winter surveys
IBS Goosefish survey
IBS Cod survey
NMFS trawl
100 fathoms
EEZ
74°0'0"W
73°0'0"W
72°0'0"W
71°0'0"W
70°0'0"W
69°0'0"W
68°0'0"W
67°0'0"W
66°0'0"W
65°0'0"W
46°0'0"N
45°0'0"N
44°0'0"N
43°0'0"N
42°0'0"N
41°0'0"N
40°0'0"N
39°0'0"N
38°0'0"N
0 12.5 25 50 75 100
Nautical Miles
0 25 50 100 150 200
Kilometers
N
W
E
S

‘Hotspot’ analysis

- Juveniles
  - Age 0 and 90% of age 1 from age-length key
  - L20 for female maturity
- Spawners
  - Largest fish comprising 20% of estimated biomass in the NMFS trawl surveys (spring and fall)
- Hurdle model approach (two step)
  - Adjust catch/tow by multiplying by proportion of non-zero tows

‘Hotspot’ analysis

- Statistical analysis identifies
  - Significant clusters of tows
  - Having above average catch compared to the survey mean for the time series

‘Hotspot’ analysis

- Gridding
  - Number of significant clusters (hotspots) with above average catches of species
    - **Juveniles having a moderate or strong substrate association**
    - **Aggregations of large fish during spawning seasons**
  - Hotspots weighted by importance factor (see following tables)
  - Weighted grids plotted seasonally
  - Areas identified from groups of higher value grids, considering the contribution to cell weight from individual species

Juvenile groundfish parameters and grid weights

Stock	Juvenile size threshold Age 0 and 1 length (90th percentile, cm)	Length at 20% female maturity (cm) (re-estimated by CATT)	Vulnerability of species (Bmsy/B)[1]	Sub-populations[2]	Residency[3]	Substrate[4]	Final Weighting Sum
GB Cod	24 (Sp), 34 (Fa)	36	14.11	2	1	3	20.11
GOM Cod	24 (Sp), 34 (Fa)	36	5.53	3	1	3	12.53
GB Yellowtail Flounder	13 (Sp), 15 (Fa)	25	9.39	1	2	1	13.39
CC/GOM Yellowtail Flounder	13 (Sp), 15 (Fa)	25	4.21	1	2	1	8.21
SNE/MA Yellowtail Flounder	13 (Sp), 15 (Fa)	25	0.77	1	2	1	4.77
GOM Winter Flounder	18 (Sp), 28 (Fa)	27	UNK	UNK	2	1	10.50
GB Winter Flounder	18 (Sp), 28 (Fa)	27	1.22	3	2	1	7.22
SNE/MA Winter Flounder	18 (Sp), 28 (Fa)	27	6.17	3	2	1	12.17
White Hake	34 (Sp), 39 (Fa)	25	1.21	UNK	2	1	6.21
GOM Haddock	24 (Sp), 34 (Fa)	28	1.71	1	1	3	6.71
GB Haddock	24 (Sp), 34 (Fa)	28	0.75	1	1	3	5.75
Witch Flounder	20 (Sp), 19 (Fa)	28	2.45	3	2	1	8.45
American Plaice	12 (Sp), 18 (Fa)	24	1.70	UNK	1	2	6.70
Pollock	23 (Sp), 32 (Fa)	39	0.46	2	2	2	6.46
Acadian Redfish	14 (Sp), 13 (Fa)	19	0.76	1	2	2	5.76
Atlantic Halibut	see winter flounder	NA	28.82	UNK	2	2	34.82
Ocean Pout	29	29[6]	12.05	UNK	1	3	18.05
Northern (GOM-GB) Windowpane Flounder	see yellowtail flounder	18	3.48	UNK	2	1	8.48
Southern (SNE-MA) Windowpane Flounder	see yellowtail flounder	18	0.69	UNK	2	1	5.69
Atlantic Wolffish	47	47[7]	3.48	UNK	UNK	2	9.08
Sum			98.96	22	32	35	211.06
Mean			**5.50**	**2.00**	**1.6**	**1.75**	**10.55**

[1]Either SSBmsy/SSB or Bmsy/B used depending on what is reported in the assessment

[2]Derived from Table 81 in Framework 48 or from NEFSC biological data. 1=no subpopulations, 2=some evidence, 3=known subpopulations

[3]Based on information in literature. 1=less resident, more migratory; 2=more resident, less migratory

[4]Based on information in literature. 1=affinity for soft substrates, 2=no strong association with any substrate, 3=affinity for coarse or hard substrates

[5]Sums include a mean value for unknowns

[6] From O'Brien et al. (1993)

[7] From Templeman (1986)

Large spawner groundfish parameters and grid weights

Stock	Large spawner threshold (20% of total biomass)	Length at 80% female maturity (cm) (re-estimated by CATT)	Vulnerability of species (Bmsy/B)[1]	Sub-populations[2]	Residency[3]	Final weighting Sum[4]	Spring multiplier	Summer multiplier	Fall multiplier	Winter multiplier
GB Cod	50	52	14.11	2	1	17.1	*1*	*1*	*0*	*1*
GOM Cod	50	52	5.53	3	1	9.5	*1*	*1*	*0*	*1*
GB Yellowtail Flounder	40	30	9.39	1	2	12.4	*1*	*0*	*0*	*0*
CC/GOM Yellowtail Flounder	40	30	4.21	1	2	7.2	*1*	*0*	*0*	*0*
SNE/MA Yellowtail Flounder	40	30	0.77	1	2	3.8	*1*	*0*	*0*	*0*
GOM Winter Flounder	45	31	UNK	UNK	2	9.5	*1*	*0*	*0*	*1*
GB Winter Flounder	45	31	1.22	3	2	6.2	*1*	*0*	*0*	*1*
SNE/MA Winter Flounder	45	31	6.17	3	2	11.2	*1*	*0*	*0*	*1*
White Hake	75	45	1.21	UNK	2	5.2	*1*	*0*	*0*	*0*
GOM Haddock	50	40	1.71	1	1	3.7	*1*	*0*	*0*	*0*
GB Haddock	50	40	0.75	1	1	2.7	*1*	*0*	*0*	*0*
Witch Flounder	45		2.45	3	2	7.5	*1*	*1*	*1*	*0*
American Plaice	40	32	1.70	UNK	1	4.7	*1*	*0*	*0*	*0*
Pollock	75	52	0.46	2	2	4.5	*0*	*0*	*0*	*1*
Acadian Redfish	30	25	0.76	1	2	3.8	*1*	*1*	*0*	*0*
Atlantic Halibut		NA	28.82	UNK	2	32.8	*1*	*1*	*1*	*1*
Ocean Pout	60	NA	12.05	UNK	1	15.0	*0*	*1*	*1*	*1*
Northern (GOM-GB) Windowpane Flounder	30	24	3.48	UNK	2	7.5	*1*	*1*	*1*	*1*
Southern (SNE-MA) Windowpane Flounder	30	24	0.69	UNK	2	4.7	*1*	*1*	*1*	*1*
Atlantic Wolffish		NA	3.48	UNK	UNK	7.1	*1*	*0*	*0*	*0*
Sum			98.96	22	32	176.1	18	8	5	10
Mean			**5.50**	**2.00**	**1.6**	**8.8**	**0.9**	**0.4**	**0.25**	**0.5**

[1]Either SSBmsy/SSB or Bmsy/B used depending on what is reported in the assessment

2Derived from Table 81 in Framework 48 or from NEFSC biological data. 1=no subpopulations, 2=some evidence, 3=known subpopulations

3Based on information in literature. 1=less resident, more migratory; 2=more resident, less migratory

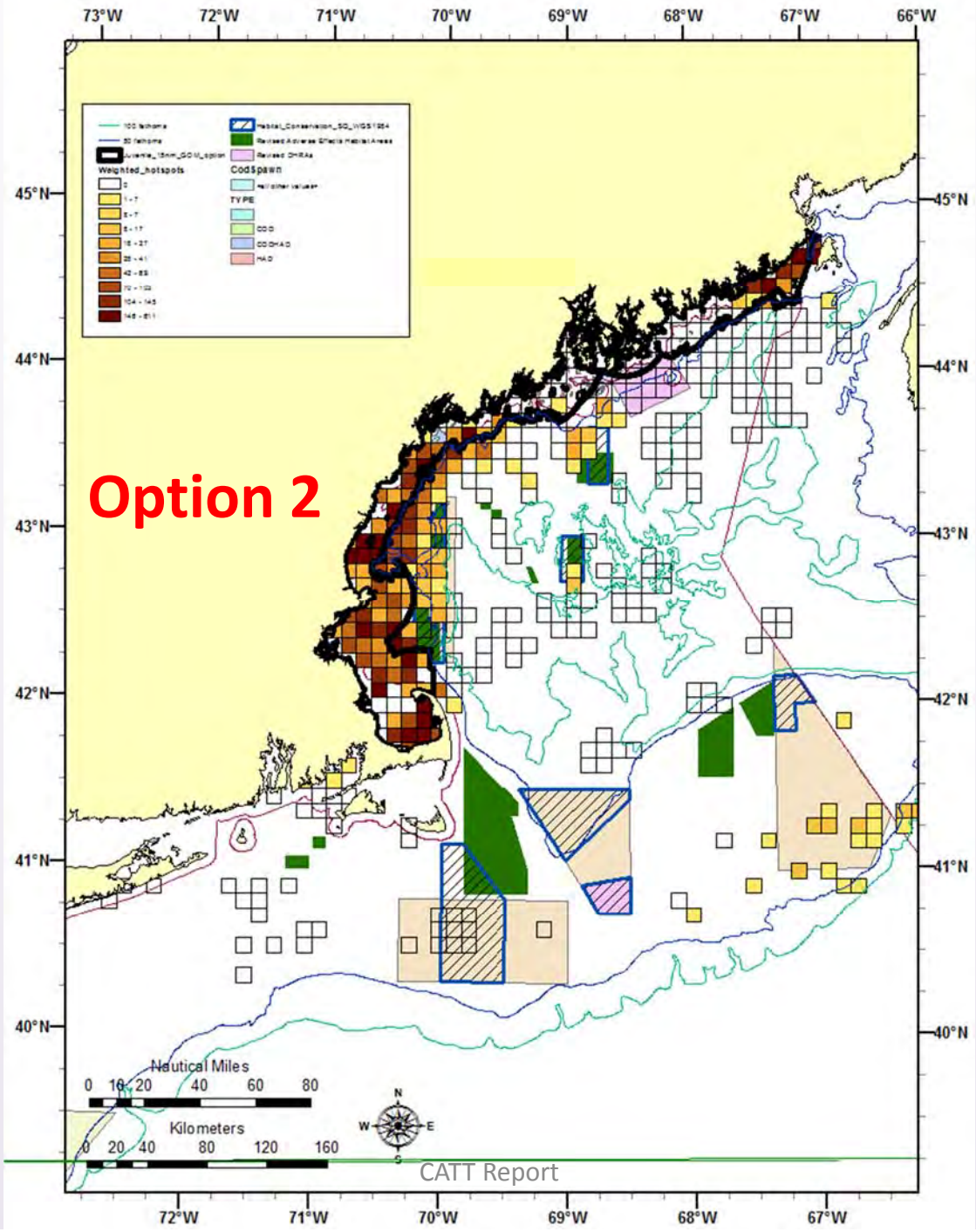
4Sums include a mean value for unknowns

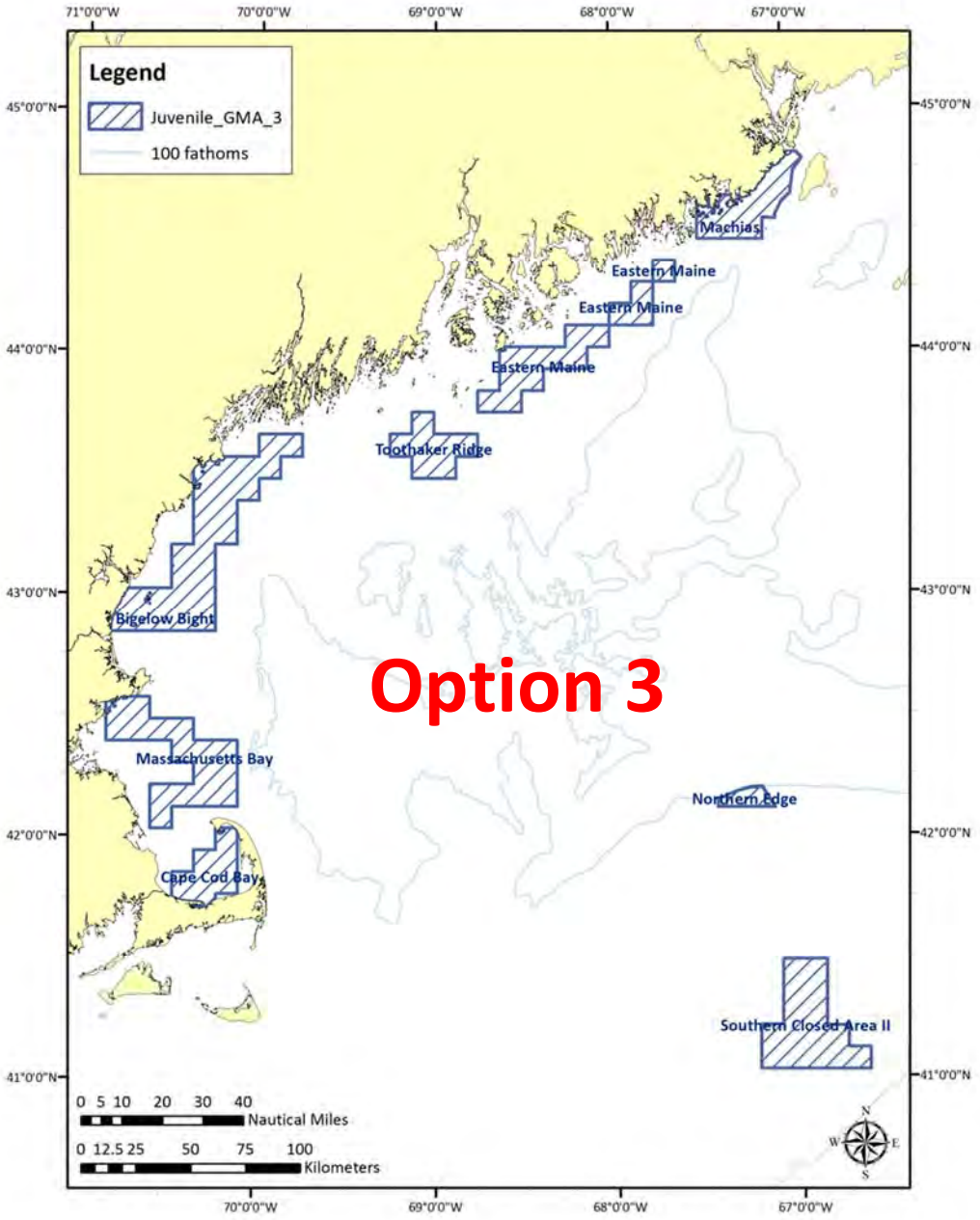
Summary of spatial analyses of survey data

- 16 surveys for 16 species examined
- Hurdle model approach applied, log transformed
- Morans I Spatial Autocorrelation peak -> Getis-Ords G* zone of indifference parameter
- 392 survey species combinations (not including skates)
- 291 hotspot analyses
- 7573 Juvenile hotspots identified for 118 survey/species combinations and gridded to 100 km2 squares
- 2701 Large spawner hotspots identified for 94 survey/species combinations and gridded to 100 km2 squares
- 1 weighted grid layer for each season and life stage (juvenile, large spawner

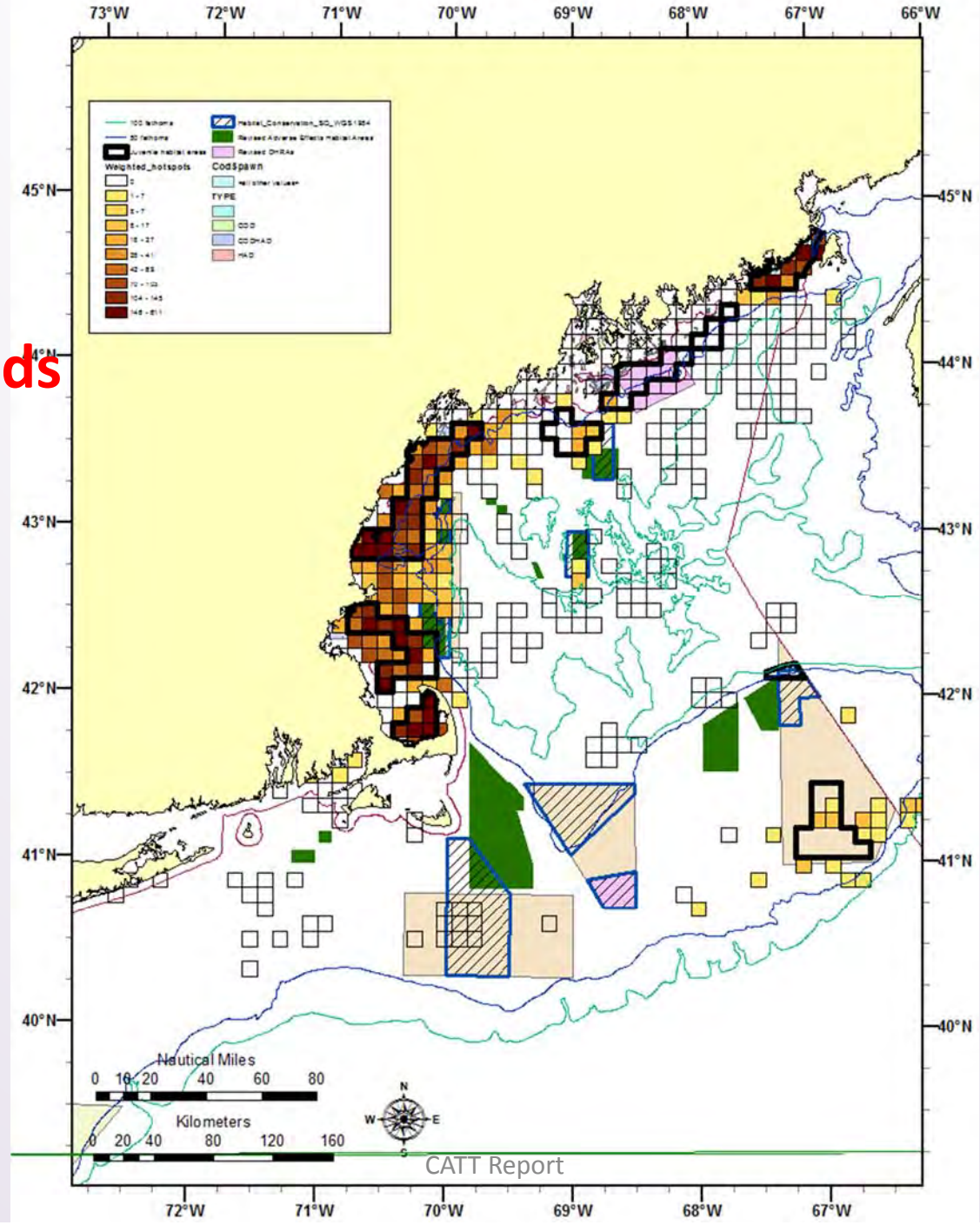
Juvenile habitat management options

- Recommended juvenile habitat alternatives
  - **Closed to bottom tending mobile gear year round**
  - Purpose is to **minimize impacts on juvenile habitat**, NOT to reduce discard mortality
  - Status quo (**Option 1**) is existing year round areas

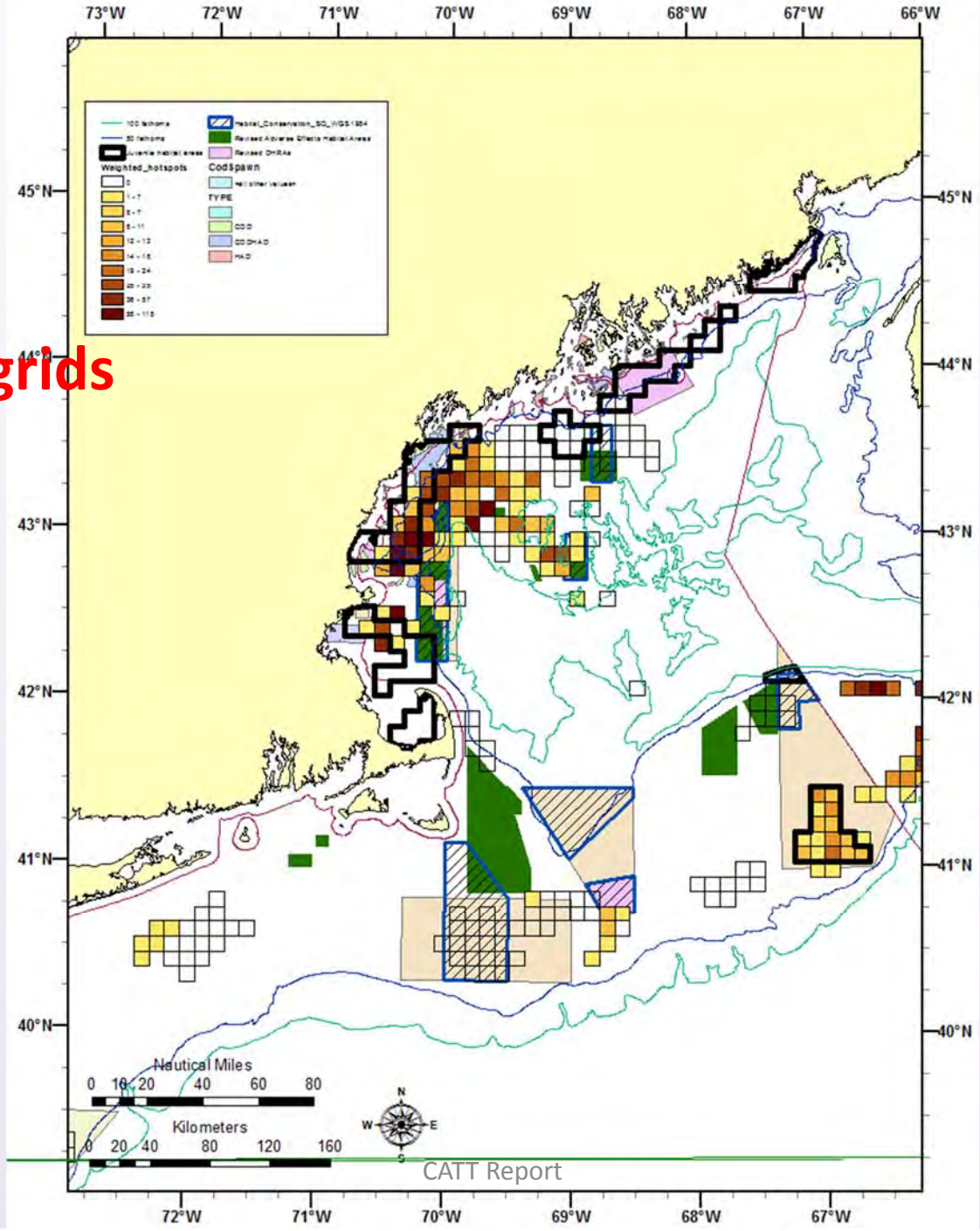

Option 2
73°W
72°W
71°W
70°W
69°W
68°W
67°W
66°W
45°N
44°N
43°N
42°N
41°N
40°N
Weighted_hotspots
CodSpawn
TYPE
Nautical Miles
0 10 20 40 60 80
Kilometers
0 20 40 80 120 160
N
W
E
S


Legend
Juvenile_GMA_3
100 fathoms
Machias
Eastern Maine
Eastern Maine
Eastern Maine
Tdothaker Ridge
Bigelow Bight
Massachusetts Bay
Cape Cod Bay
Northern Edge
Southern Closed Area II
Option 3
0 5 10 20 30 40
Nautical Miles
0 12.5 25 50 75 100
Kilometers
71°0'0"W
70°0'0"W
69°0'0"W
68°0'0"W
67°0'0"W
45°0'0"N
44°0'0"N
43°0'0"N
42°0'0"N
41°0'0"N

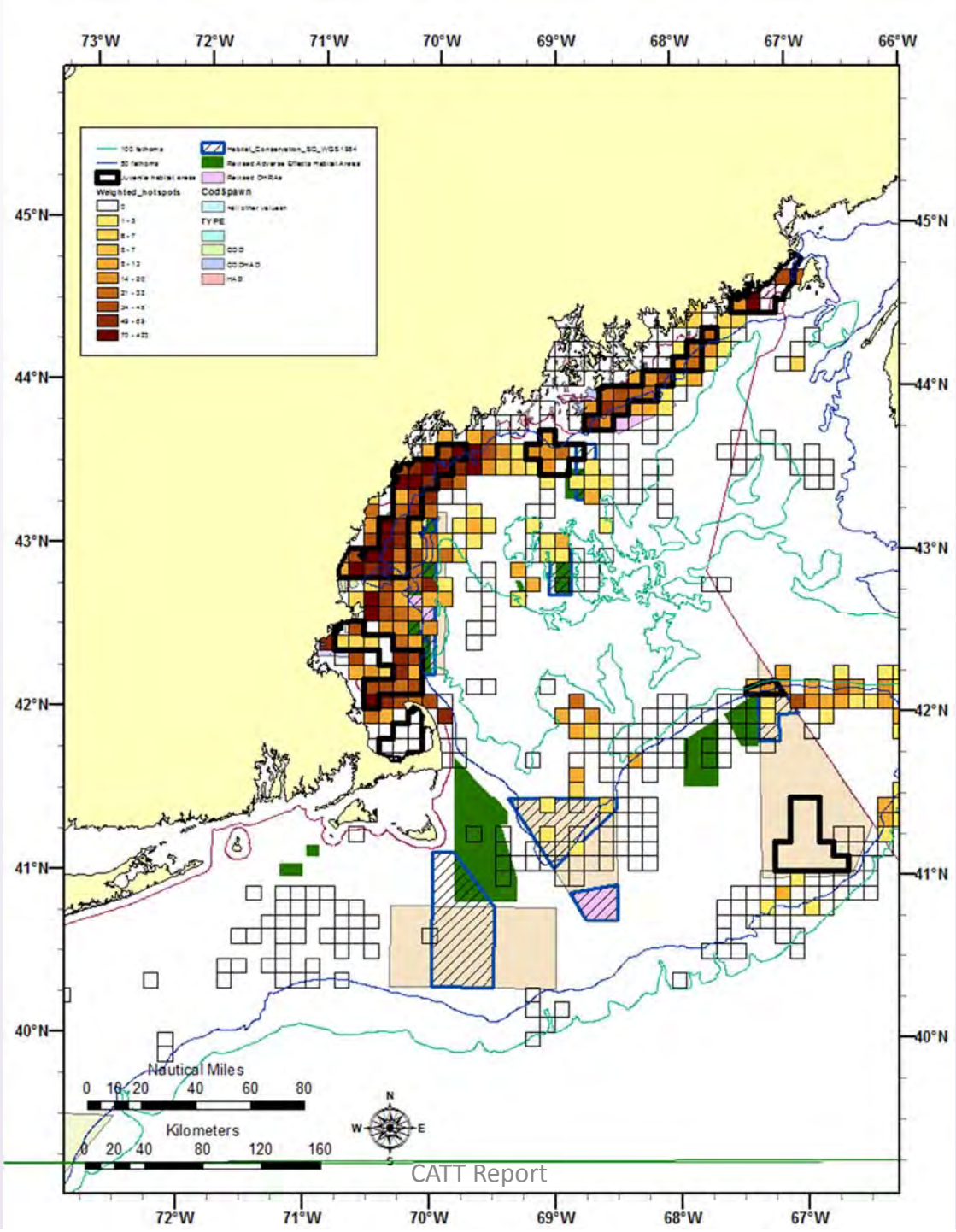
Spring grids



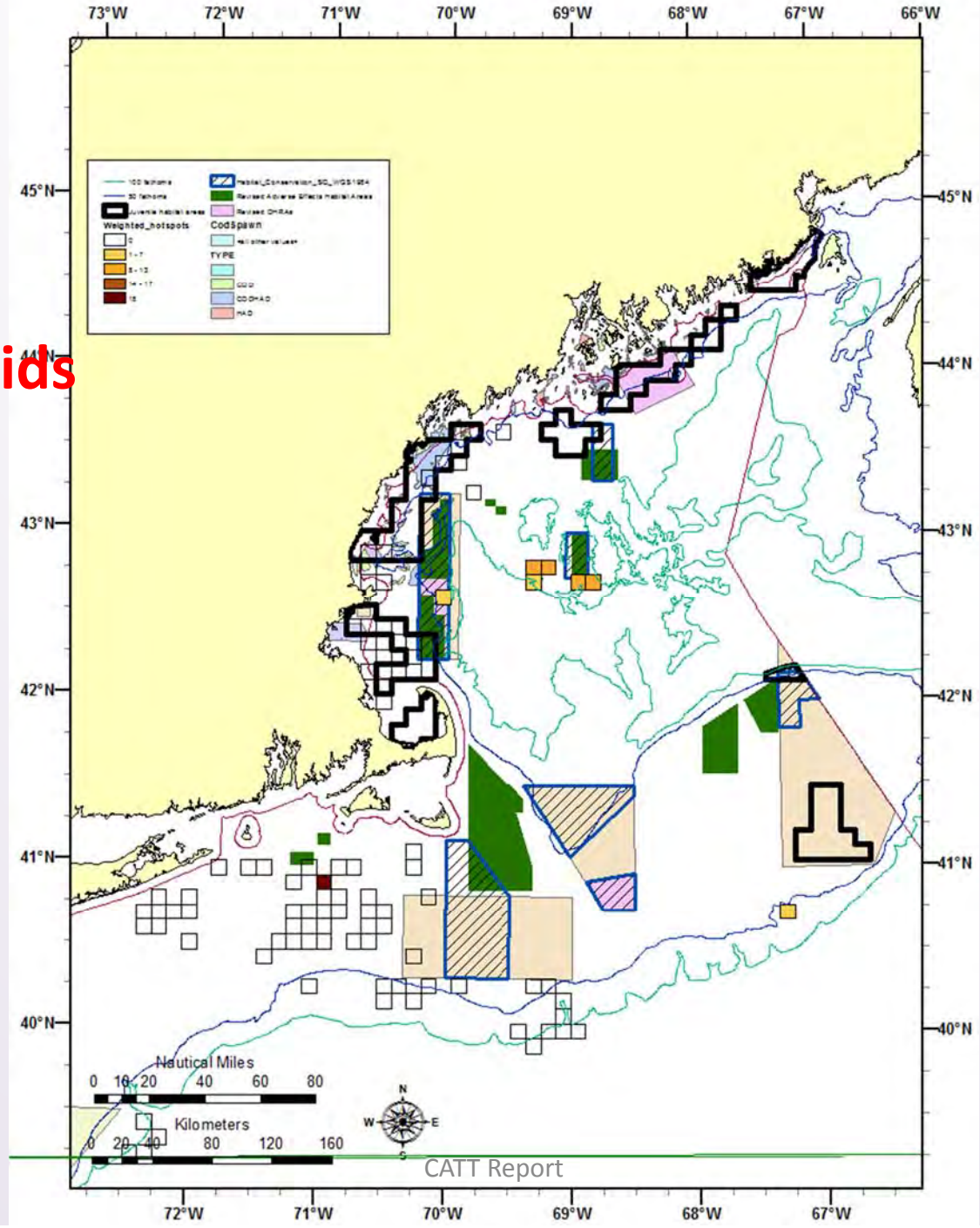
Summer grids



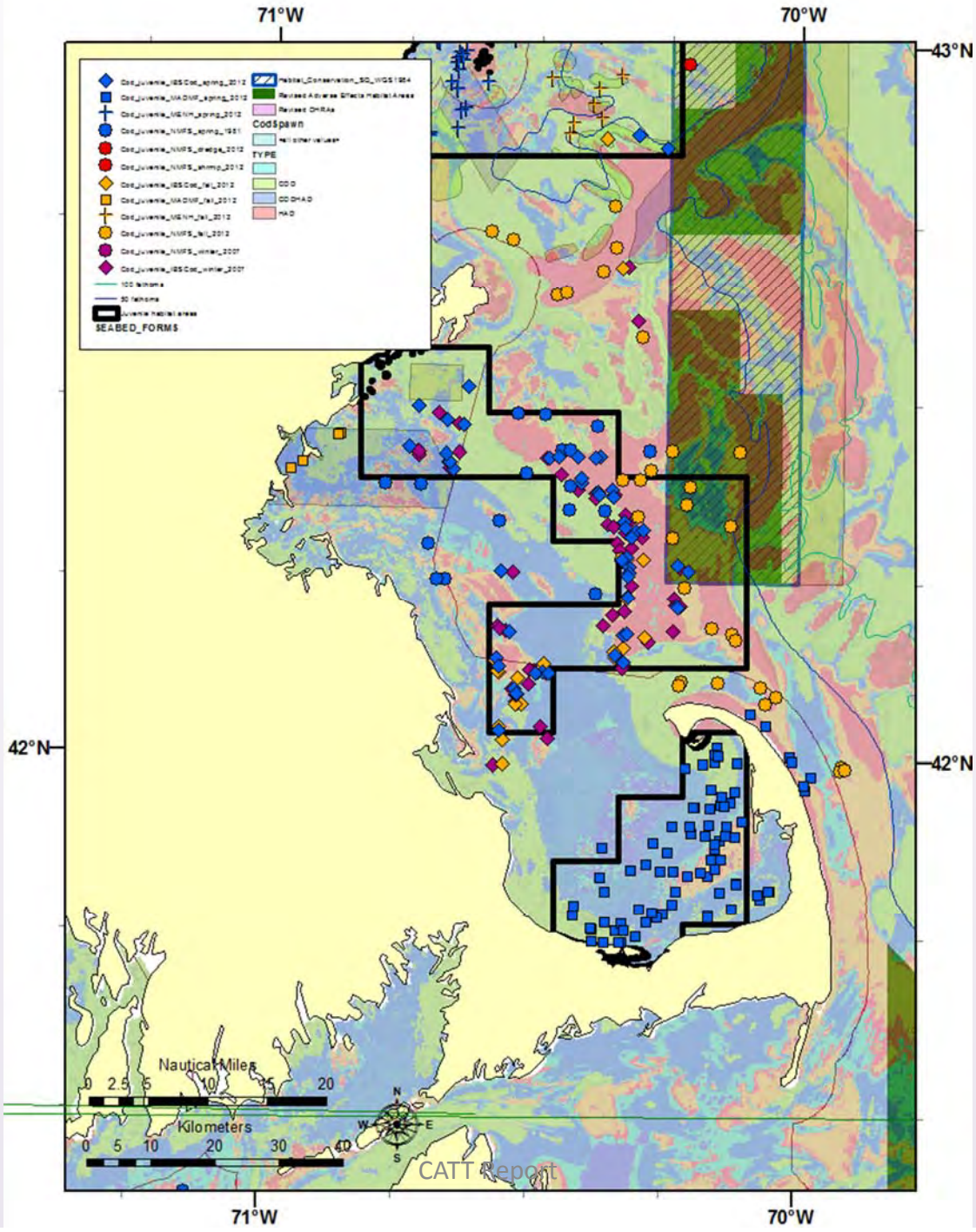
Fall grids


73°W
72°W
71°W
70°W
69°W
68°W
67°W
66°W
45°N
44°N
43°N
42°N
41°N
40°N
Weighted_hotspots
CodSpawn
TYPE
Nautical Miles
0 10 20 40 60 80
Kilometers
0 20 40 80 120 160
N
W
E
S

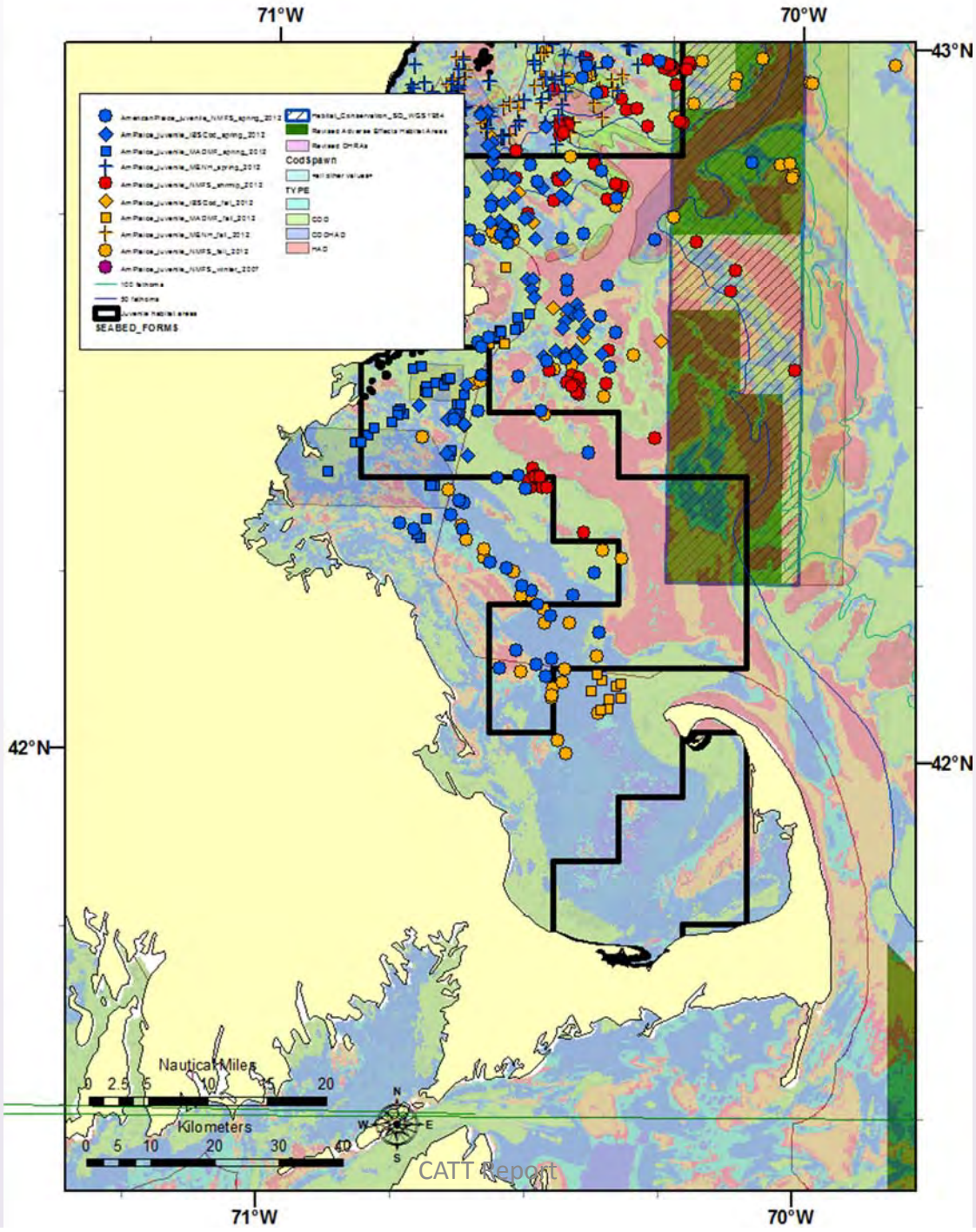
Winter grids



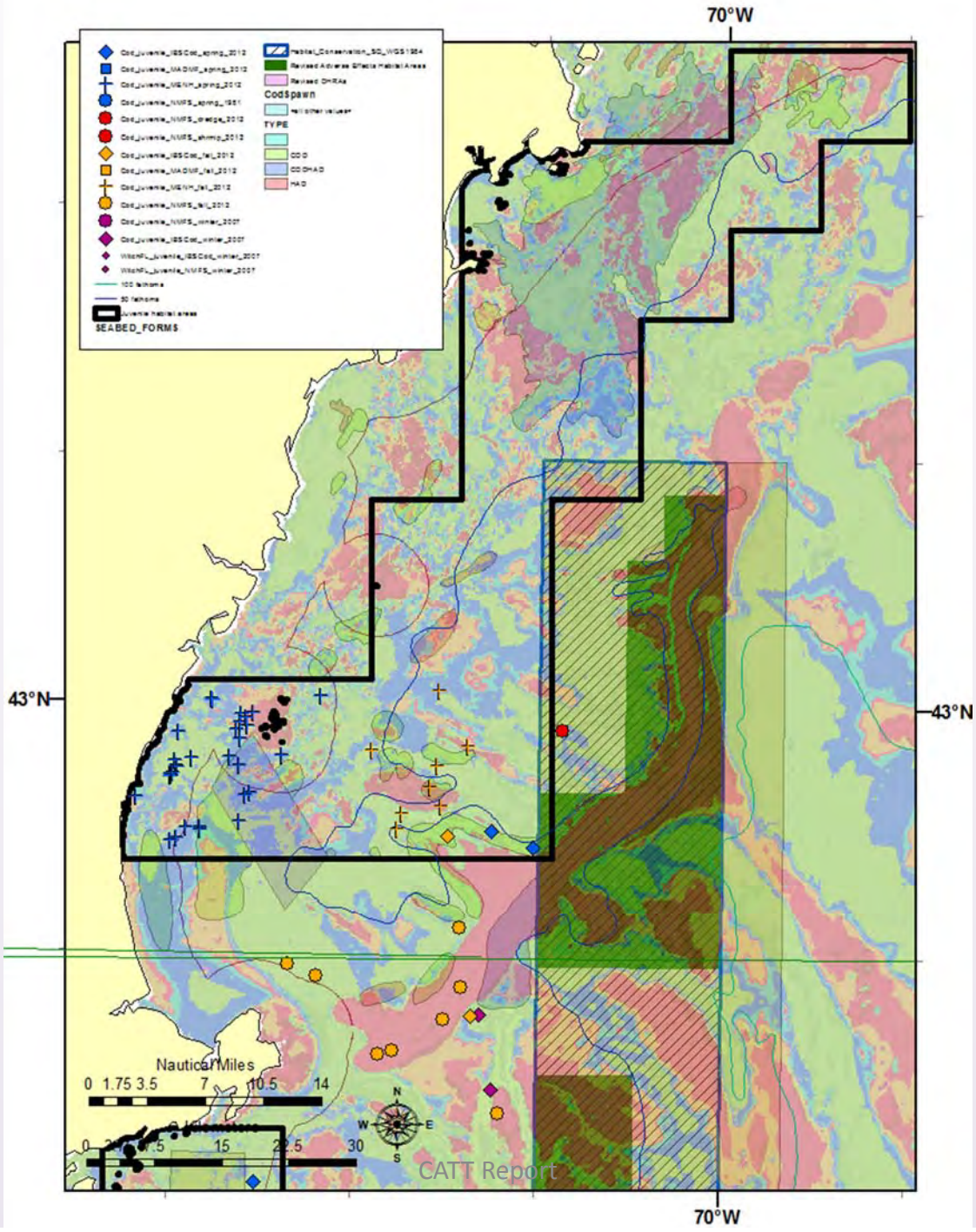
Cod


71°W
70°W
43°N
42°N
42°N
71°W
70°W
Cod spawn
TYPE
SEABED_FORMS
Nautical Miles
0 2.5 5 10 15 20
Kilometers
0 5 10 20 30 40
N
W
E
S

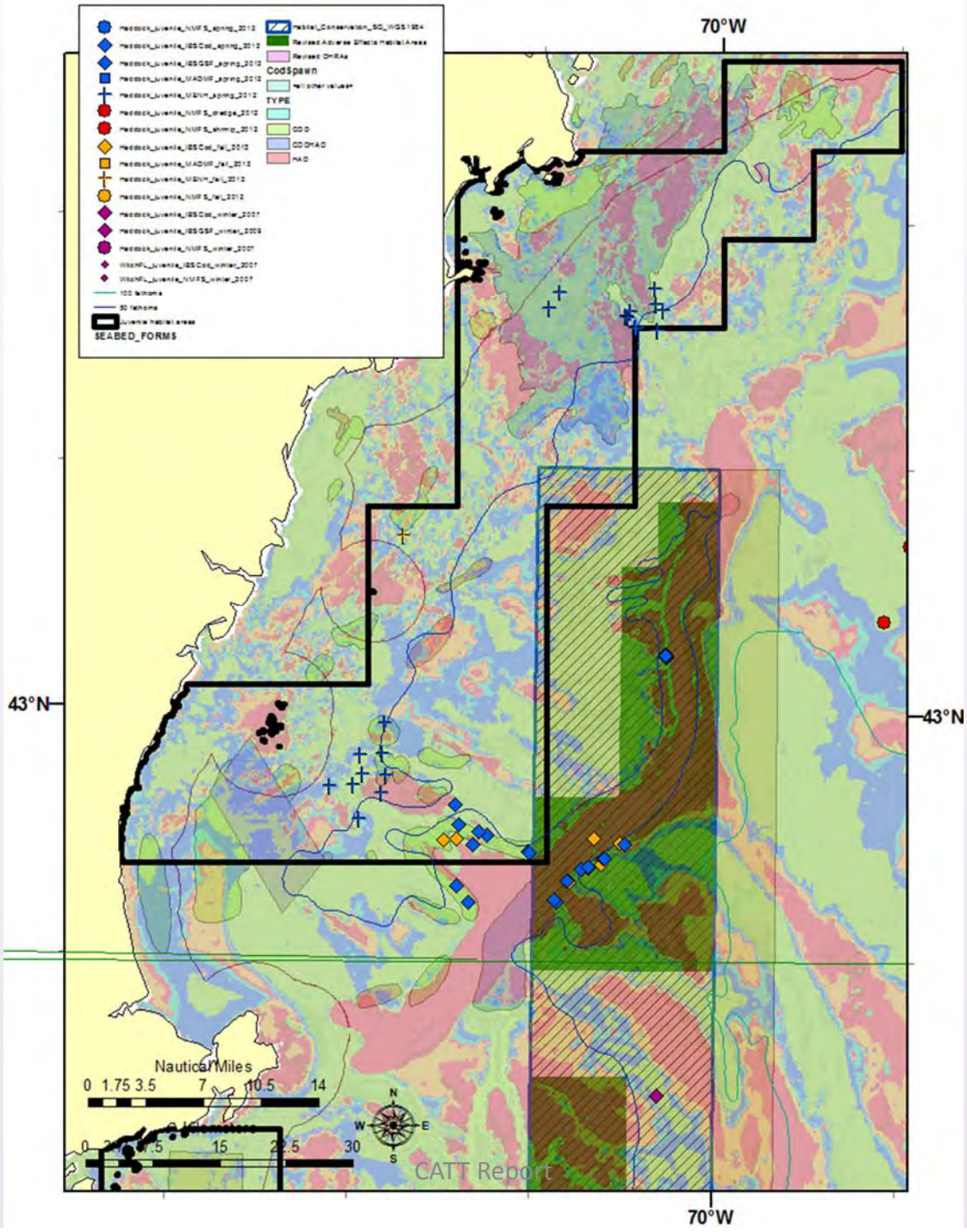
American plaice



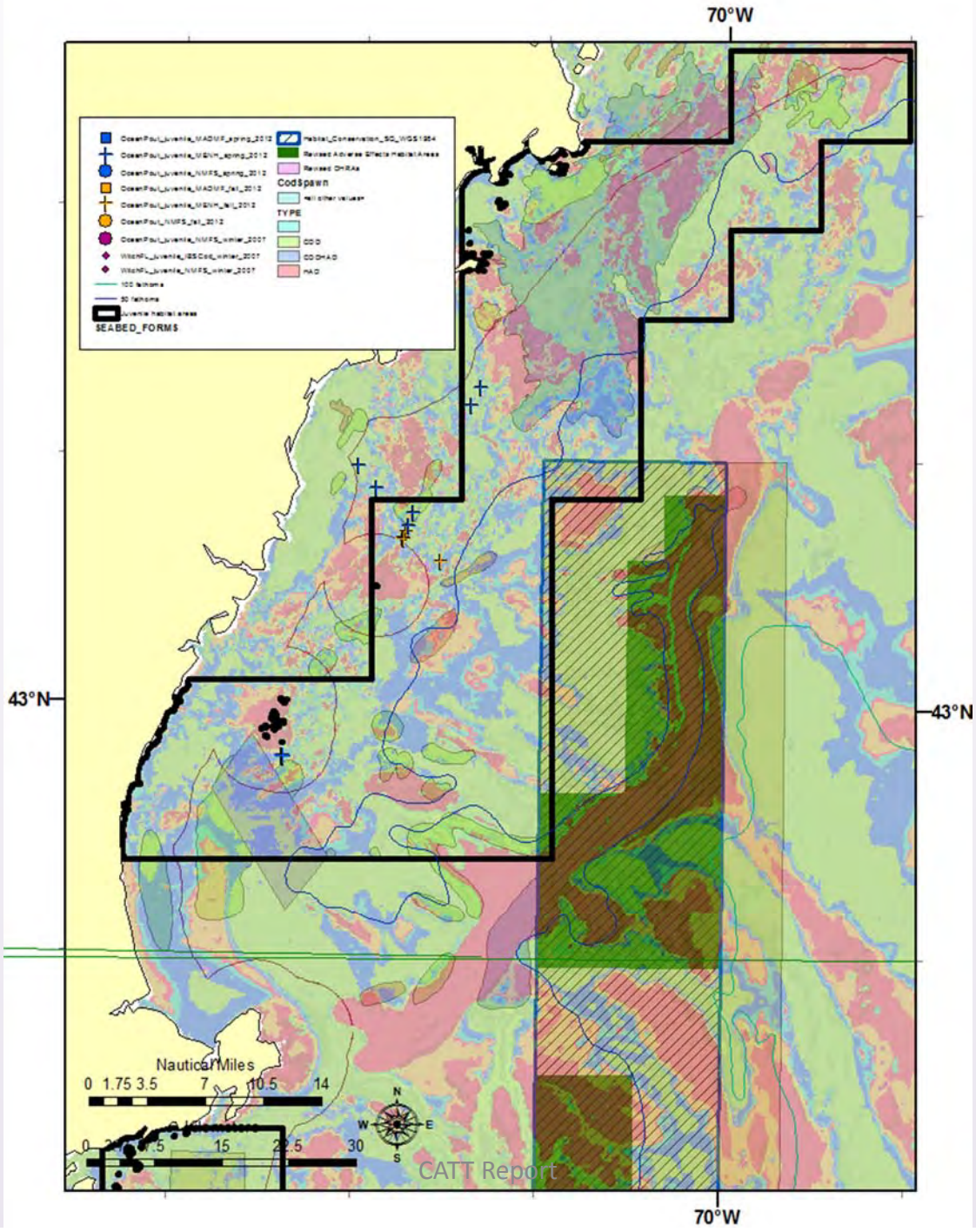
Cod


70°W
43°N
43°N
70°W
Codspawn
TYPE
SEABED_FORMS
Nautical Miles
0 1.75 3.5 7 10.5 14
N
W
E
S

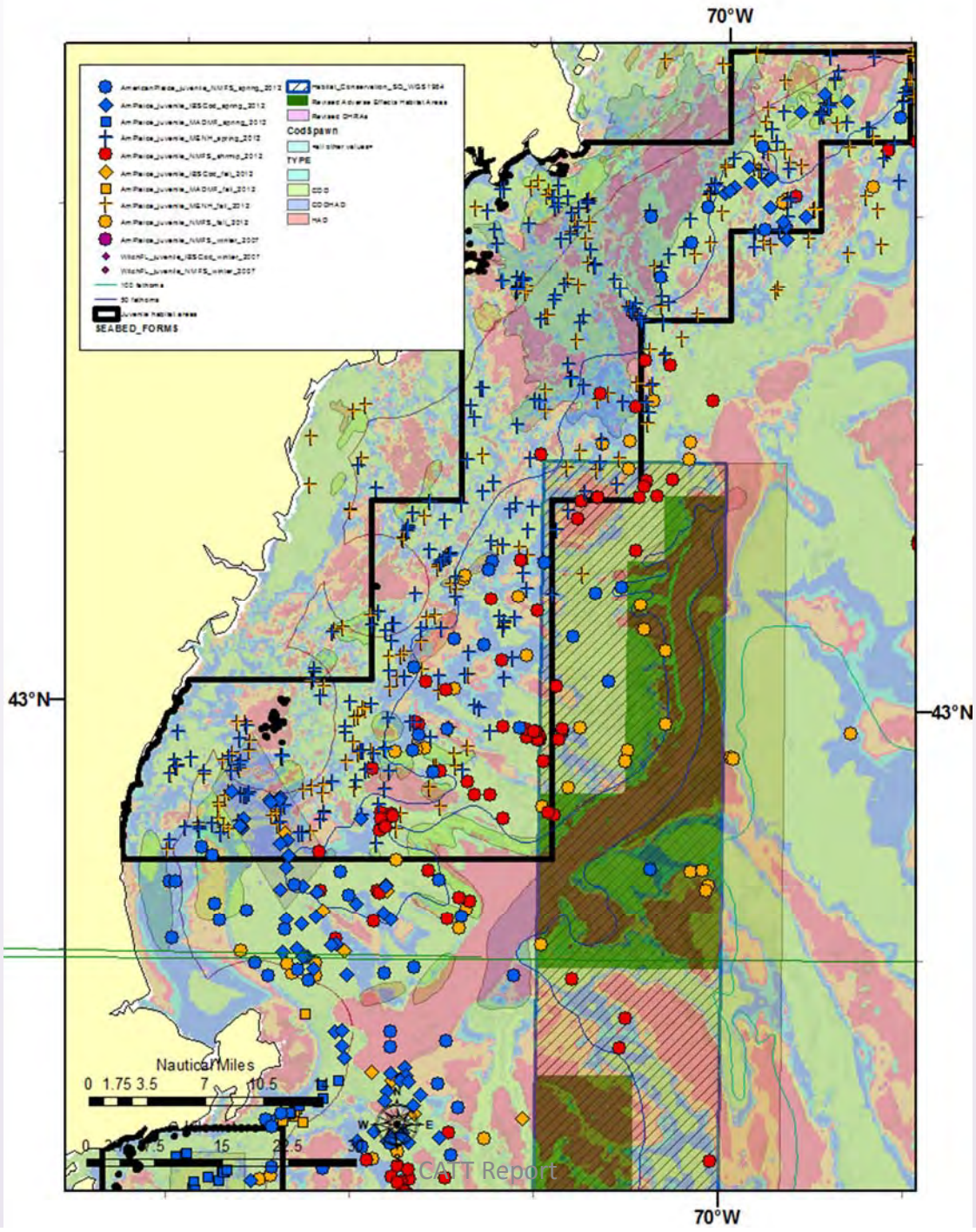
Haddock


70°W
43°N
43°N
70°W
Cod Spawn
TYPE
SEABED_FORMS
Nautical Miles
0 1.75 3.5 7 10.5 14
N
W
E
S

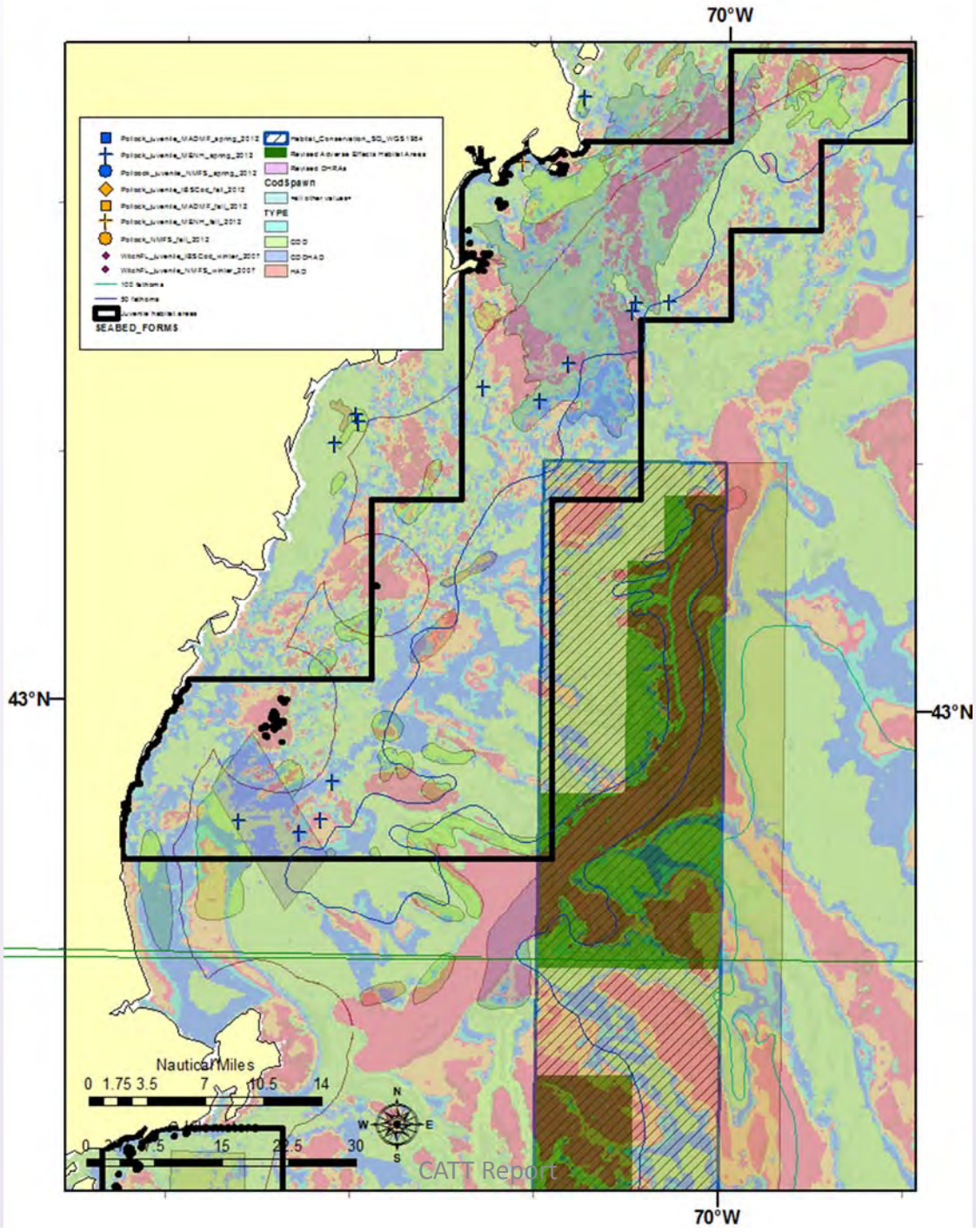
Ocean pout


70°W
43°N
43°N
70°W
Codspawn
TYPE
SEABED_FORMS
Nautical Miles
0 1.75 3.5 7 10.5 14
N
W
E
S

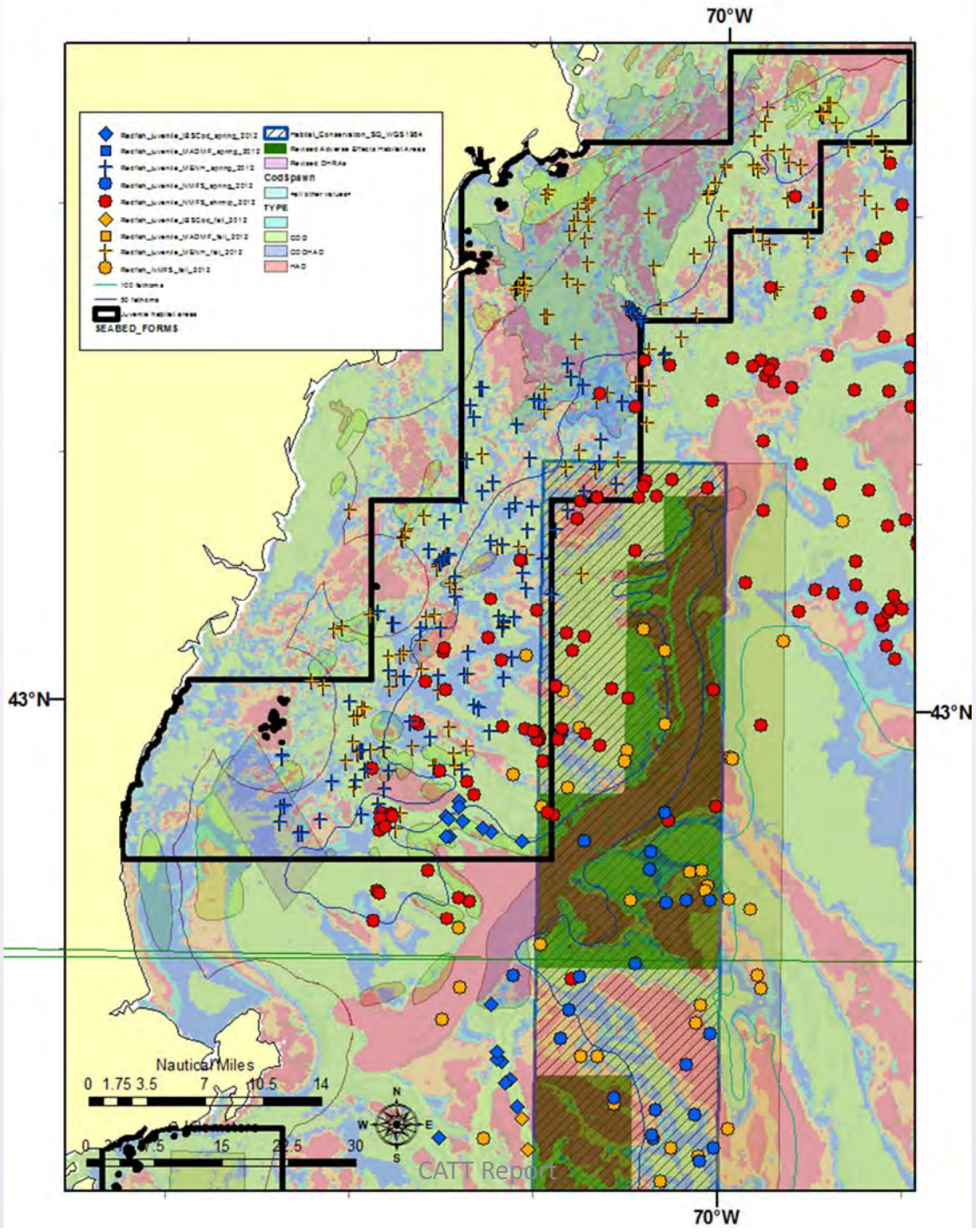
American plaice



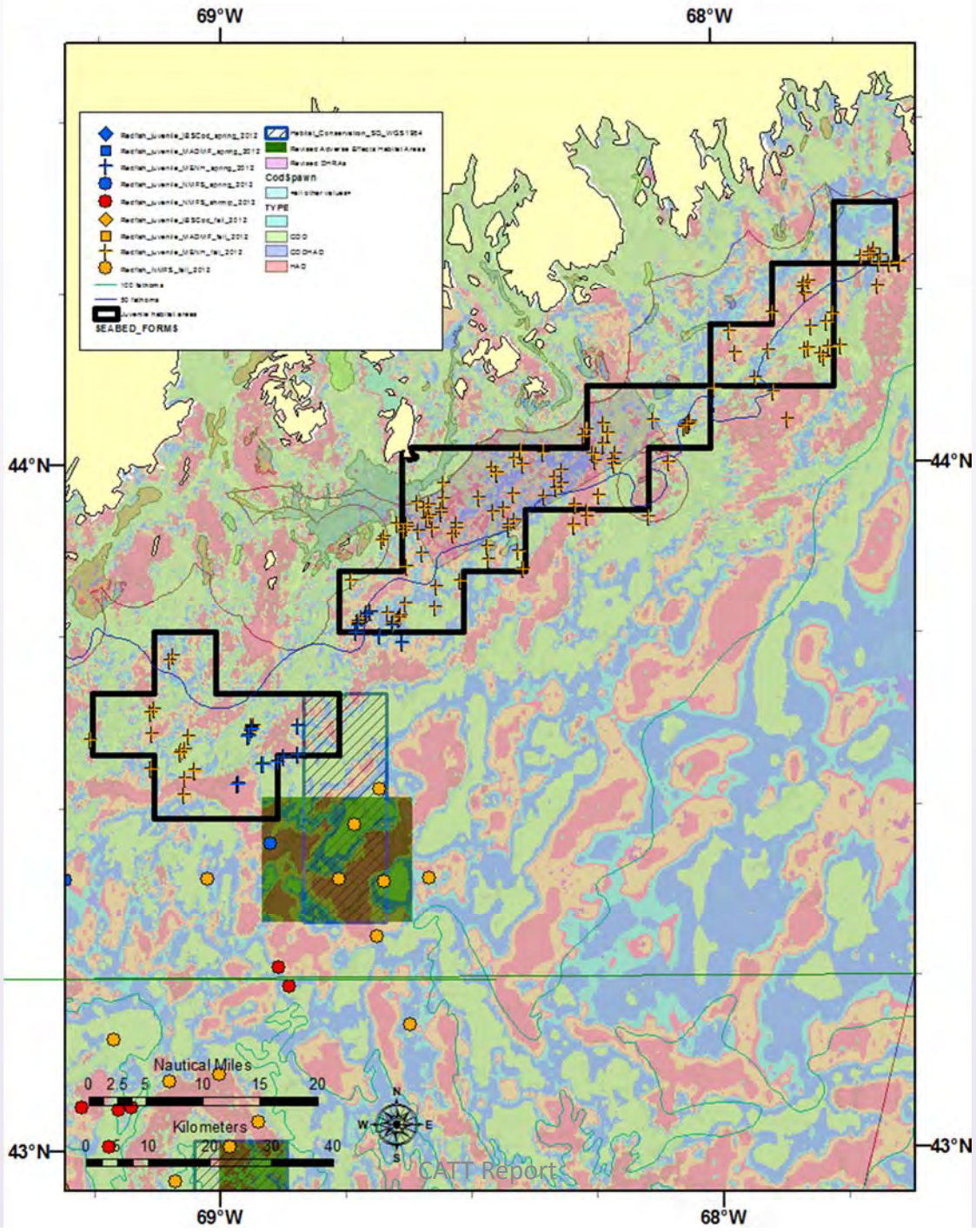
Pollock


70°W
43°N
43°N
70°W
Cod Spawn
TYPE
SEABED_FORMS
Nautical Miles
0 1.75 3.5 7 10.5 14
N
W
E
S

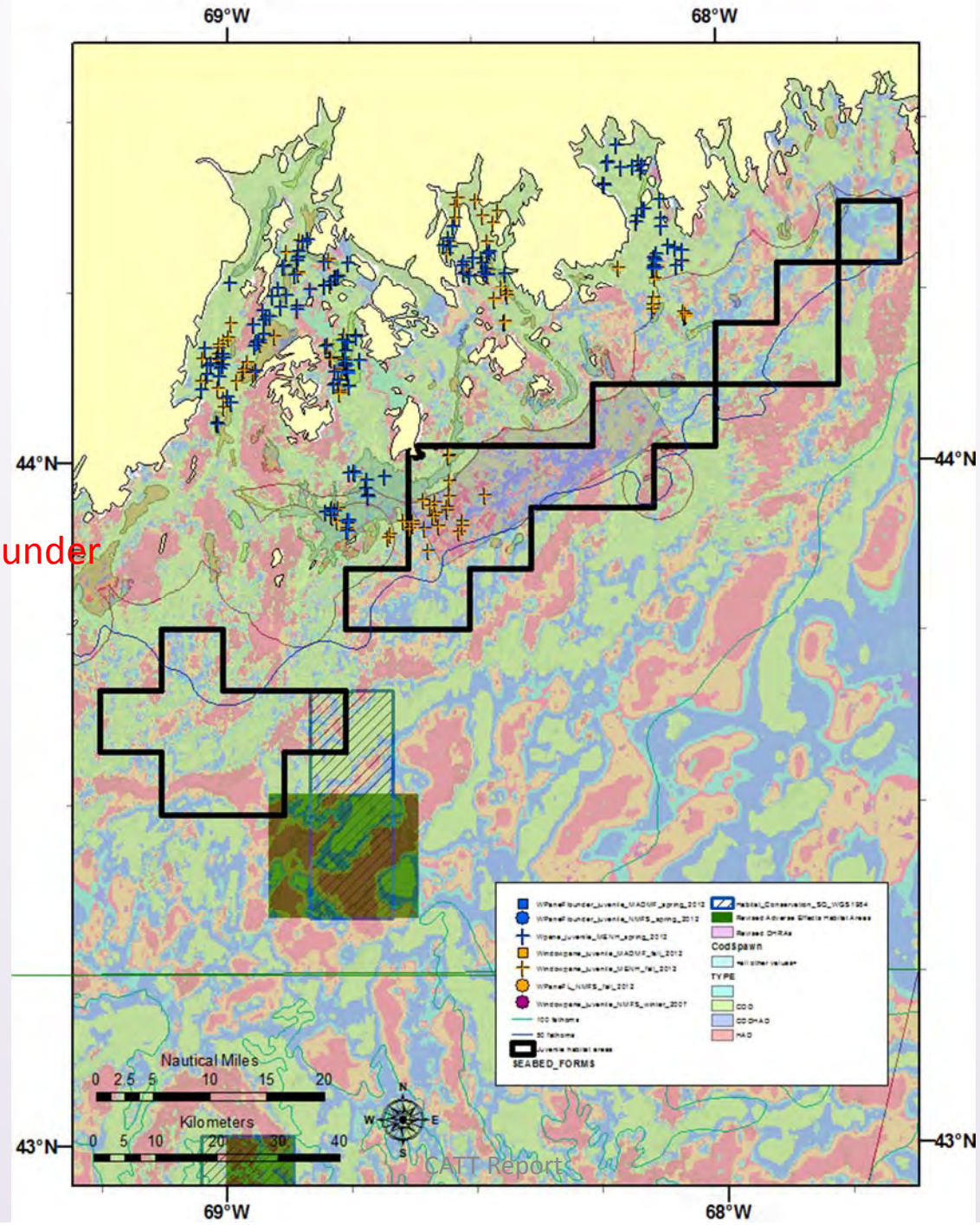
Redfish


70°W
43°N
43°N
70°W
Codspawn
TYPE
SEABED_FORMS
Nautical Miles
0 1.75 3.5 7 10.5 14
N
W
E
S

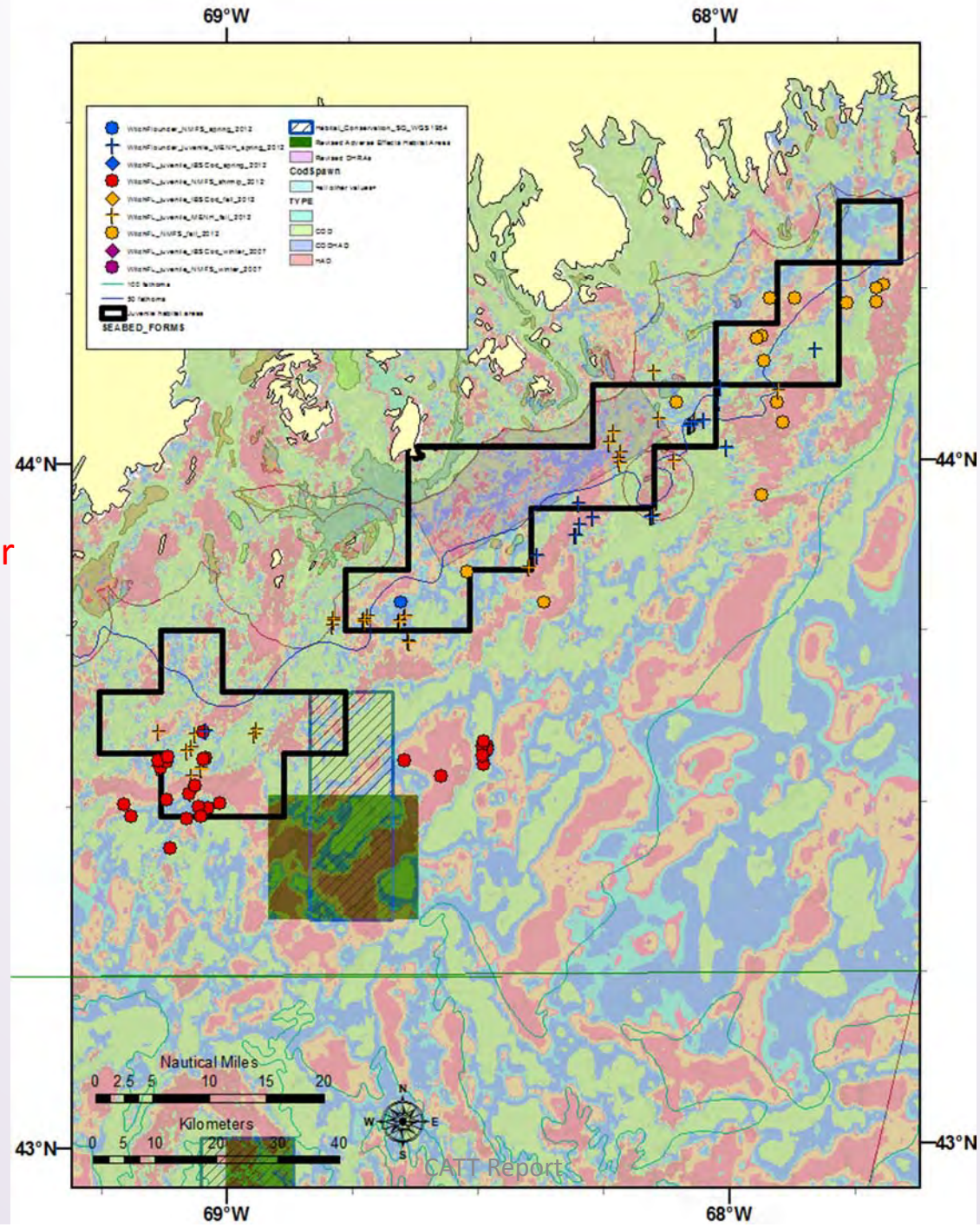
Redfish


69°W
68°W
44°N
43°N
Codspawn
TYPE
SEABED_FORMS
Nautical Miles
0 2.5 5 10 15 20
Kilometers
0 5 10 20 30 40
N
W
E
S

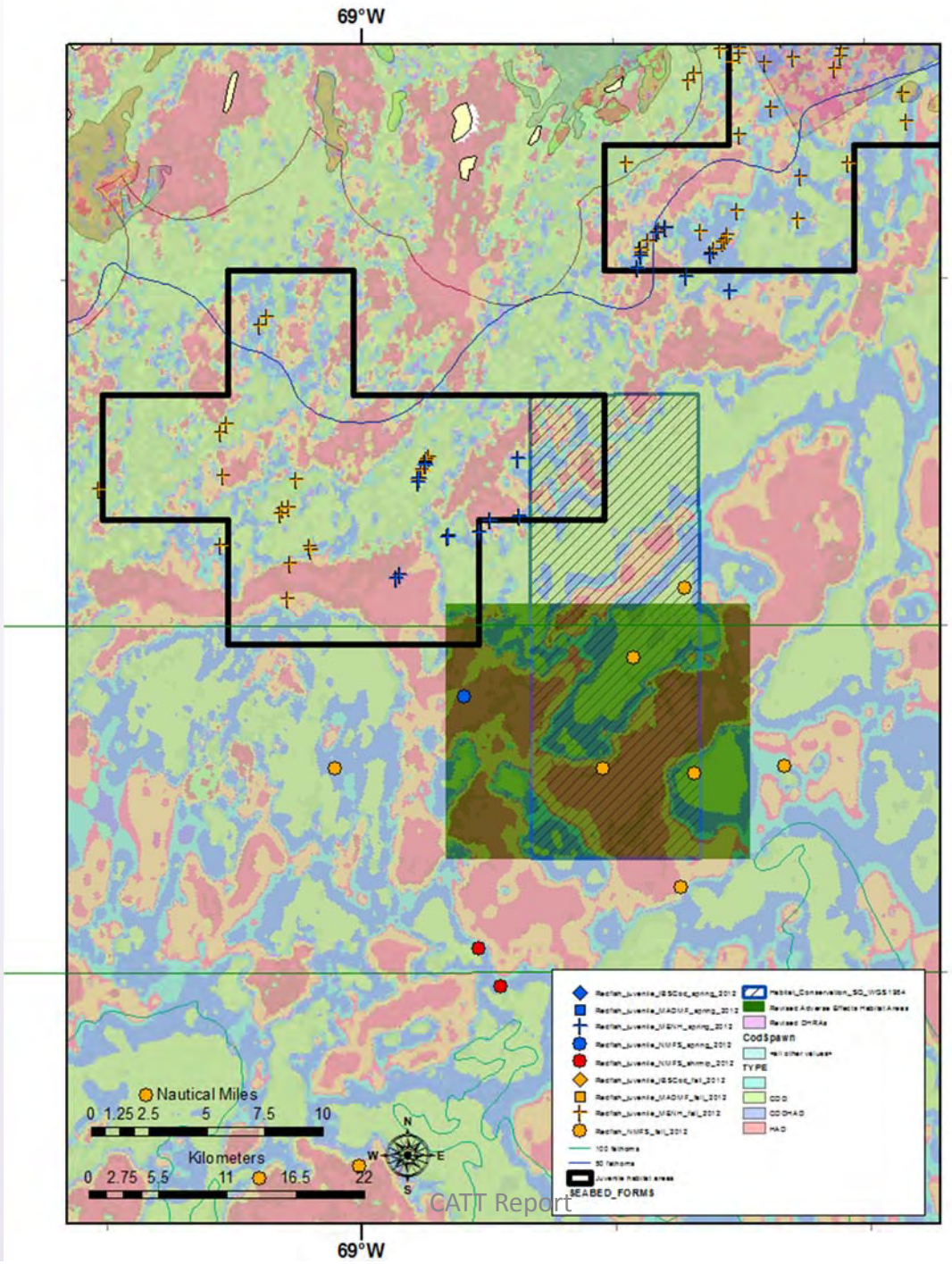
Windowpane flounder



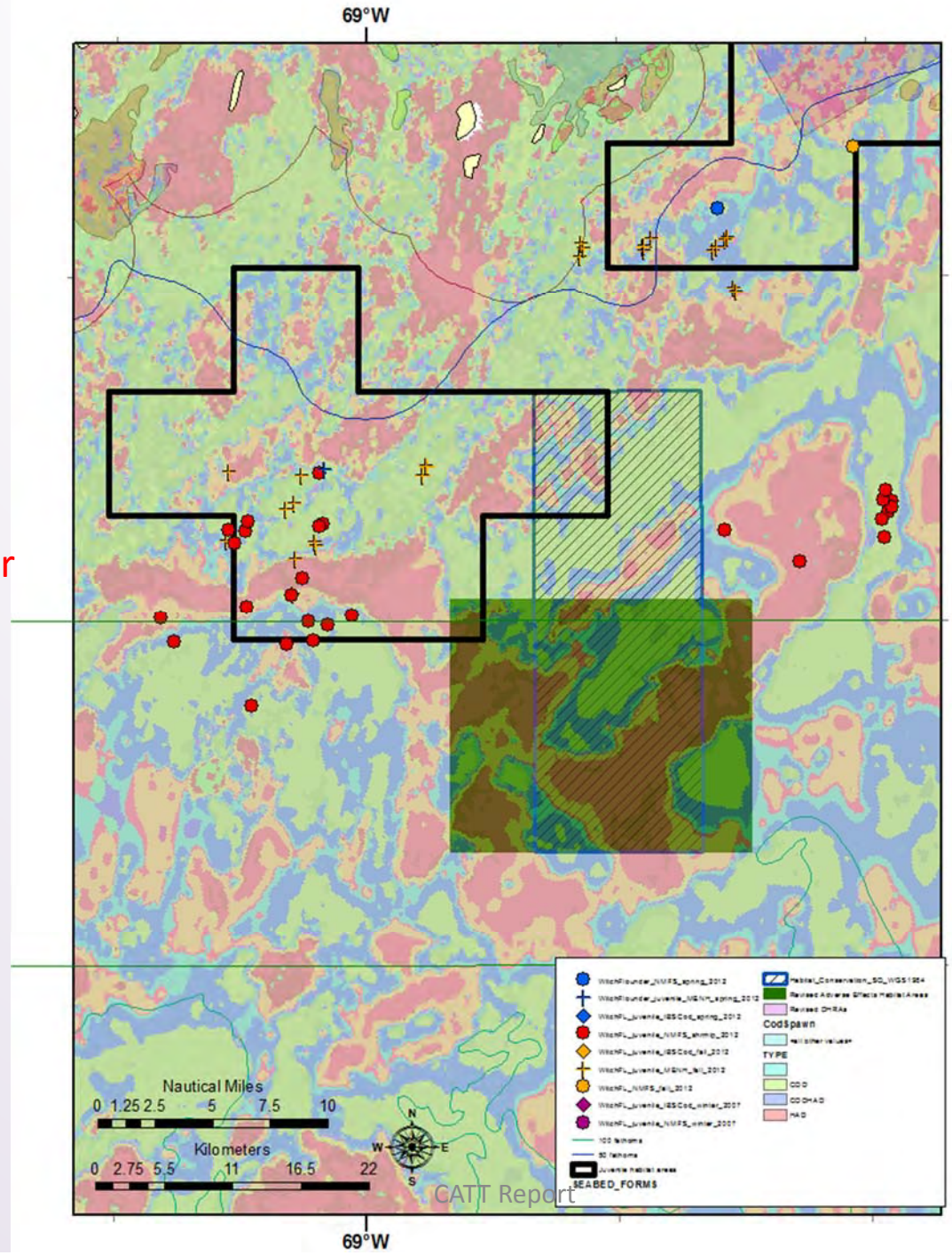
Witch flounder



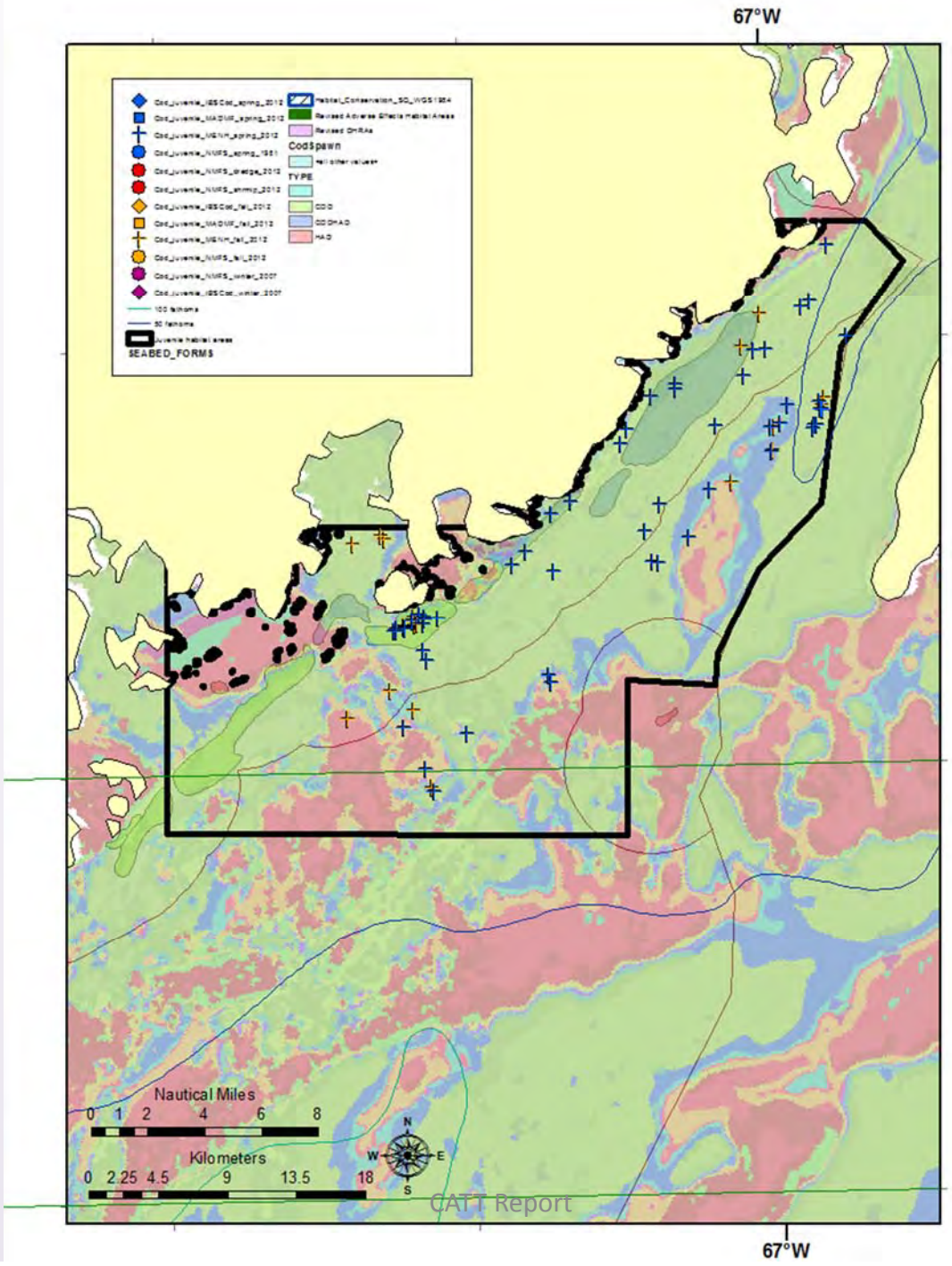
Redfish


69°W
69°W
Nautical Miles
0 1.25 2.5 5 7.5 10
Kilometers
0 2.75 5.5 11 16.5 22
N
S
E
W
Cod Spawn
TYPE
SEABED_FORMS

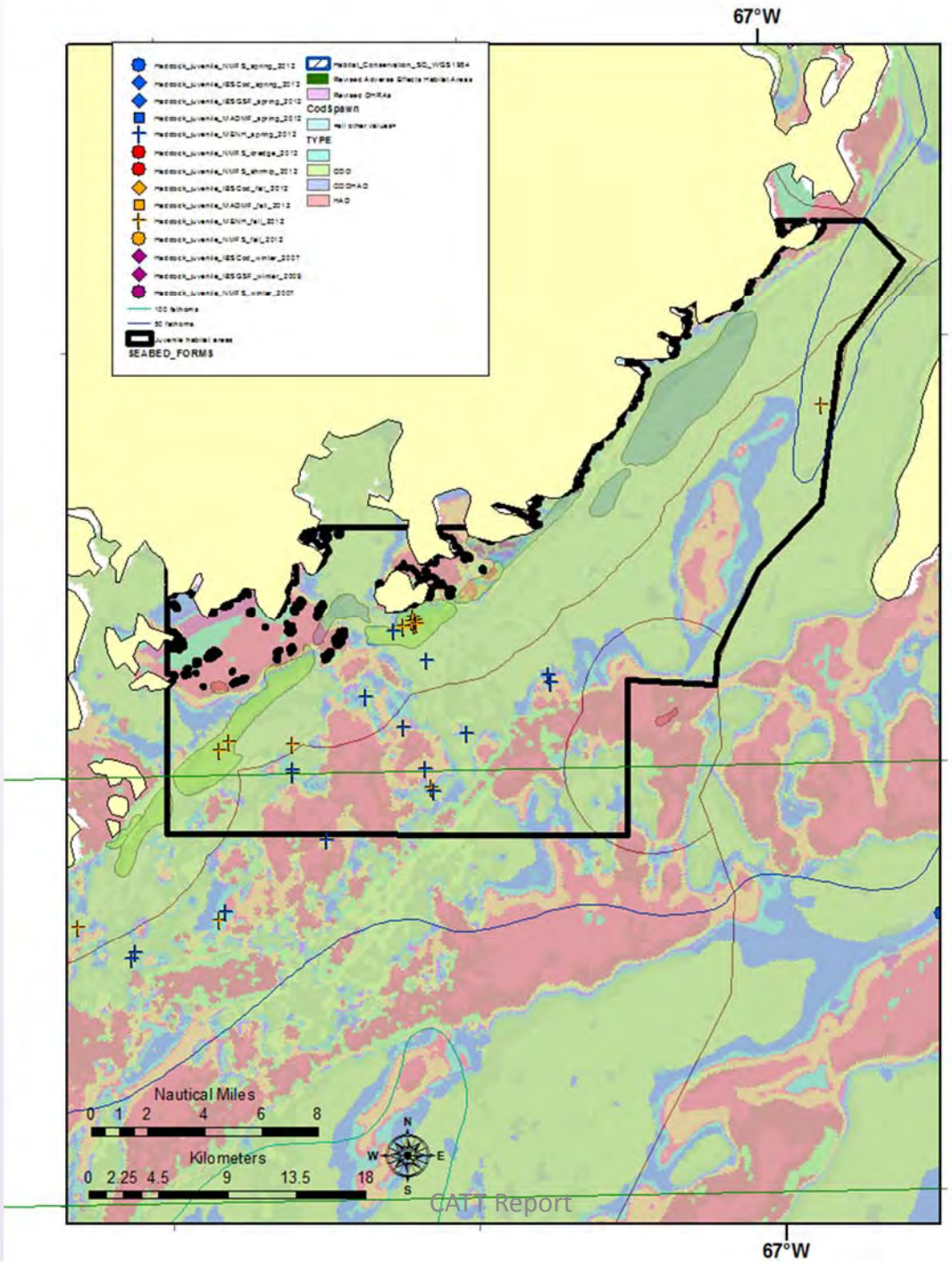
Witch flounder



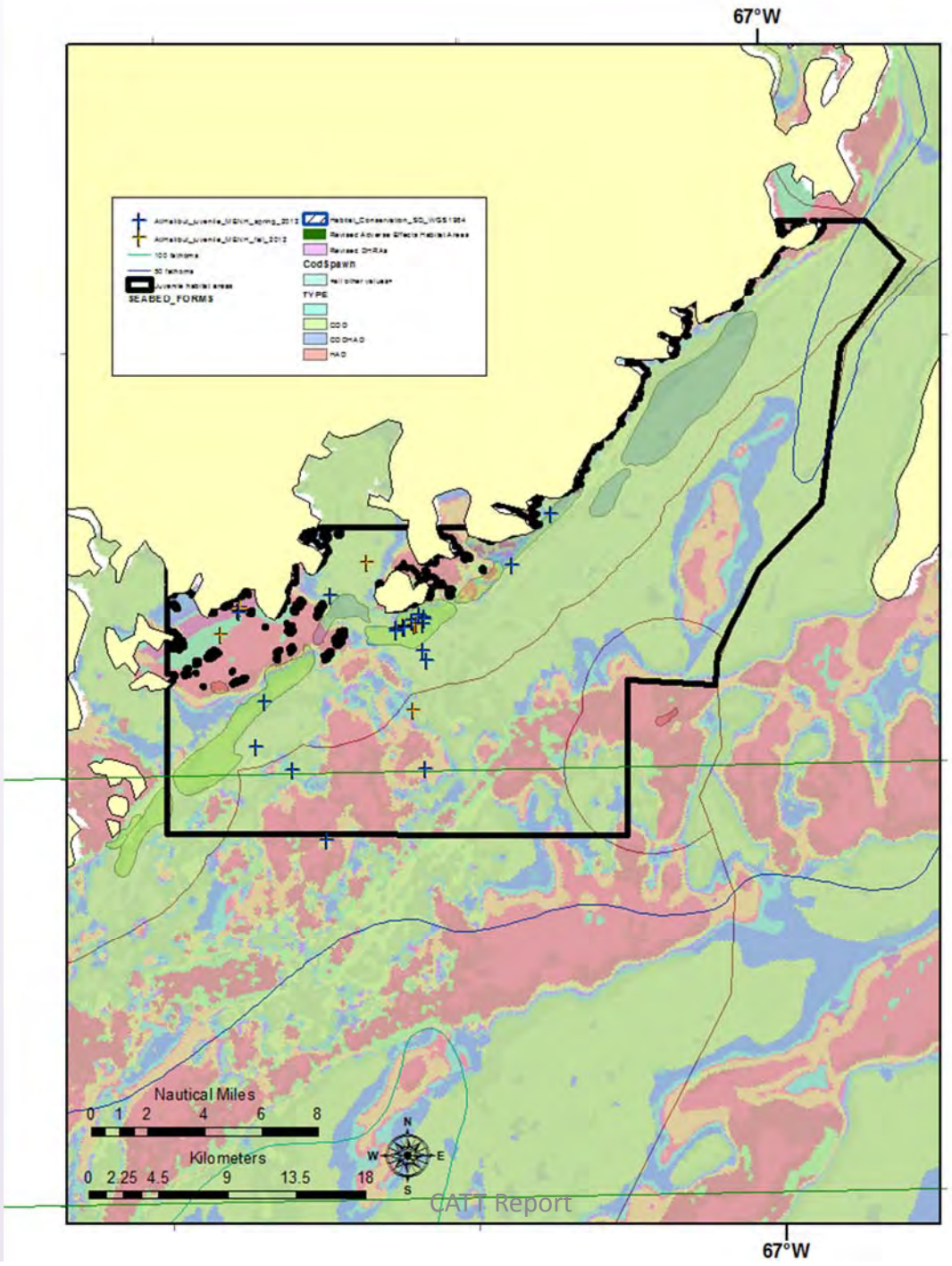
Cod


67°W
Codspawn
TYPE
SEABED_FORMS
Nautical Miles
0 1 2 4 6 8
Kilometers
0 2.25 4.5 9 13.5 18
N
W
E
S
67°W

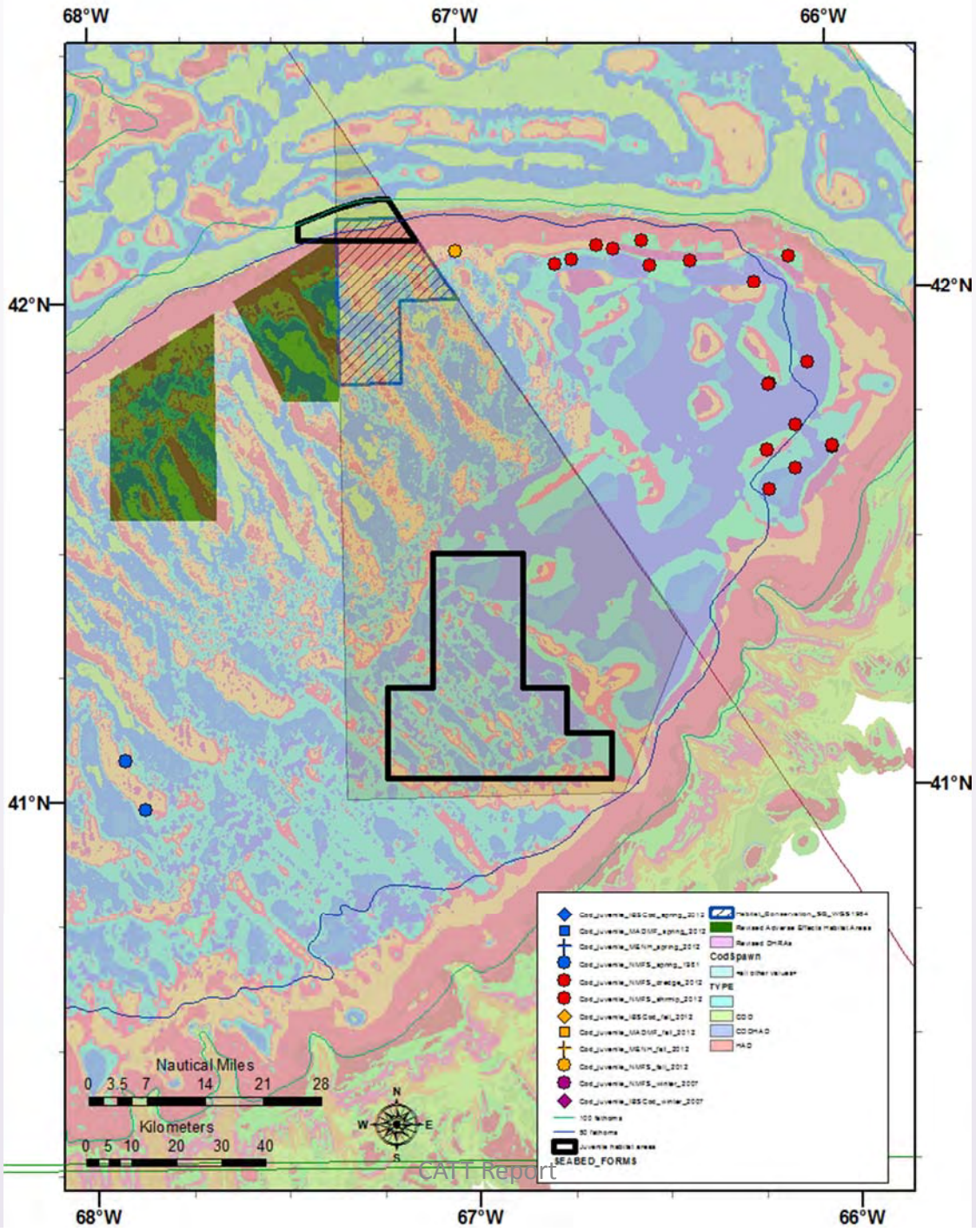
Haddock


67°W
Habitat_Conservation_SO_WGS1984
Revised Adverse Effects Habitat Areas
Revised OHRAs
Cod Spawn
TYPE
GOM
GOMHAD
HAD
100 fathoms
50 fathoms
Juvenile habitat areas
SEABED_FORMS
Nautical Miles
0 1 2 4 6 8
Kilometers
0 2.25 4.5 9 13.5 18
N
W
E
S
67°W

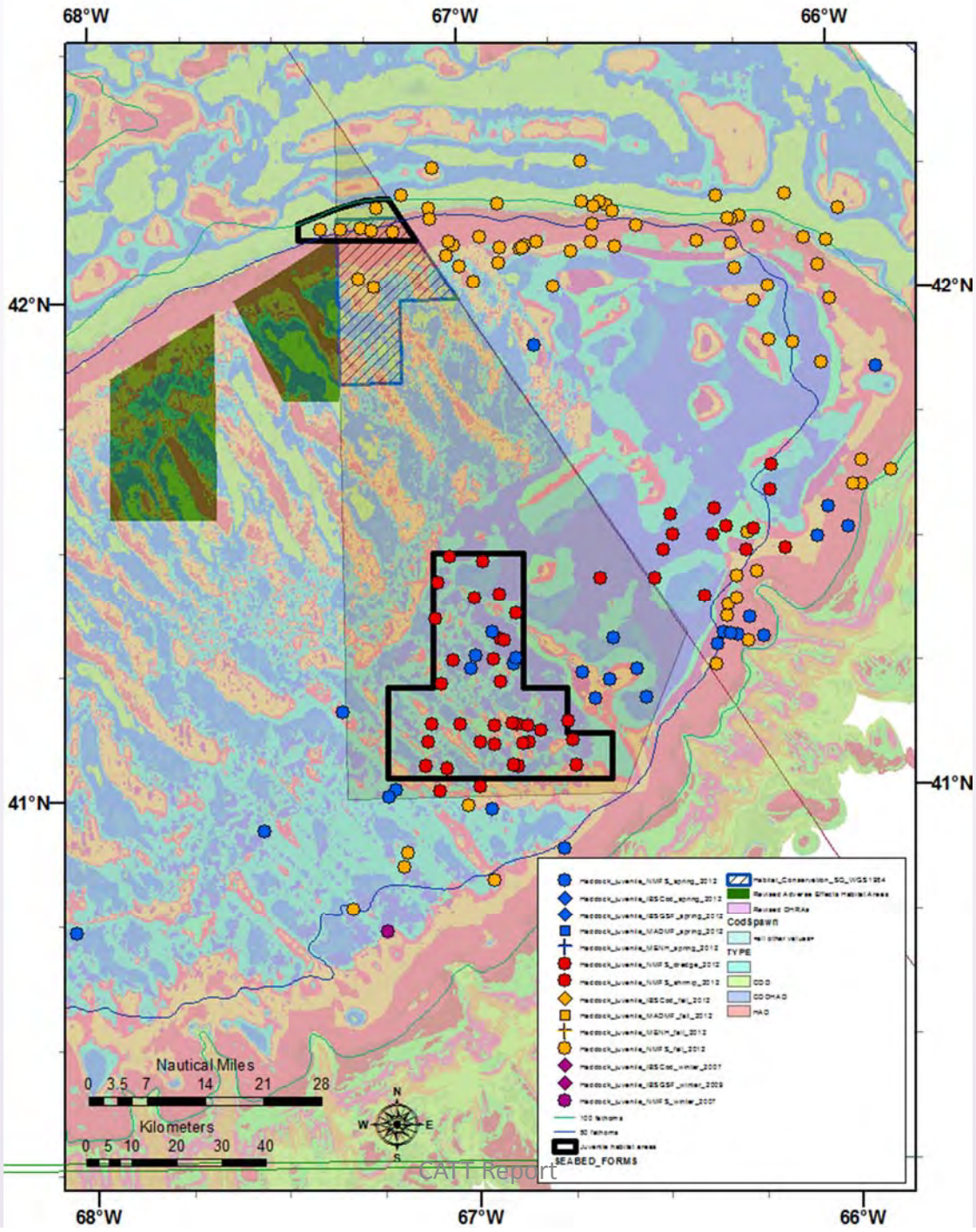
Atlantic halibut



Cod


68°W
67°W
66°W
42°N
41°N
Nautical Miles
0 3.5 7 14 21 28
Kilometers
0 5 10 20 30 40
N
W
E
S
Cod spawn
TYPE
SEABED_FORMS

Haddock

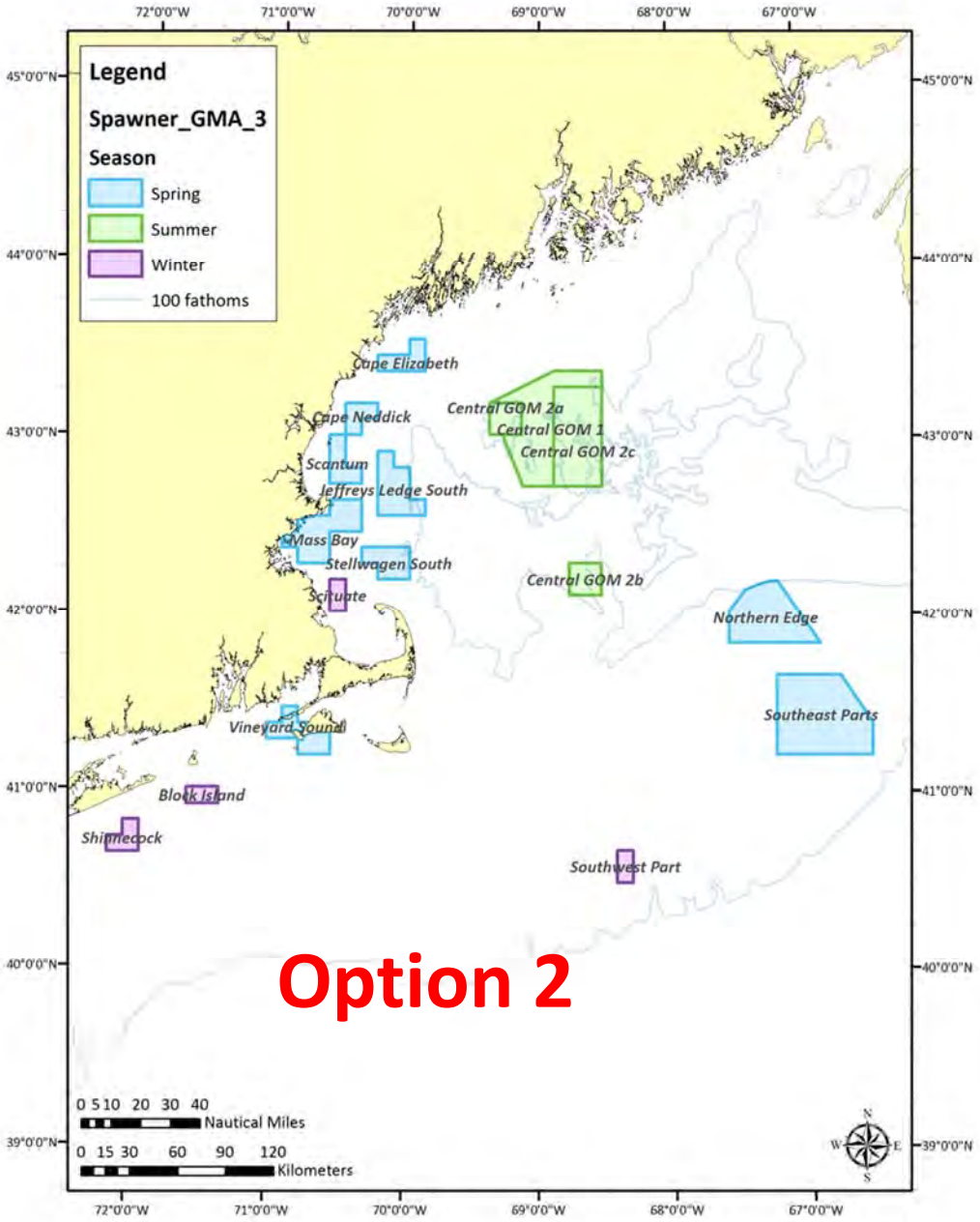

68°W
67°W
66°W
42°N
41°N
Nautical Miles
0 3.5 7 14 21 28
Kilometers
0 5 10 20 30 40
N
W
E
S
Codspawn
TYPE
SEABED_FORMS

Groundfish management options

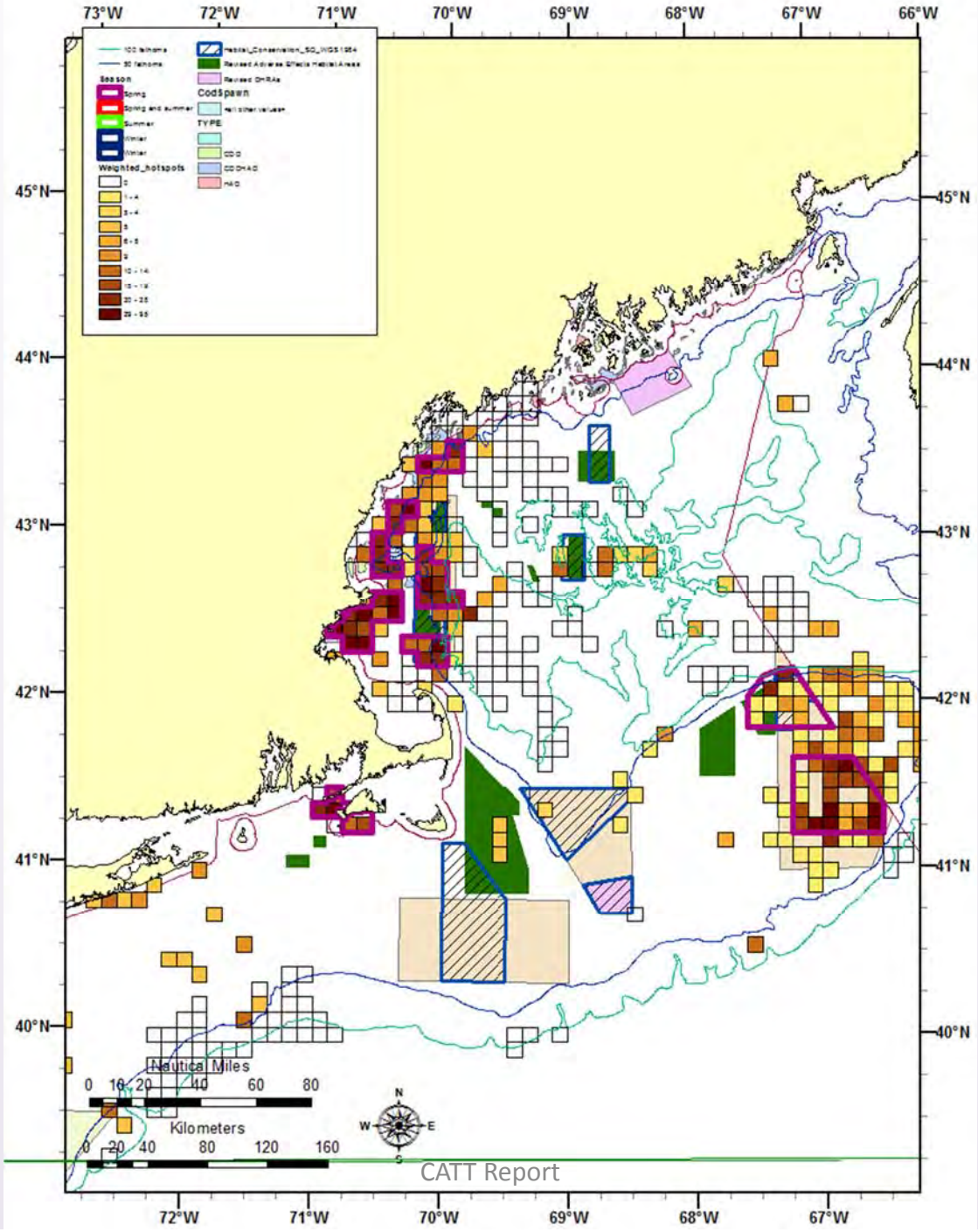
- Recommended groundfish spawning alternatives
  - **Closed seasonally to gears capable of catching groundfish, including recreational fishing**
  - Purpose is to **reduce impacts on spawning**, not simply reduce catches of large groundfish
  - Status quo (Option 1) is existing year round areas, rolling closures, and Whaleback area

Groundfish management options

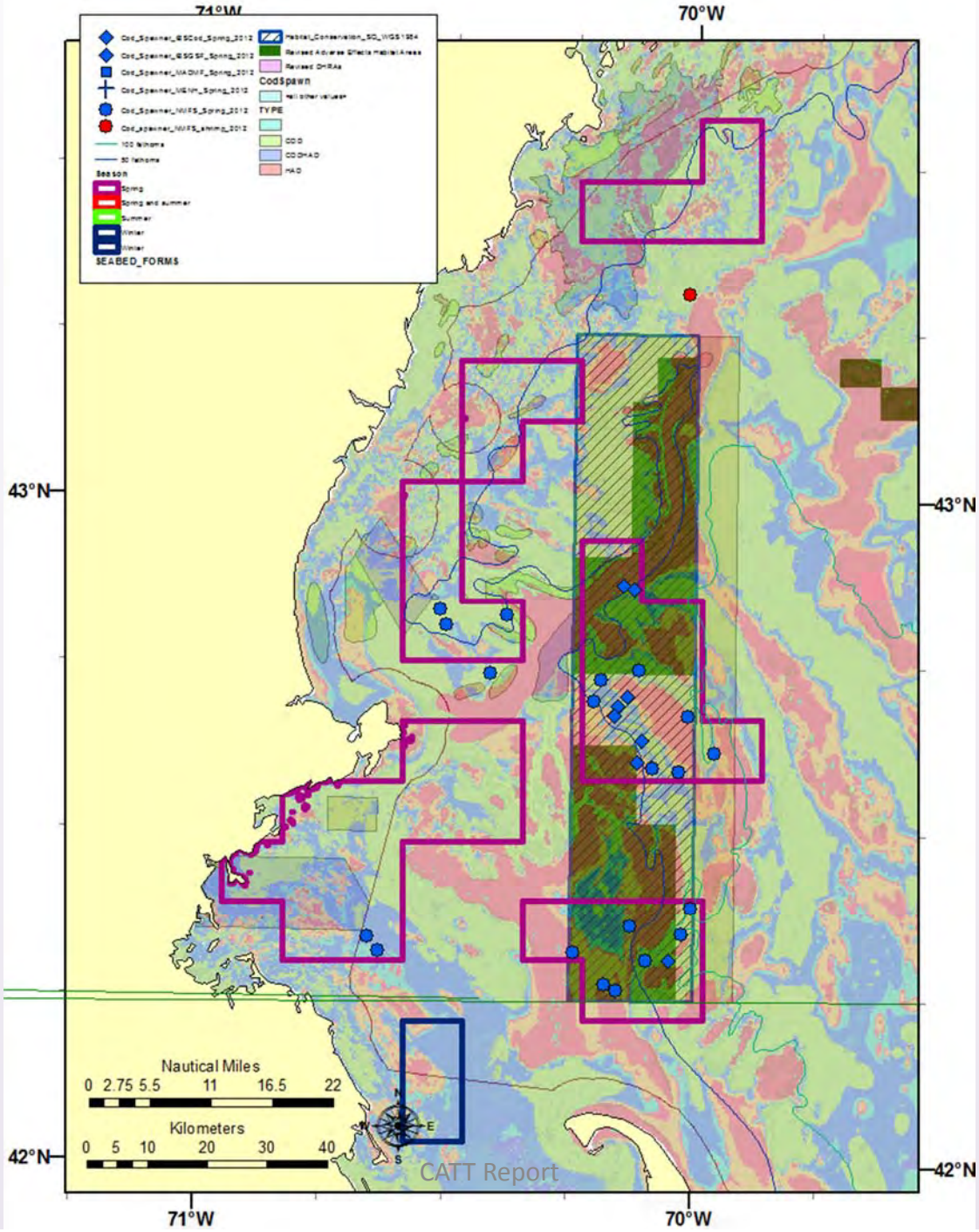
- Option 2
  - Six areas Western Gulf of Maine following the timing of existing rolling closures, from March (February?) to June
  - Cashes Ledge and Howell Swell in summer
  - Northern edge and Eastern Georges Bank area in spring
  - Vineyard Sound and Southwest Shoal in spring
  - Ocean pout spawning areas south of Block Island in winter
  - South Channel cod area in winter


Legend
Spawner_GMA_3
Season
Spring
Summer
Winter
100 fathoms
Cape Elizabeth
Cape Neddick
Scantum
Jeffreys Ledge South
Mass Bay
Stellwagen South
Scituate
Central GOM 2a
Central GOM 1
Central GOM 2c
Central GOM 2b
Northern Edge
Southeast Parts
Vineyard Sound
Block Island
Shinnecock
Southwest Part
Option 2
0 5 10 20 30 40
Nautical Miles
0 15 30 60 90 120
Kilometers
72°0'0"W
71°0'0"W
70°0'0"W
69°0'0"W
68°0'0"W
67°0'0"W
45°0'0"N
44°0'0"N
43°0'0"N
42°0'0"N
41°0'0"N
40°0'0"N
39°0'0"N

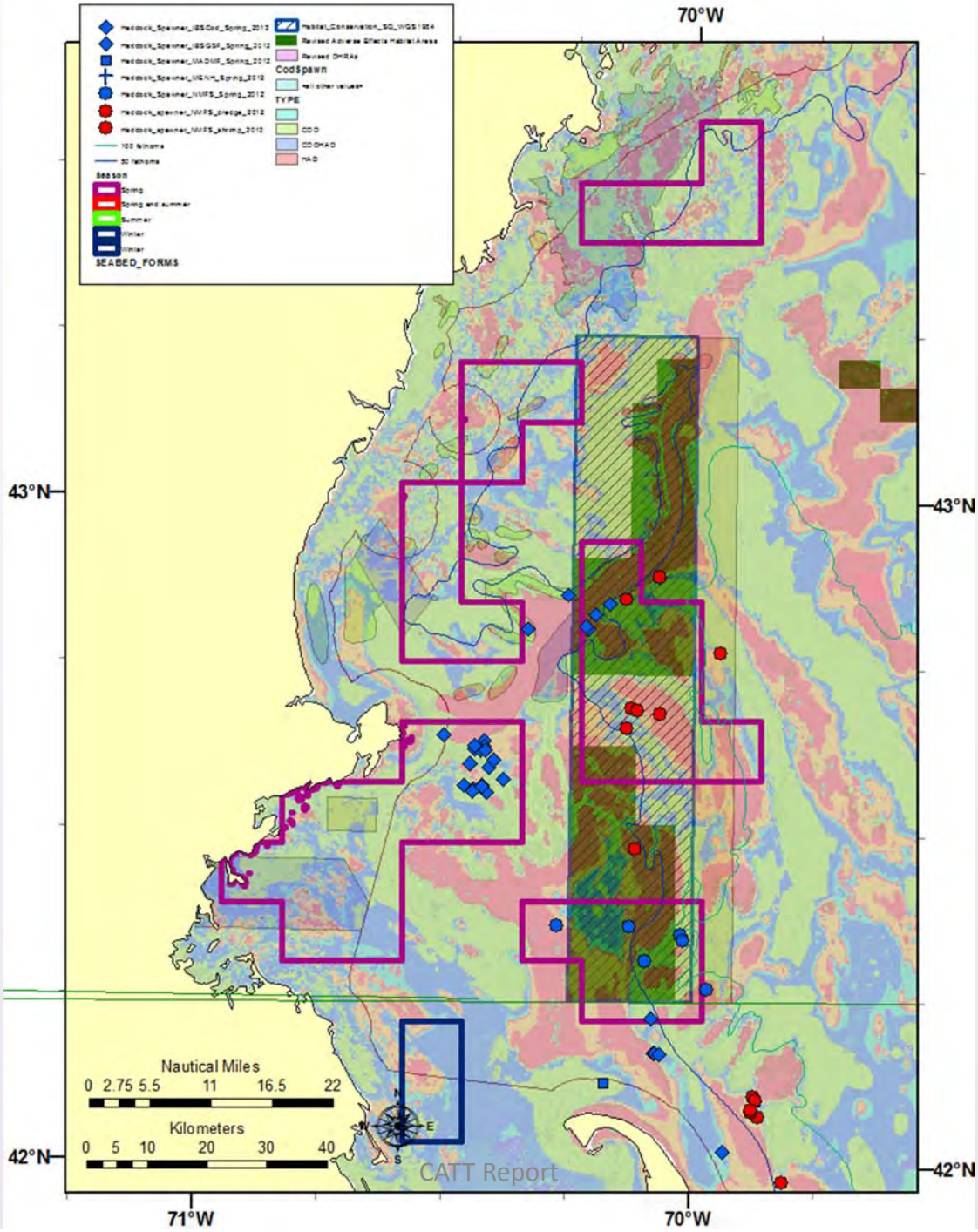
Spring grids and spawning areas



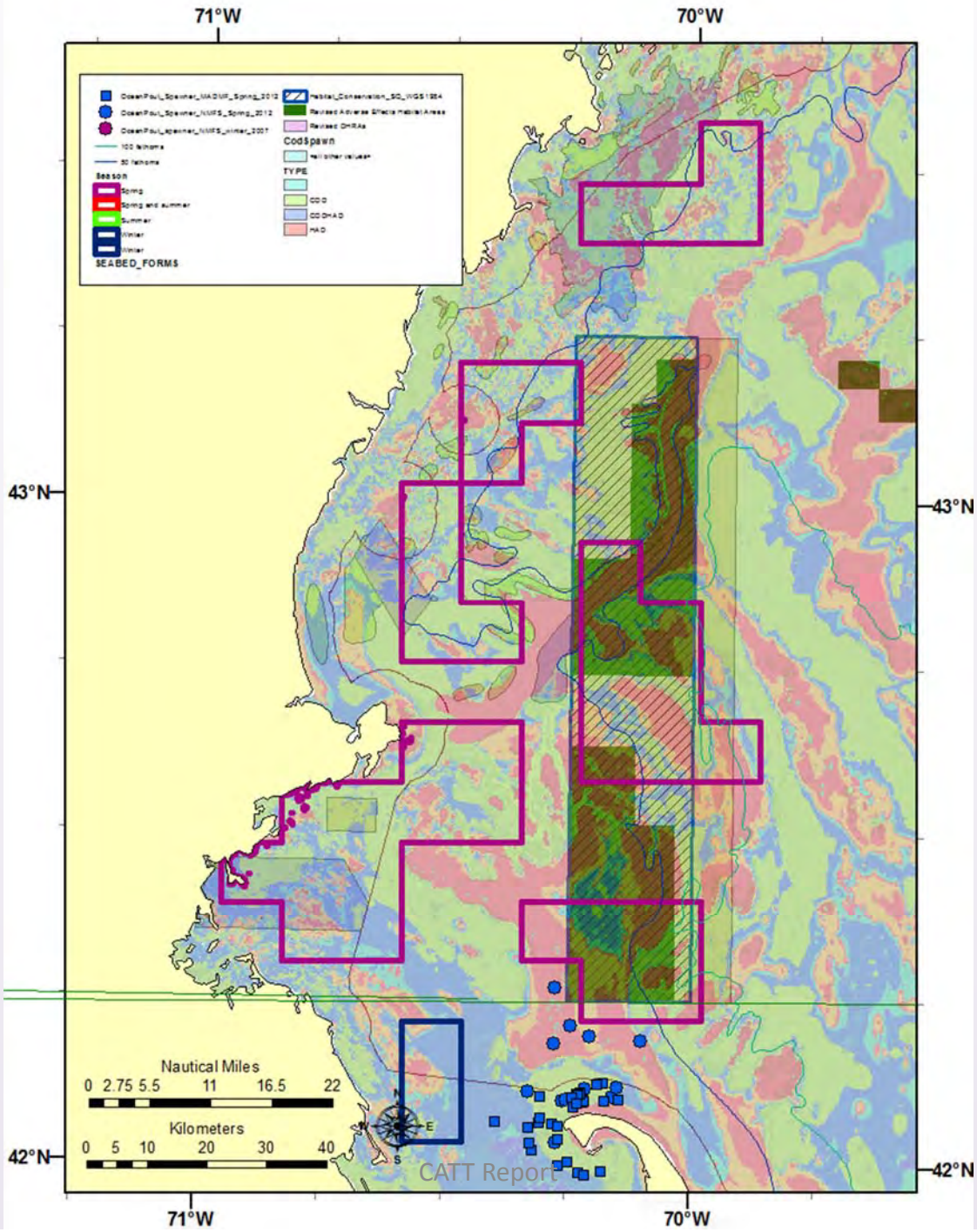
Cod


71°W
70°W
43°N
42°N
CodSpawn
TYPE
SEABED_FORMS
Nautical Miles
0 2.75 5.5 11 16.5 22
Kilometers
0 5 10 20 30 40

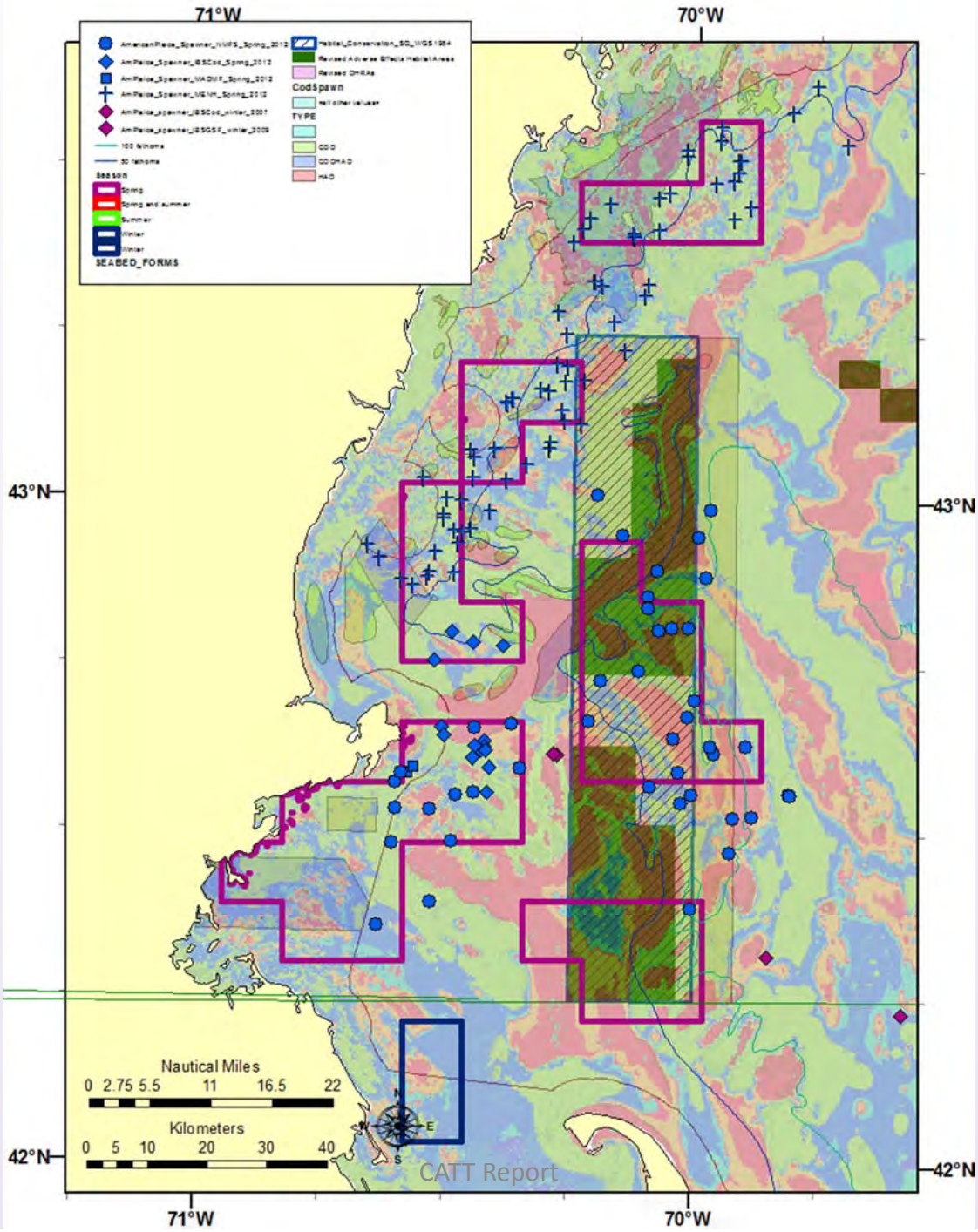
Haddock


70°W
43°N
42°N
71°W
70°W
Season
SEABED_FORMS
Codspawn
TYPE
Nautical Miles
0 2.75 5.5 11 16.5 22
Kilometers
0 5 10 20 30 40

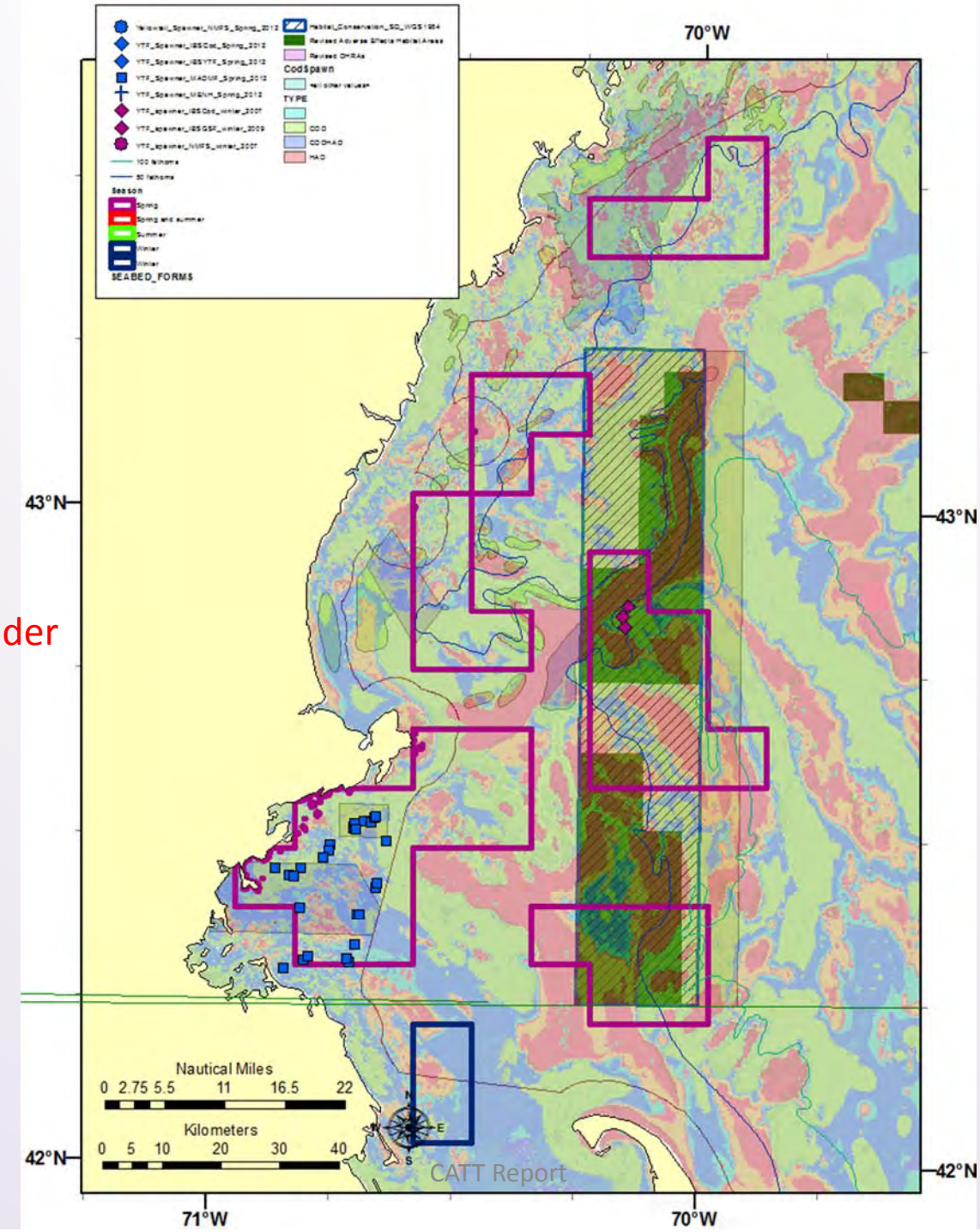
Ocean pout


71°W
70°W
43°N
42°N
Season
Spring
Spring and summer
Summer
Winter
SEABED_FORMS
Codspawn
TYPE
CO
CO HAD
HAD
Nautical Miles
0 2.75 5.5 11 16.5 22
Kilometers
0 5 10 20 30 40
N
E
S

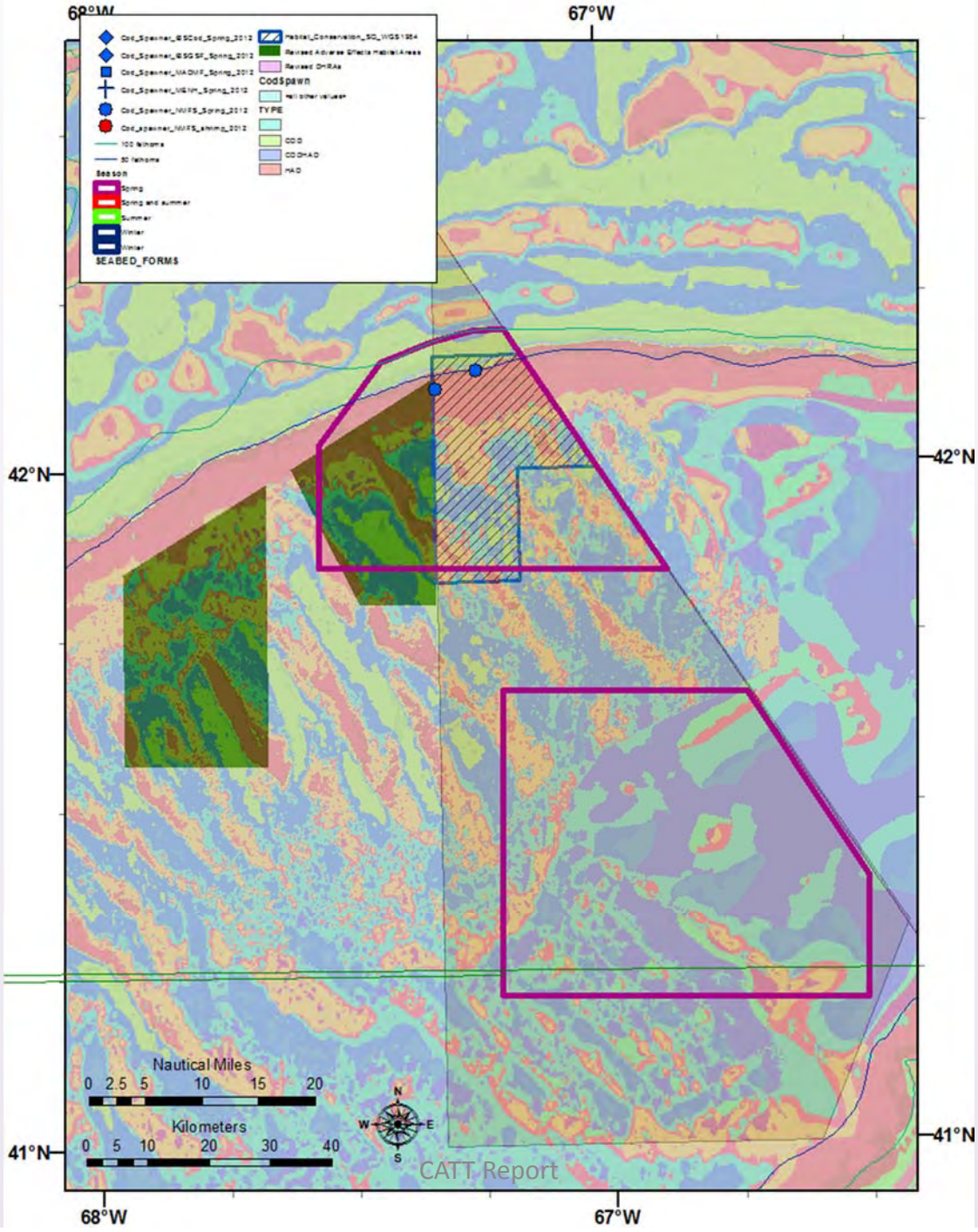
American plaice



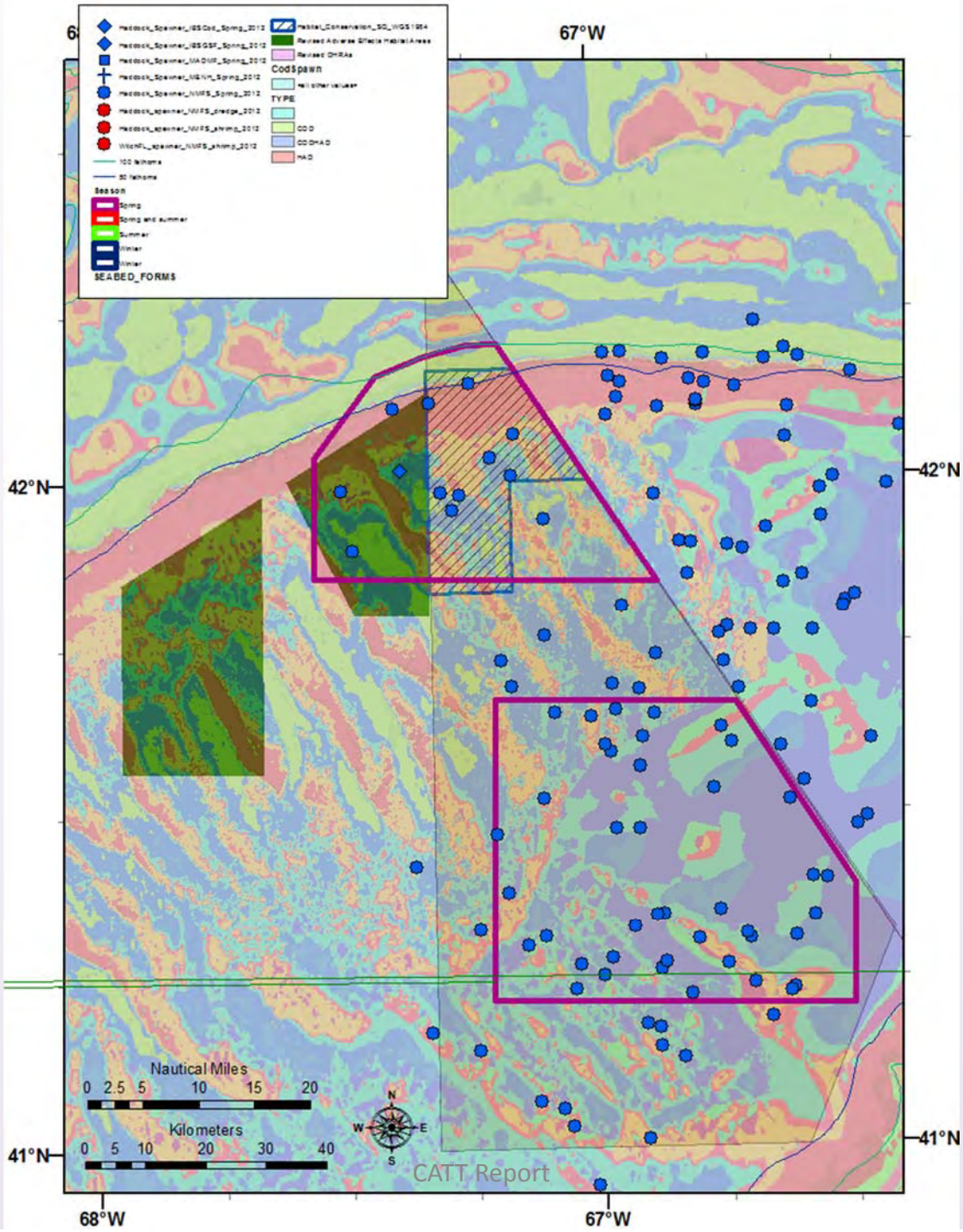
Yellowtail flounder



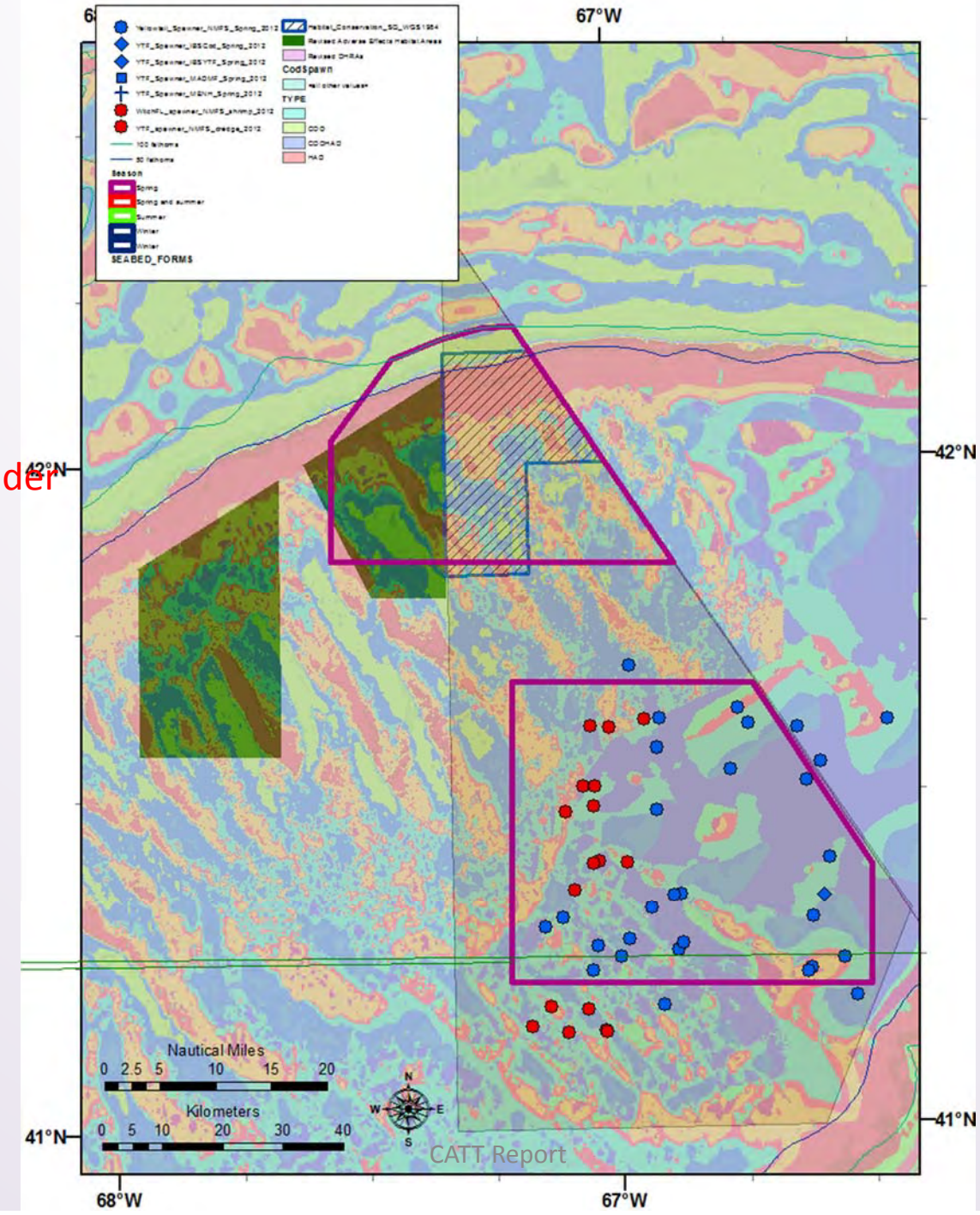
Cod


68°W
67°W
42°N
41°N
Cod_Spawner_GBCod_Spring_2012
Cod_Spawner_GBSS_Spring_2012
Cod_Spawner_MAOMF_Spring_2012
Cod_Spawner_GOM_Spring_2012
Cod_Spawner_NMFS_Spring_2012
Cod_spawner_NMFS_shrimp_2012
100 fathoms
50 fathoms
Season
Spring
Spring and summer
Summer
Winter
Winter
SEABED_FORMS
Habitat_Conservation_SQ_WGS1984
Revised Adverse Effects Habitat Areas
Revised EHRAs
CodSpawn
TYPE
CCD
CCDHAD
HAD
Nautical Miles
0 2.5 5 10 15 20
Kilometers
0 5 10 20 30 40
N
W
E
S

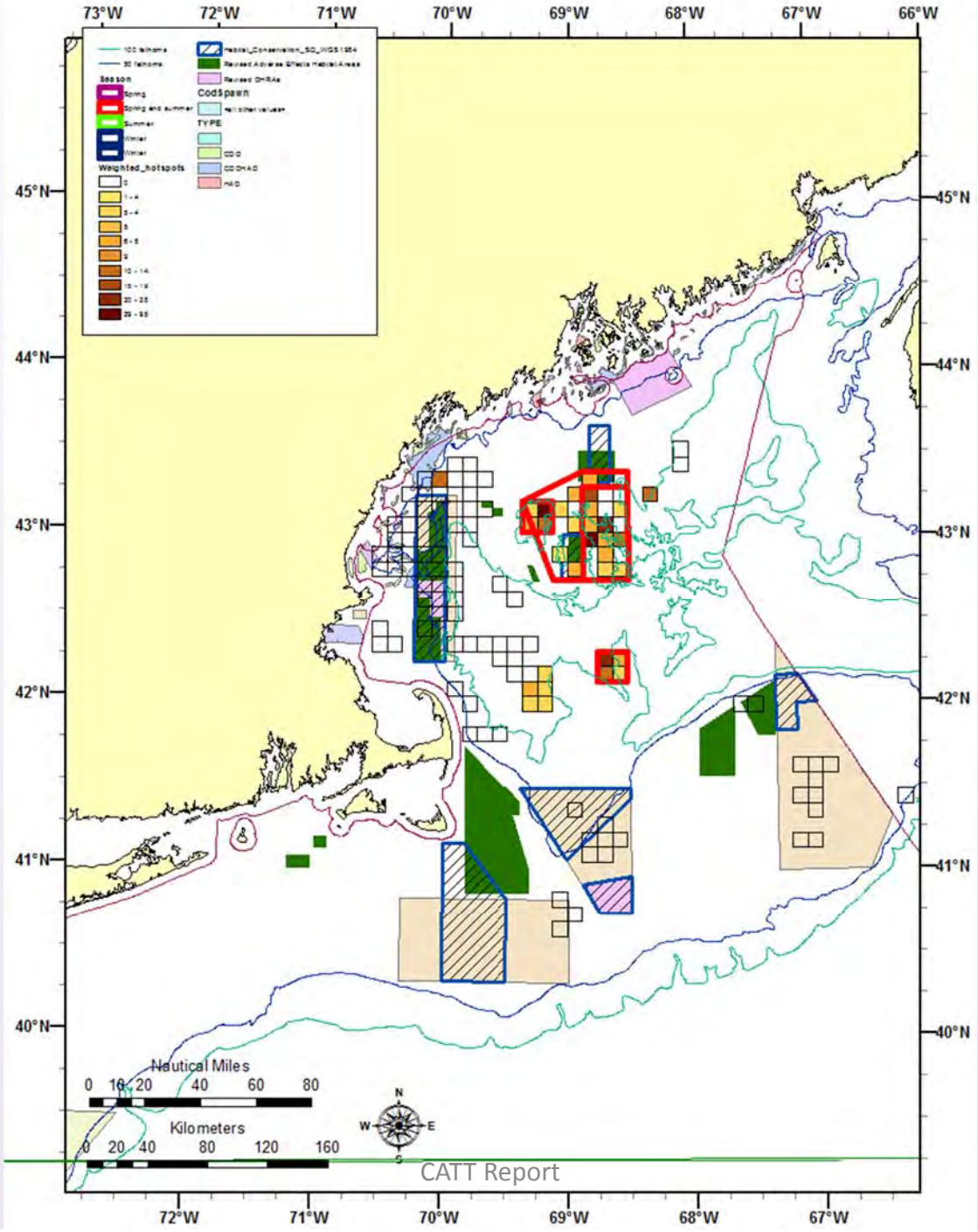
Haddock


67°W
42°N
41°N
68°W
Codspawn
TYPE
SEABED_FORMS
Nautical Miles
0 2.5 5 10 15 20
Kilometers
0 5 10 20 30 40
N
W
E
S

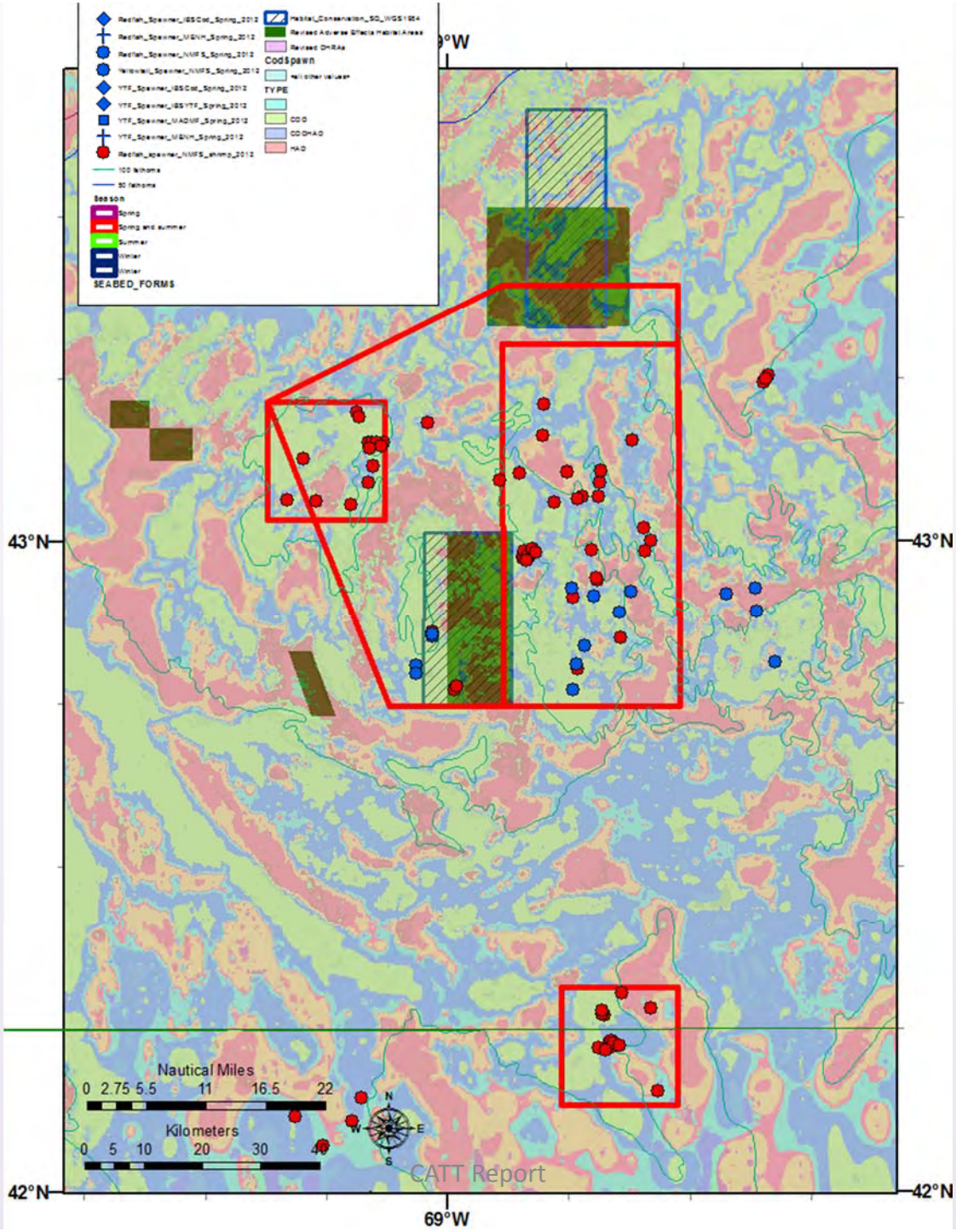
Yellowtail flounder



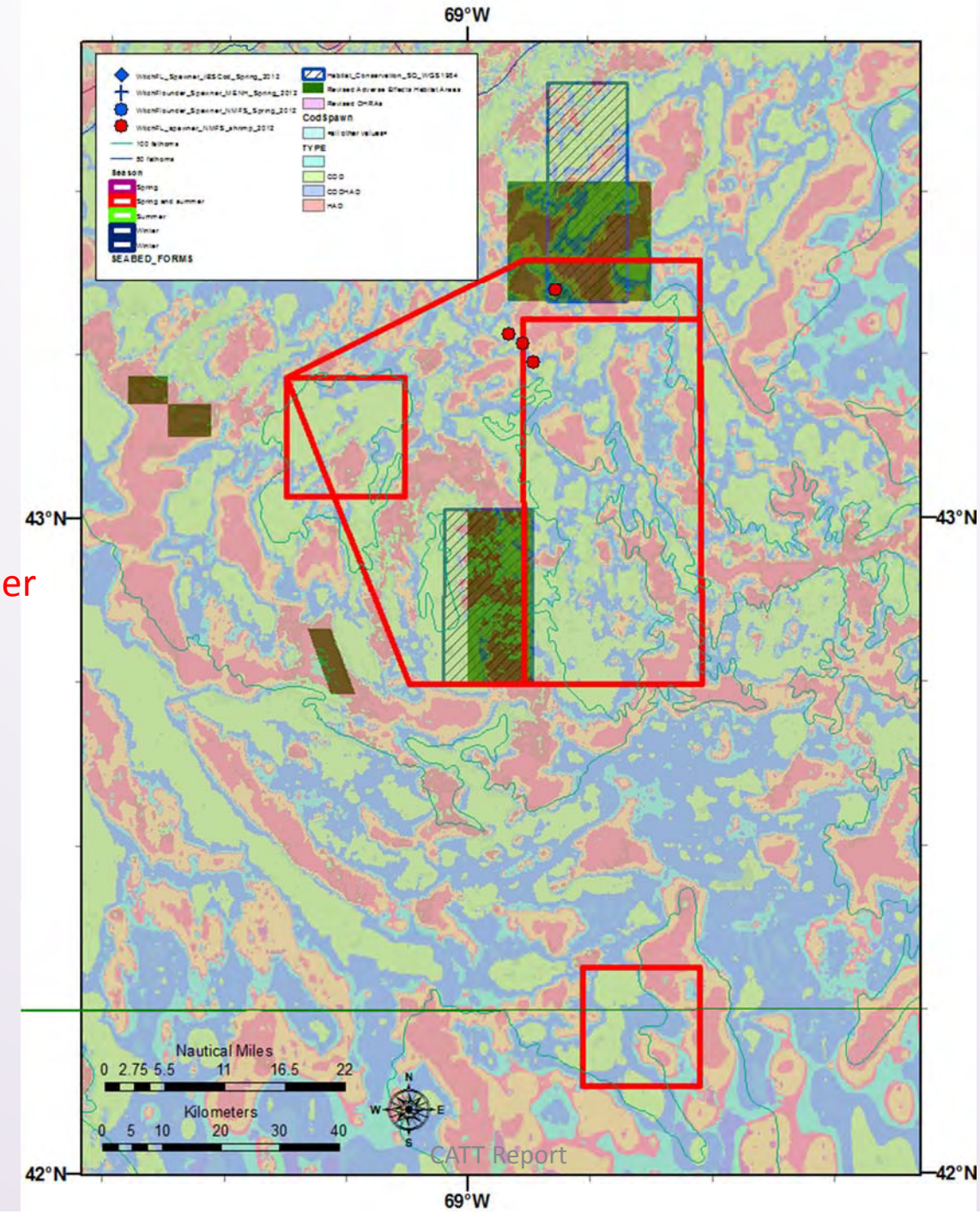
Summer grids and spawning areas



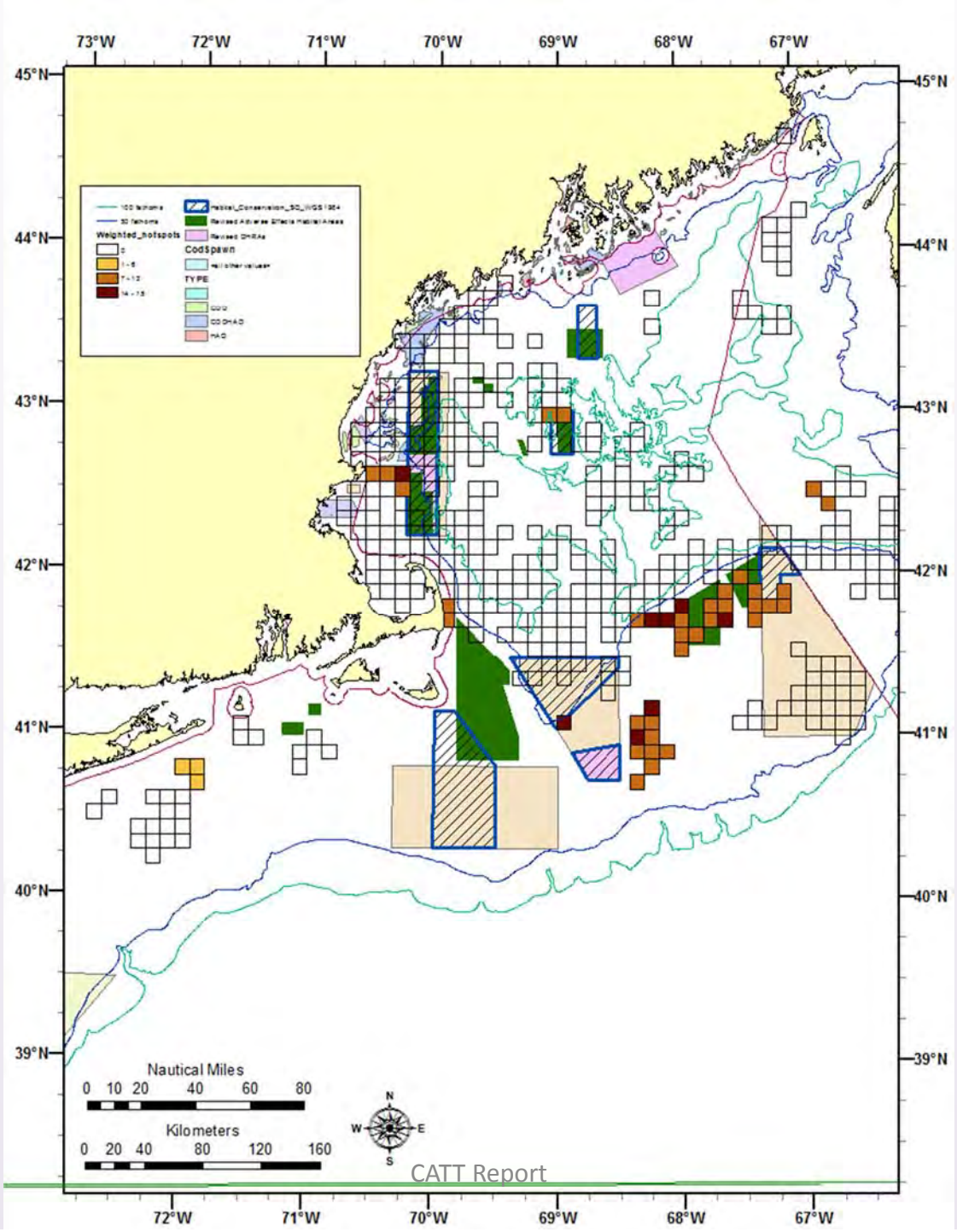
Redfish


Redfish_Spawner_IBSCod_Spring_2012
Redfish_Spawner_MENH_Spring_2012
Redfish_Spawner_NMFS_Spring_2012
Redfish_Spawner_NMFS_Spring_2012
YTF_Spawner_IBSCod_Spring_2012
YTF_Spawner_IBSYTF_Spring_2012
YTF_Spawner_MADMF_Spring_2012
YTF_Spawner_MENH_Spring_2012
Redfish_spawner_NMFS_shrimp_2012
100 fathoms
50 fathoms
Season
Spring
Spring and summer
Summer
Winter
Winter
SEABED_FORMS
Habitat_Conservation_SD_WGS1984
Revised Adverse Effects Habitat Areas
Revised OHRAs
CodSpawn
values other values
TYPE
CCO
CCOHAO
HAO
69°W
43°N
42°N
Nautical Miles
0 2.75 5.5 11 16.5 22
Kilometers
0 5 10 20 30 40
N
W
E
S

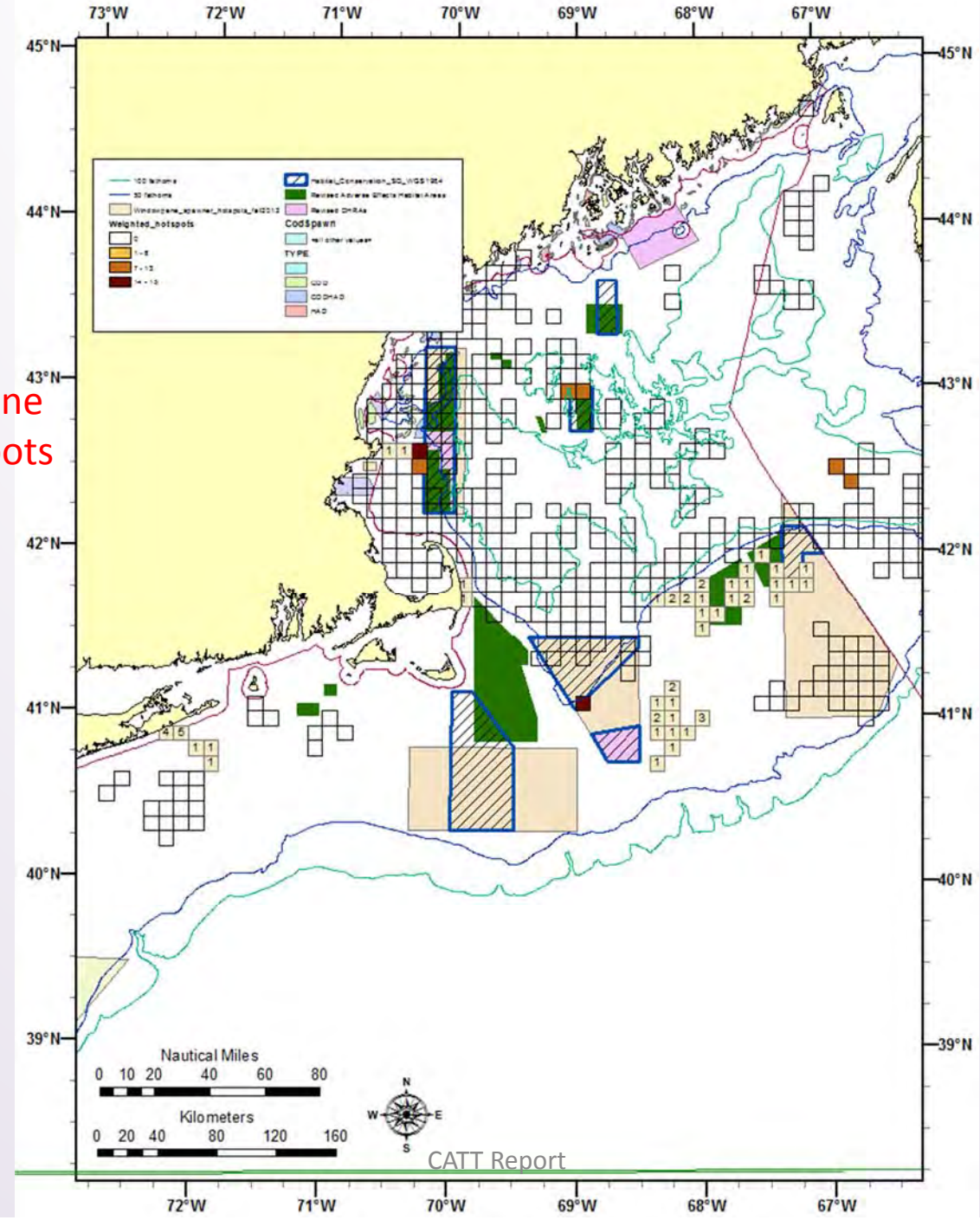
Witch flounder



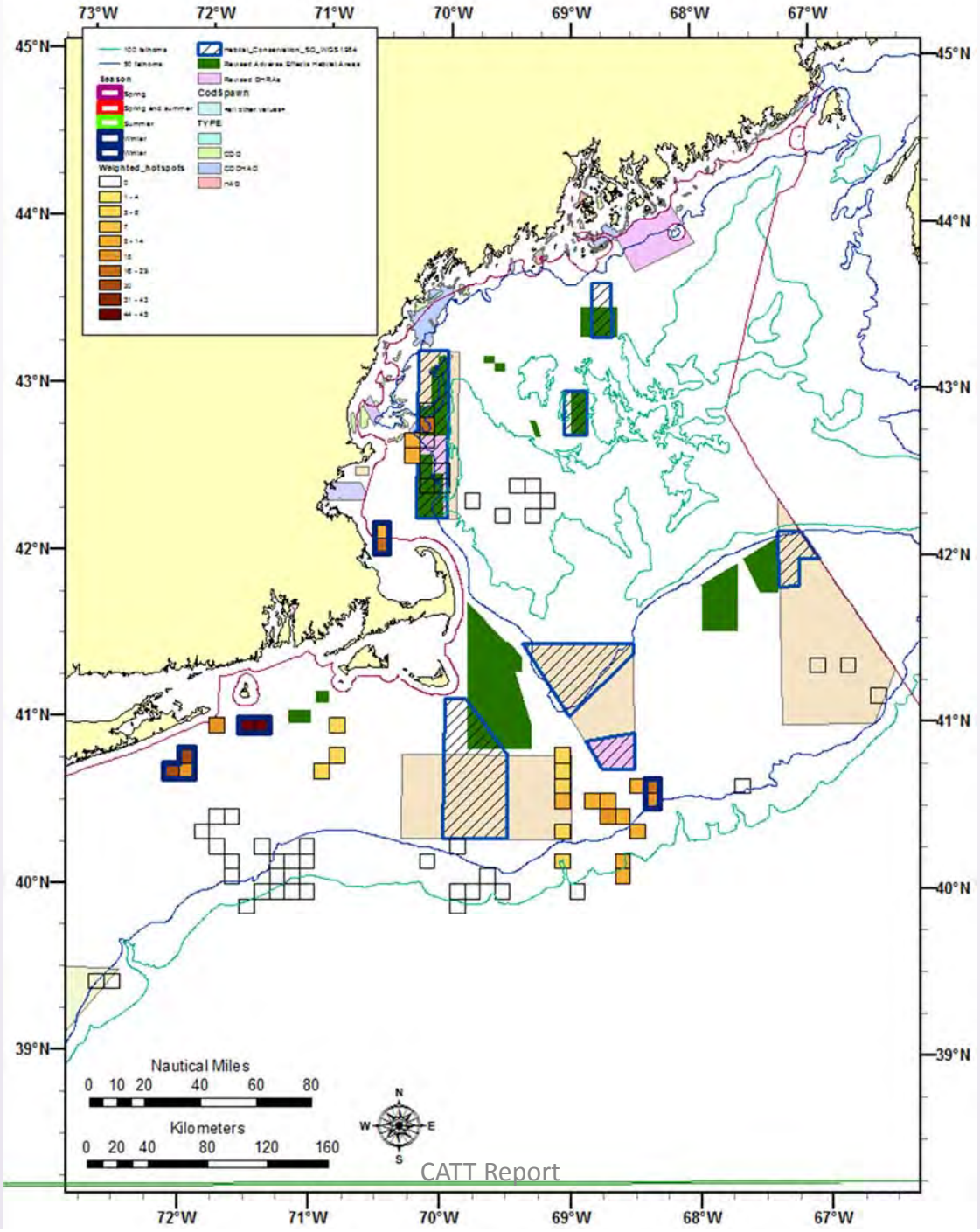
Fall grids


73°W
72°W
71°W
70°W
69°W
68°W
67°W
45°N
44°N
43°N
42°N
41°N
40°N
39°N
Weighted_hotspots
Codspawn
TYPE
Nautical Miles
0 10 20 40 60 80
Kilometers
0 20 40 80 120 160
N
W
E
S

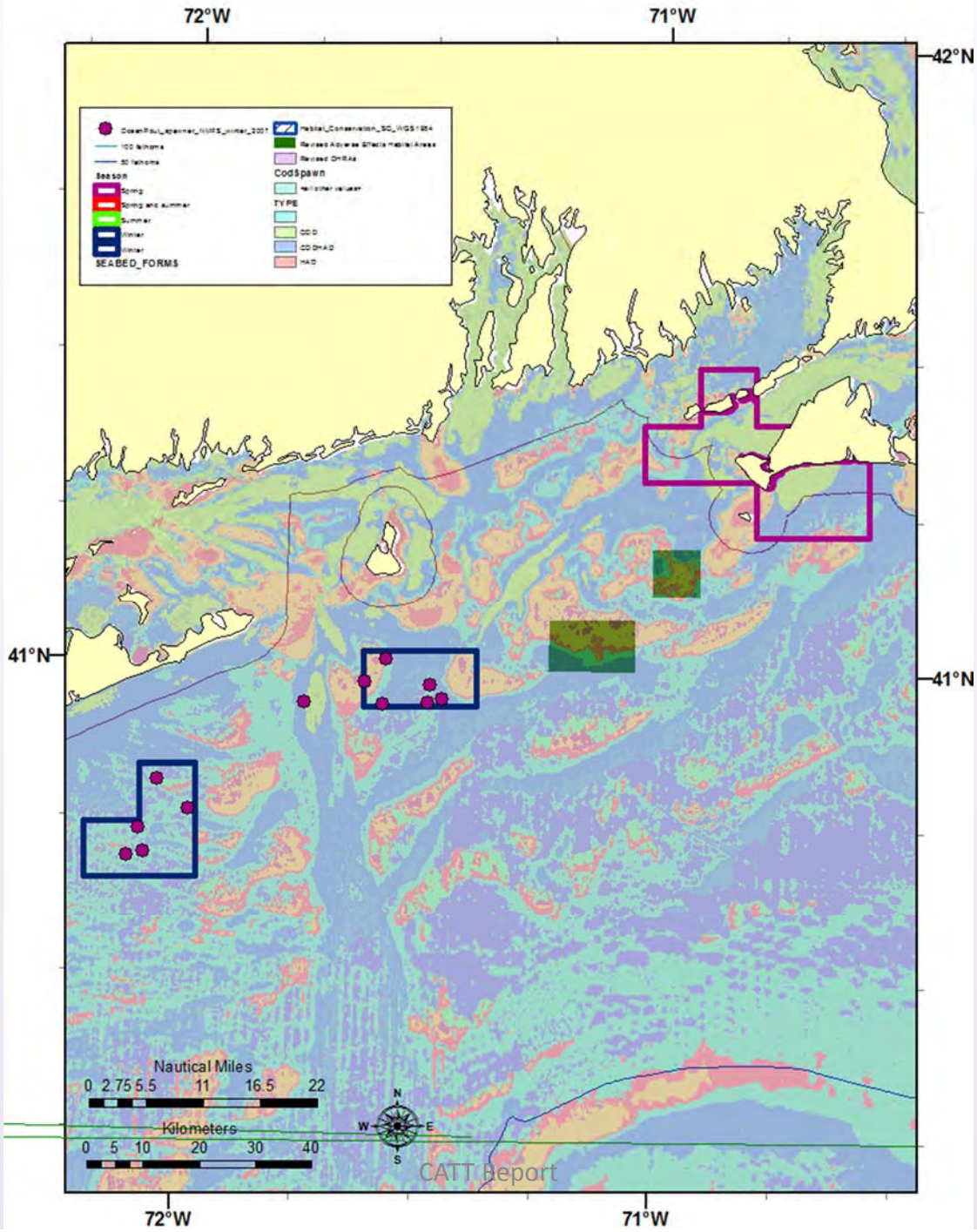
Fall grids
and windowpane
flounder hotspots



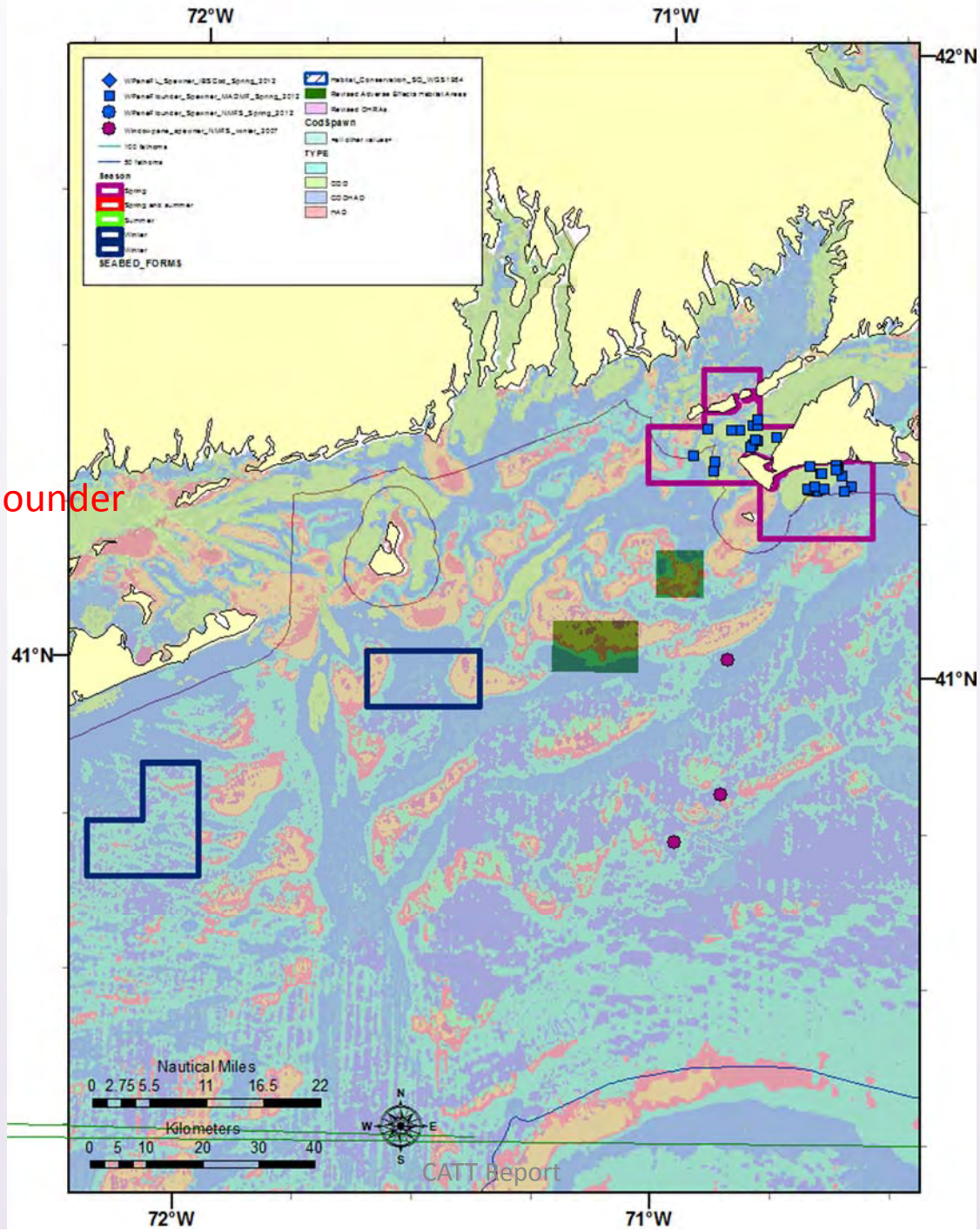
Winter grids and spawning areas



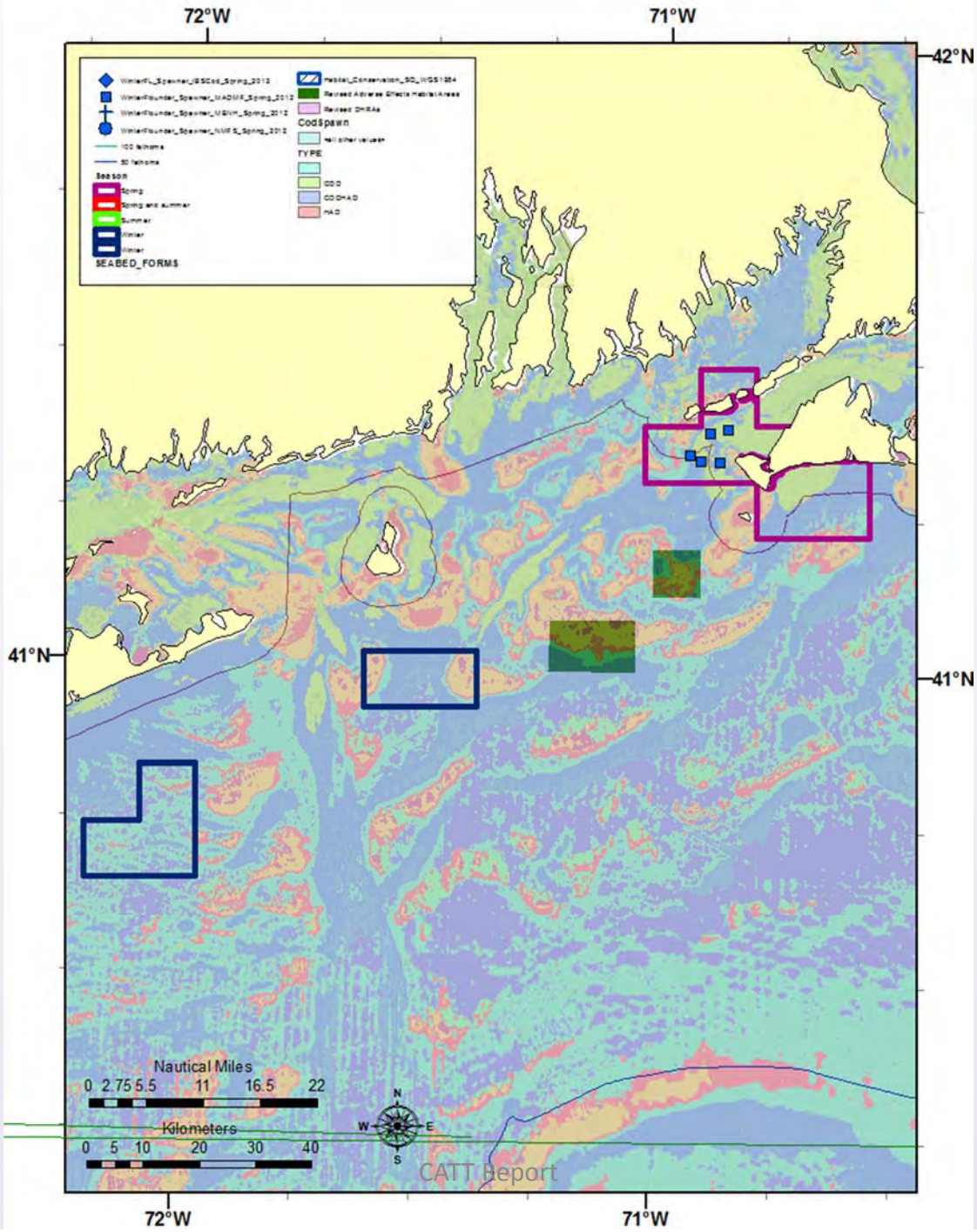
Ocean pout


72°W
71°W
42°N
41°N
41°N
72°W
71°W
Season
SEABED_FORMS
Codspawn
TYPE
Nautical Miles
0 2.75 5.5 11 16.5 22
Kilometers
0 5 10 20 30 40
N
W
E
S

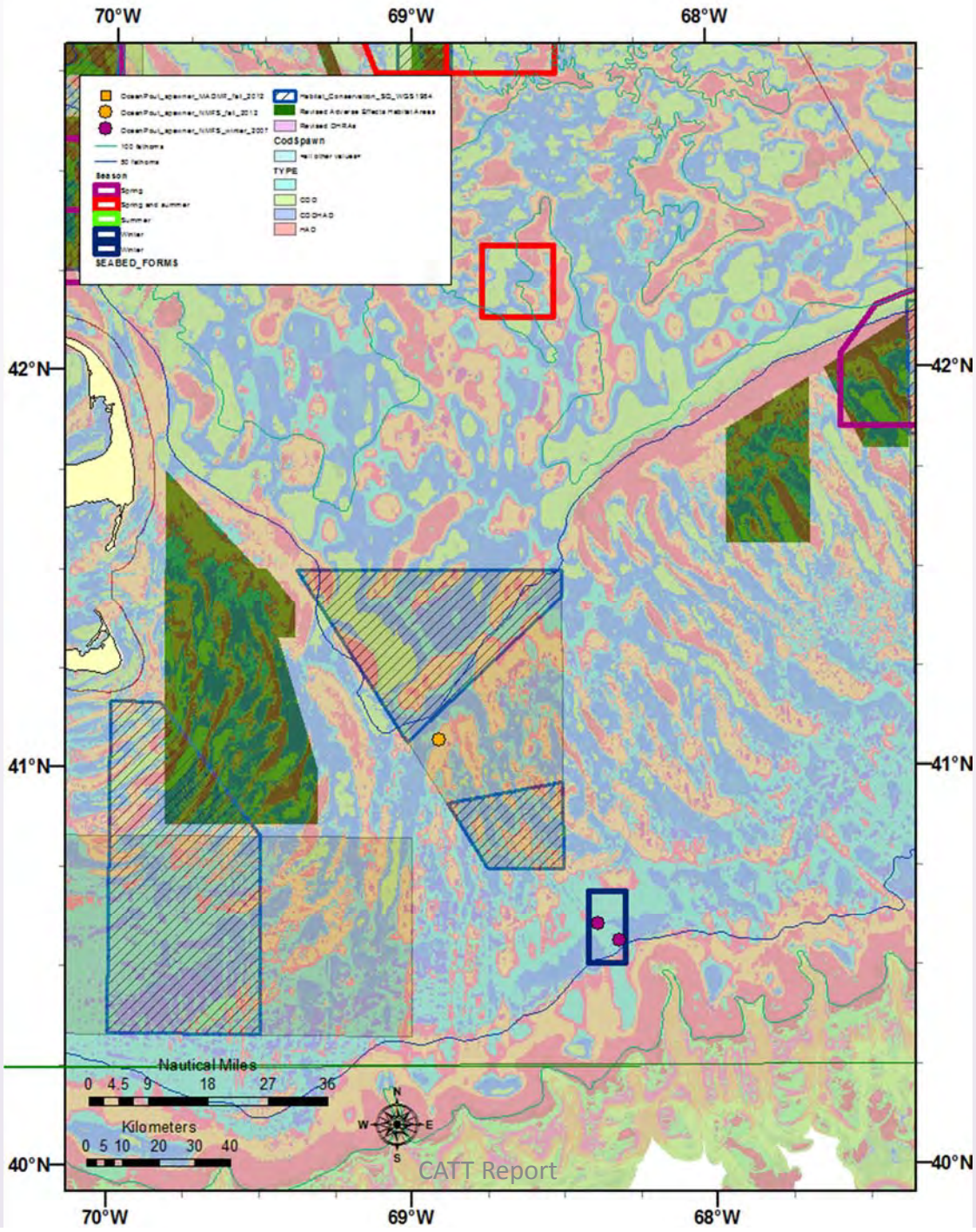
Windowpane flounder



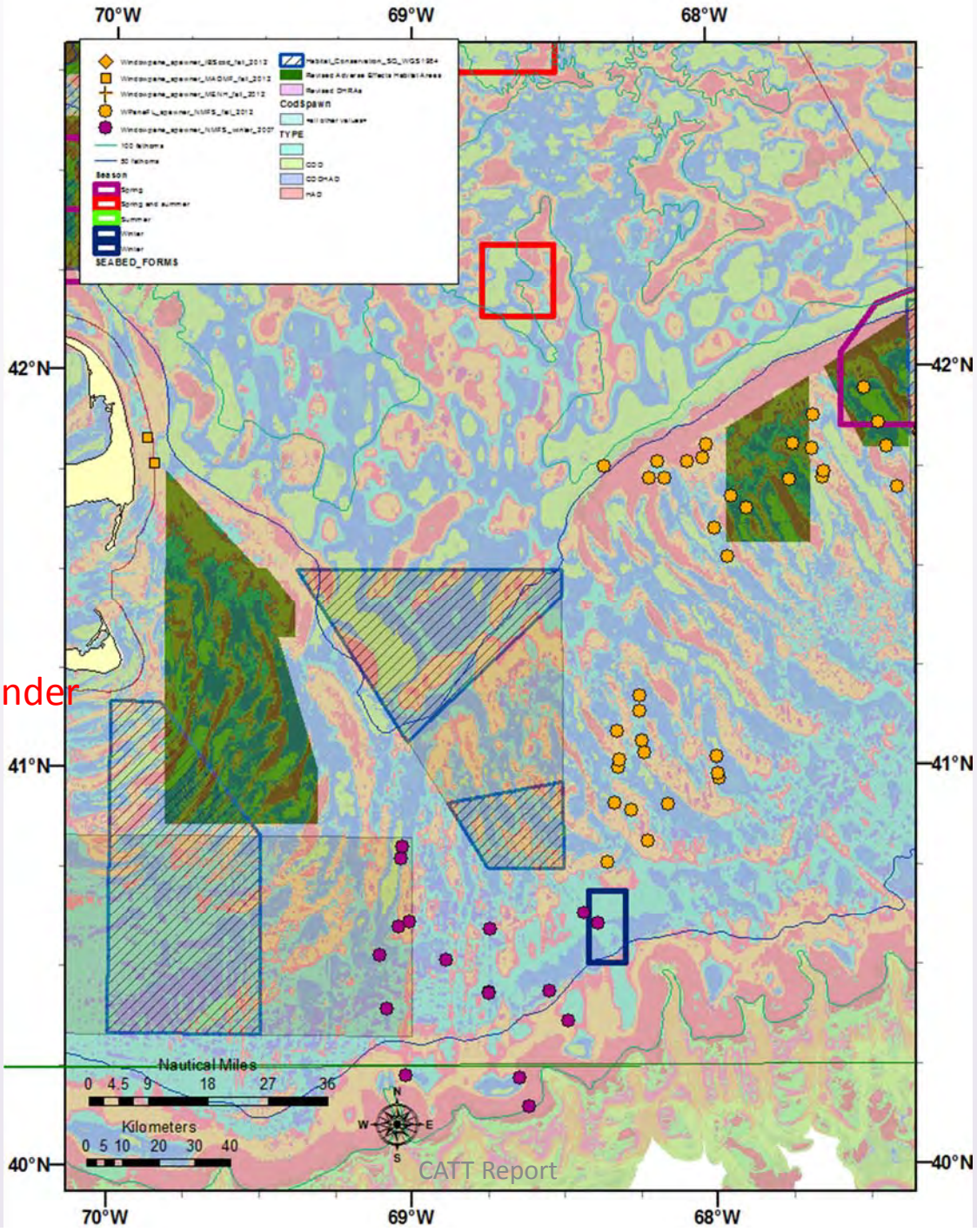
Winter flounder



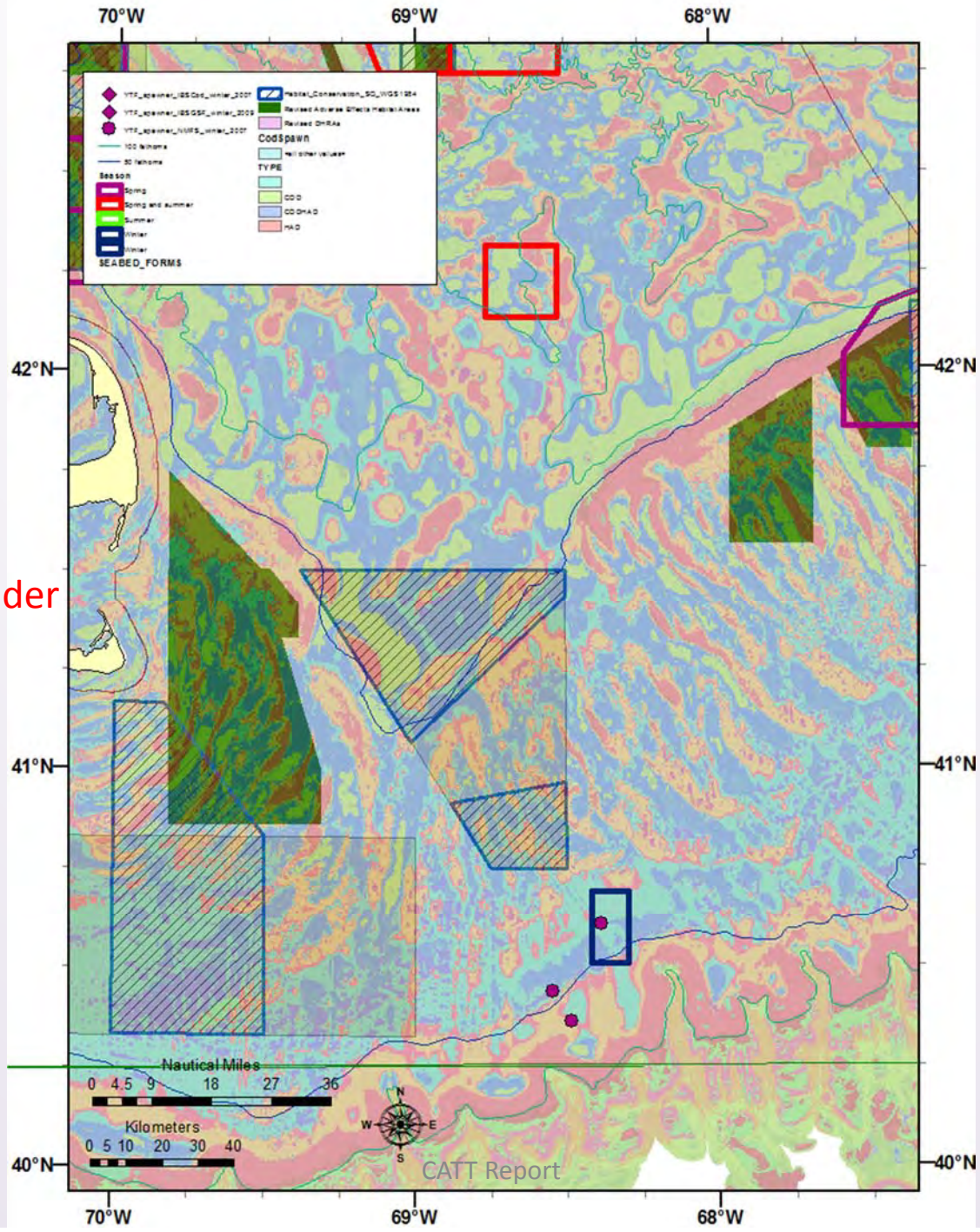
Ocean pout


70°W
69°W
68°W
42°N
41°N
40°N
Codspawn
TYPE
SEABED_FORMS
Nautical Miles
0 4.5 9 18 27 36
Kilometers
0 5 10 20 30 40
N
W
E
S

Windowpane flounder



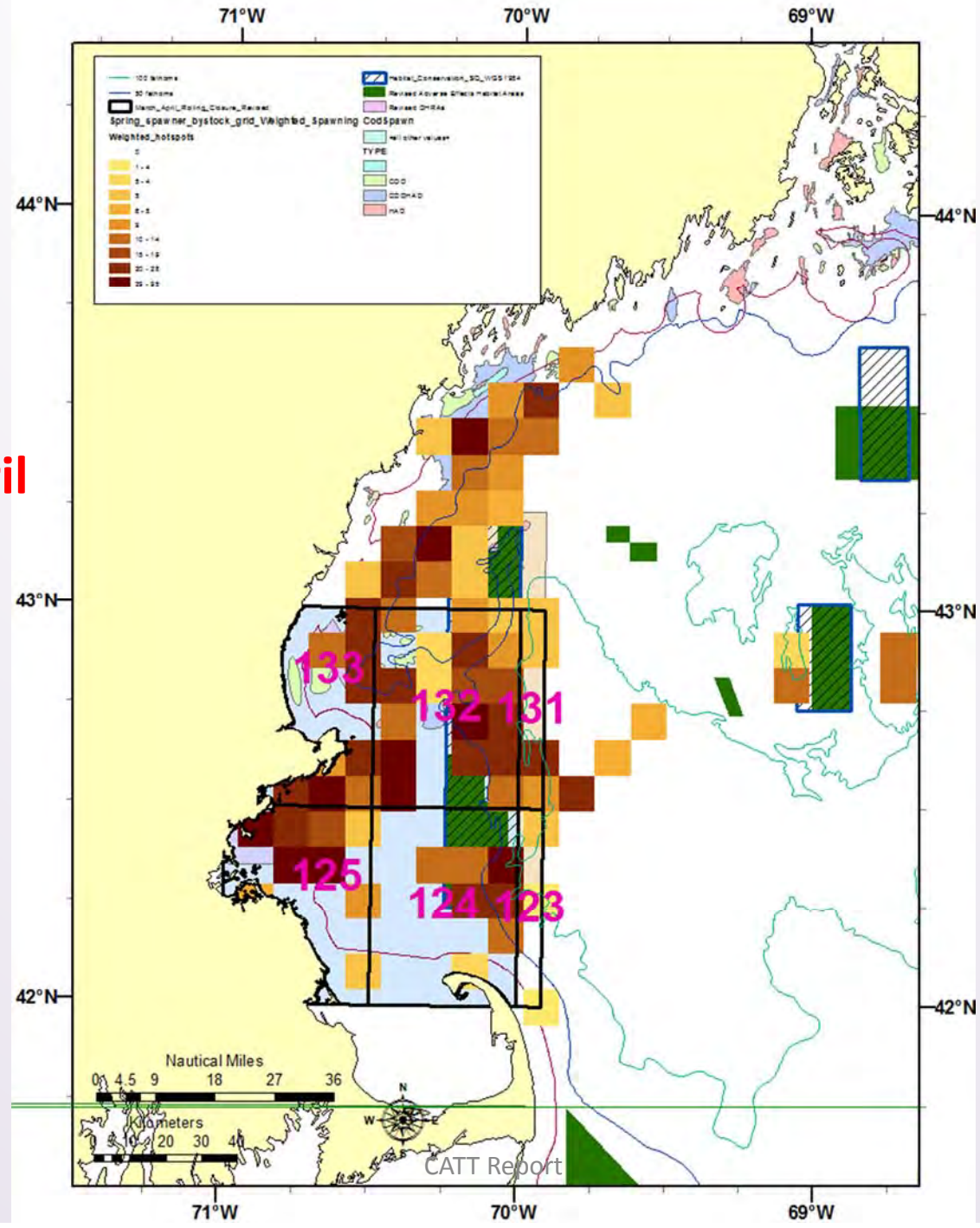
Yellowtail flounder



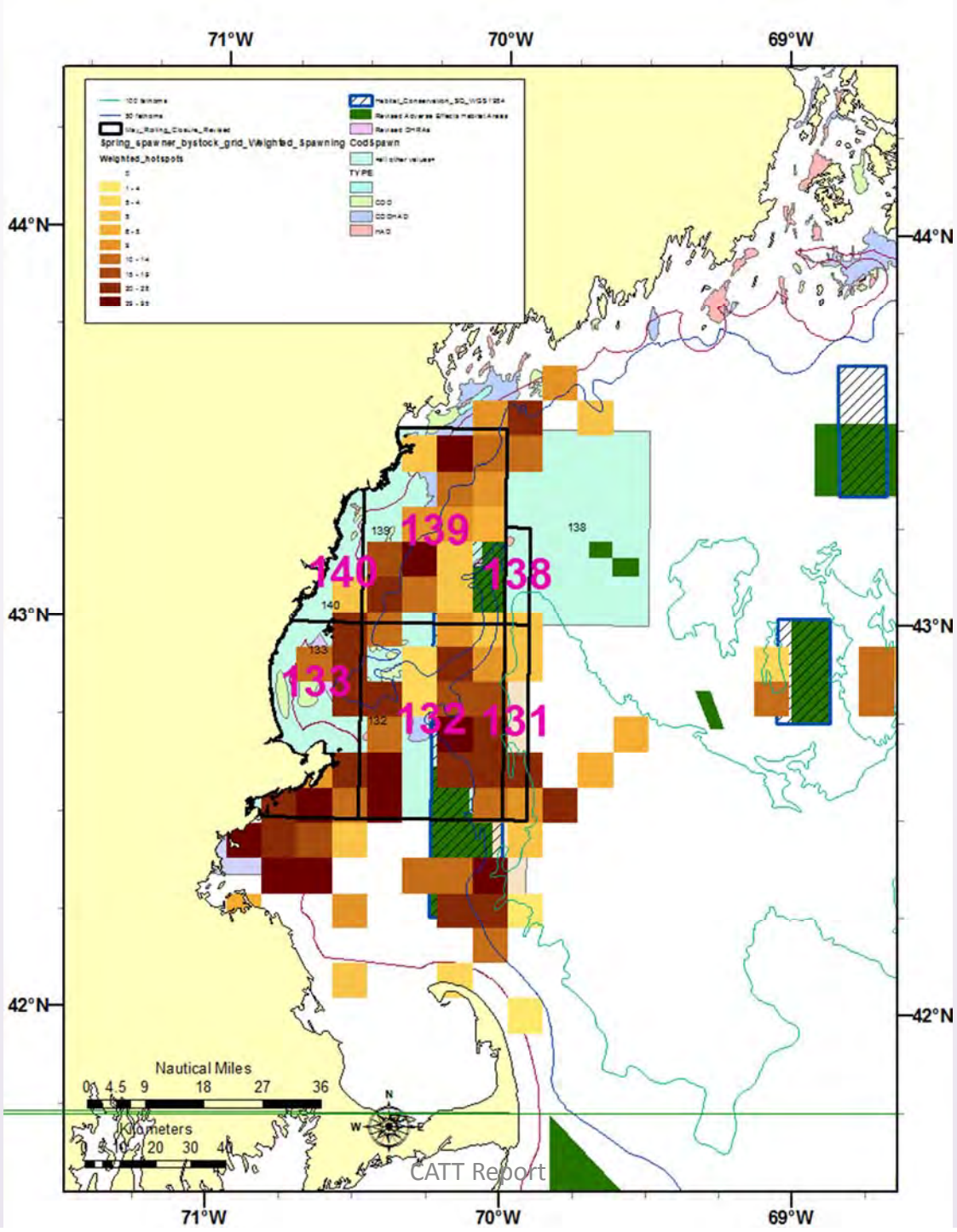
Groundfish management options

- **Option 3 - Modification of current existing Gulf of Maine rolling closures**
  - **Option 3.1 – March and April**
    - Extend Sector April rolling closure into March (Blocks 124, 125, 132, 133)
    - Include closures in Blocks 123 and 131to the edge of current WGOM closure
    - Remove common pool closure blocks (unnecessary)
  - **Option 3.2 – May**
    - Blocks 132, 133, 139, 140
    - Include closures in Blocks 131 and 138 to the edge of current WGOM closure
    - Remove rest of Block 138
    - Remove common pool closure blocks (unnecessary)
  - **Option 3.3 – June**
    - Blocks 139, 140, 147
    - Extend block 138 to the edge of WGOM closure
    - Remove Blocks 136 and rest of 138
    - Remove common pool closure blocks (unnecessary)

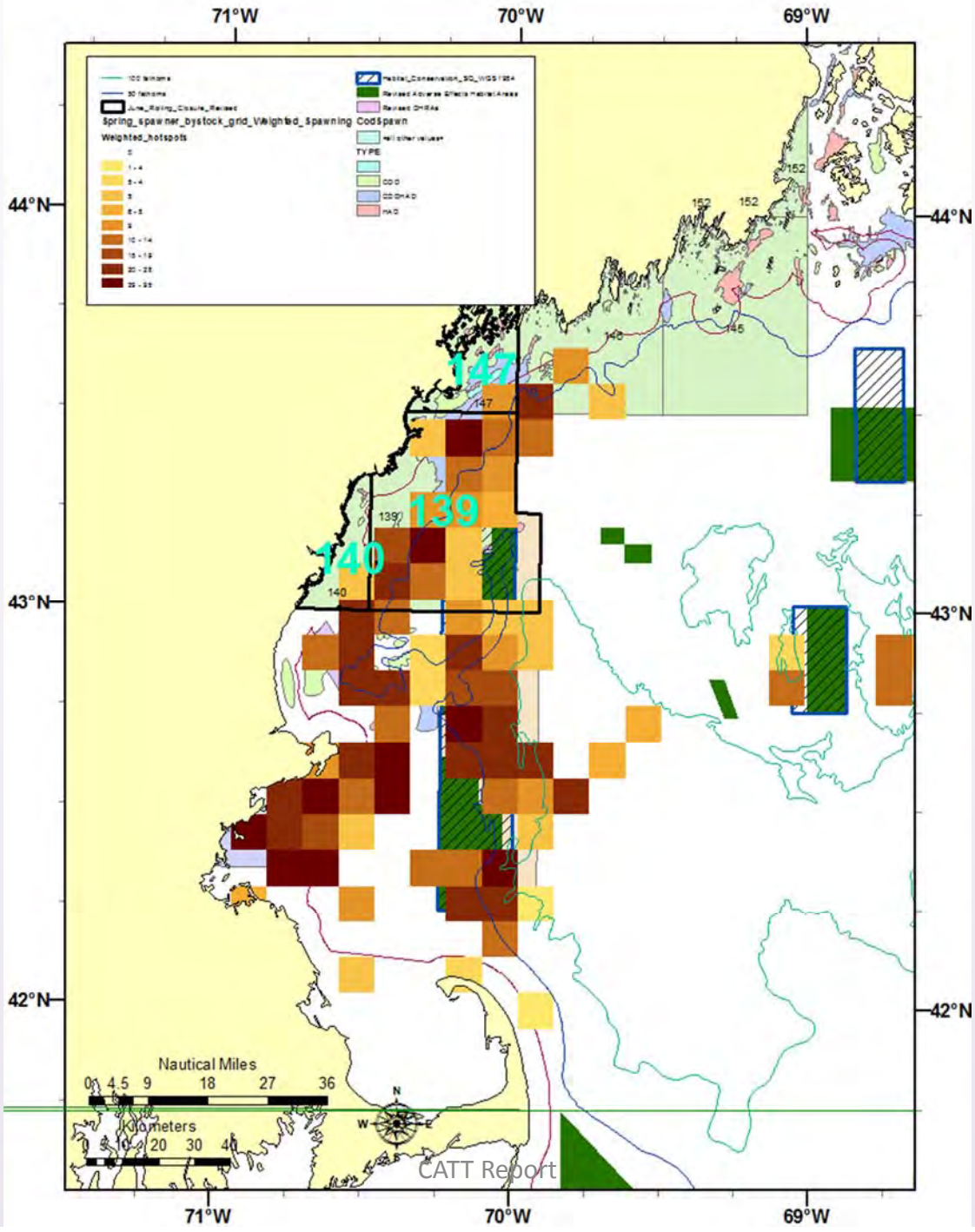
March & April


71°W
70°W
69°W
44°N
43°N
42°N
133
132
131
125
124
123
Nautical Miles
0 4.5 9 18 27 36
Kilometers
0 5 10 20 30 40
N
W
E

May


71°W
70°W
69°W
44°N
43°N
42°N
Spring_spawner_bystock_grid_Weighted_Spawning Cod$pawn
Weighted_hotspots
TYPE
139
140
138
133
132
131
Nautical Miles
0 4.5 9 18 27 36
Kilometers
0 5 10 20 30 40
N
W
E

June


71°W
70°W
69°W
44°N
43°N
42°N
147
139
140
Nautical Miles
0 4.5 9 18 27 36
Kilometers
0 5 10 20 30 40
N
W
E

Groundfish management options

- **Option 4**
  - Modify WGOM Closed Area to be effective from March – June
  - Retain Closed Area II as a spring spawning closure area

Monitoring

- Sentinel or Experimental fisheries with 100% Observer coverage
  - Data collection: Catches, biological characteristics, maturity, benthic characteristics
  - Sampling design is important: random or gridded
  - Allowable sampling gears
  - Accounting for catches: ACL
- SBRM bycatch sampling and estimation for allowed gears and fisheries to achieve an acceptable level of precision of groundfish bycatch estimates in closed areas

Monitoring

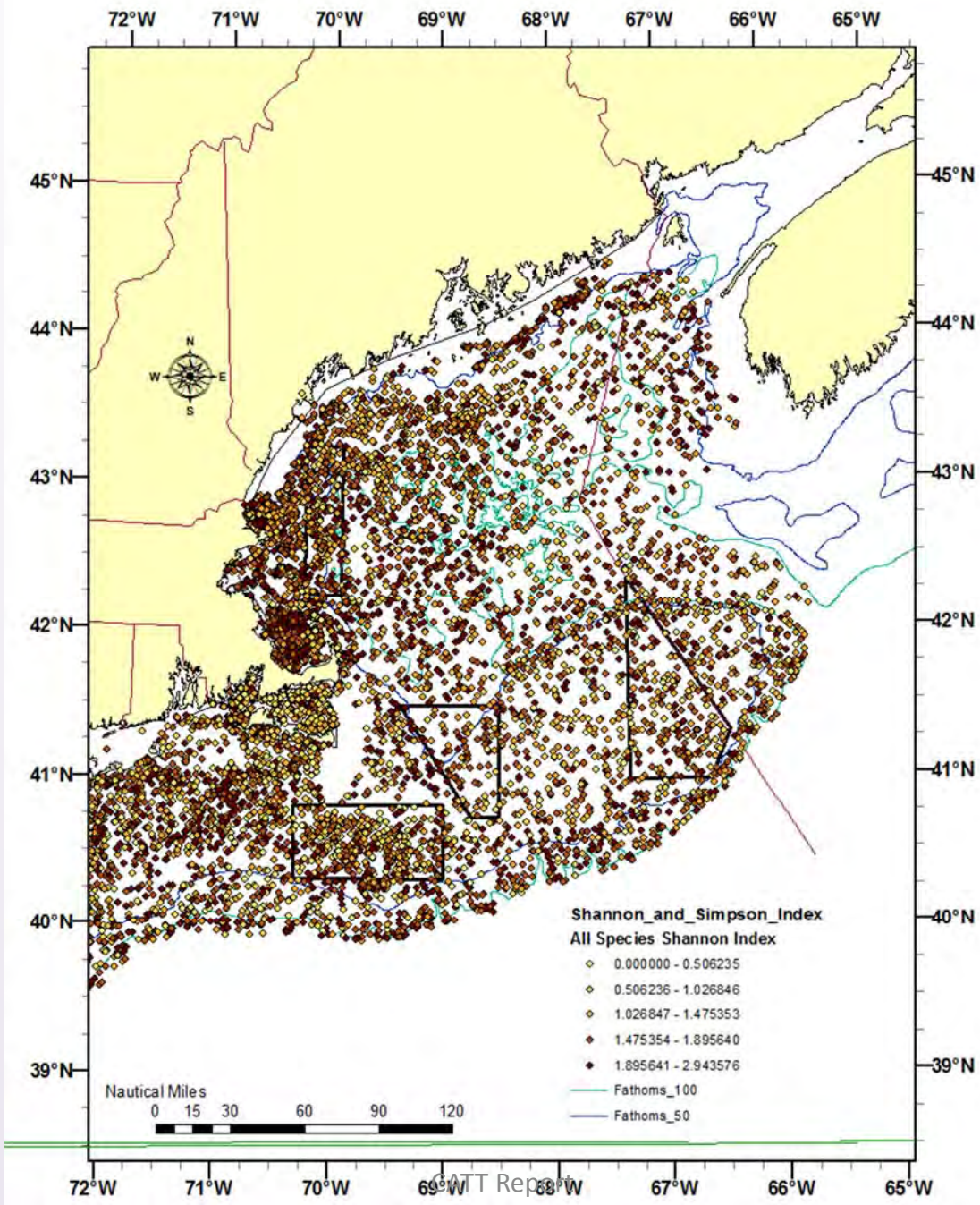
- Biological sampling on observed trips for lengths, individual fish weights, age, maturation, stomach contents, sex
- Intensified survey sampling
  - Supplemental tows on existing surveys
  - Supplemental biological samples for maturity, weights at age, sex, stomach contents, etc.
  - High precision surveys of species composition, lengths, and habitat characteristics/associations, e.g. Habcam
- Targeted tagging programs
  - Fish released in closed areas at various seasons.
  - Control releases in analogous open fishing areas

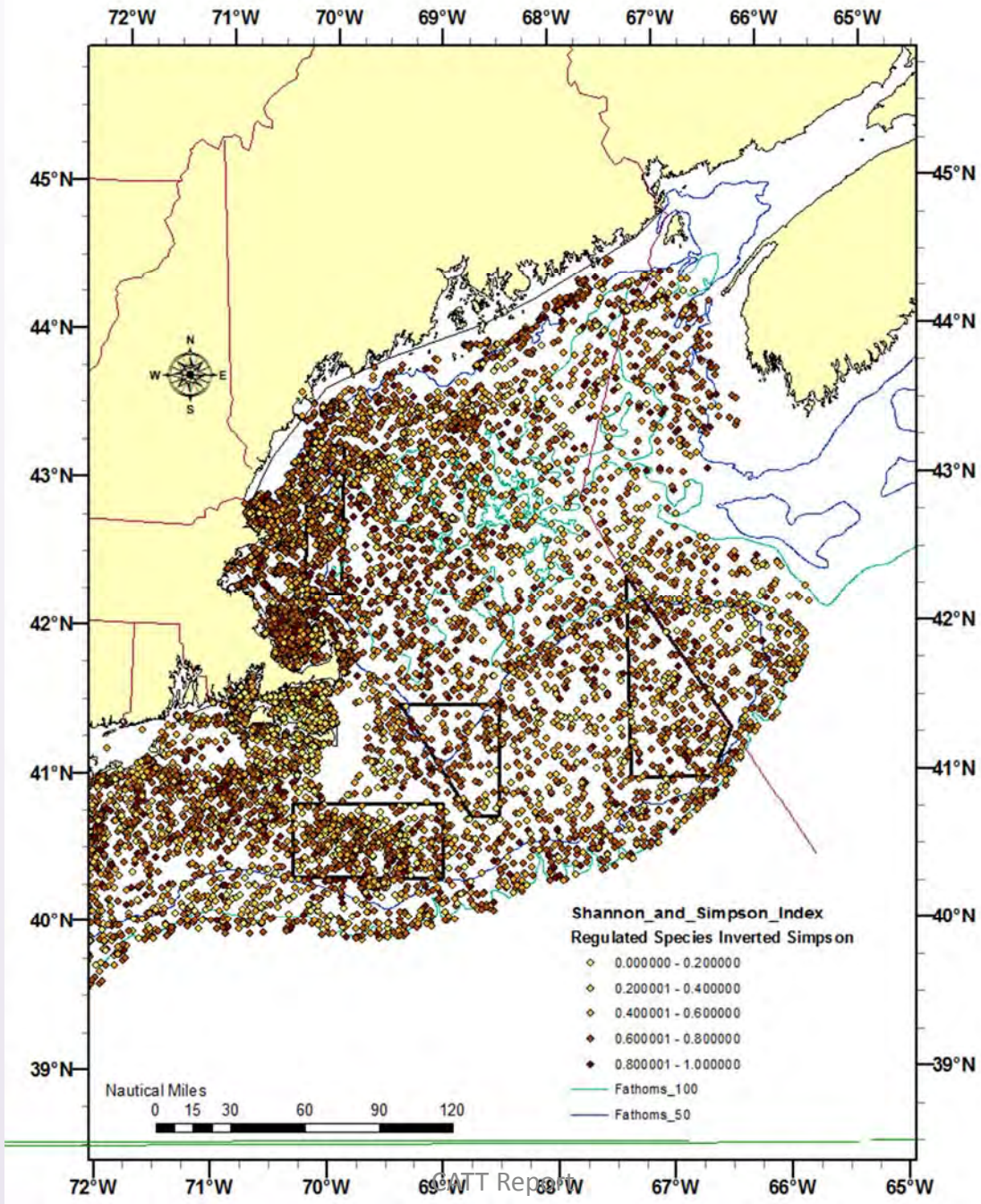
Comparative Metrics

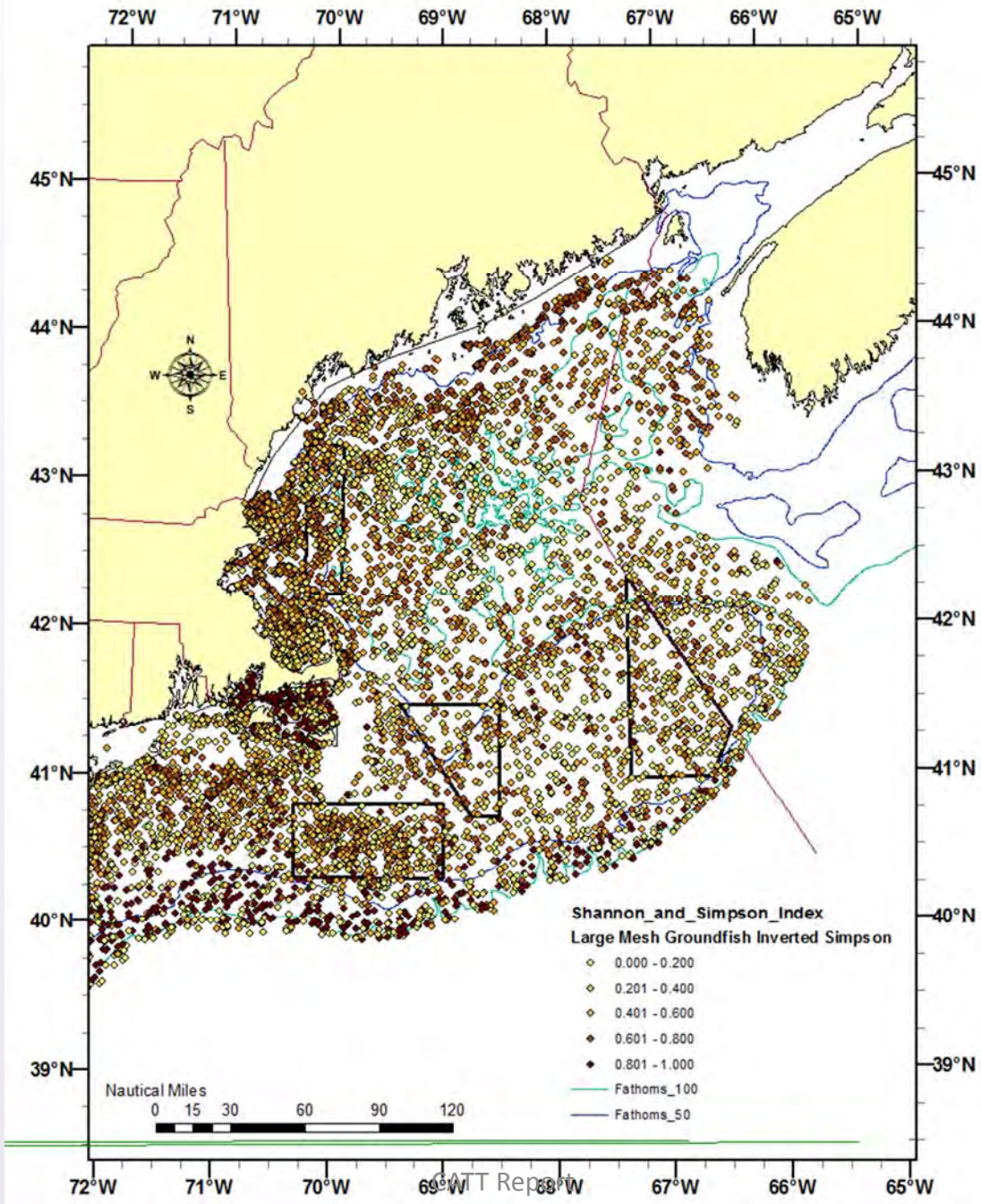
- Groundfish abundance and SSB
- Groundfish juvenile habitat association and spawning aggregation
- Species and groundfish diversity
- Substrate characteristics and vulnerability (SASI)
- Displaced net fishery revenue
- New fishing opportunities
- Productivity enhancement
- Allocation and social/community effects

Species diversity

- Shannon diversity index by tow
  - All recorded catch
  - NEFMC/MAFMC/ASMFC regulated species (including large mesh groundfish)
  - Large mesh groundfish


72°W
71°W
70°W
69°W
68°W
67°W
66°W
65°W
45°N
44°N
43°N
42°N
41°N
40°N
39°N
N
W
E
S
Shannon_and_Simpson_Index
All Species Shannon Index
0.000000 - 0.506235
0.506236 - 1.026846
1.026847 - 1.475353
1.475354 - 1.895640
1.895641 - 2.943576
Fathoms_100
Fathoms_50
Nautical Miles
0 15 30 60 90 120

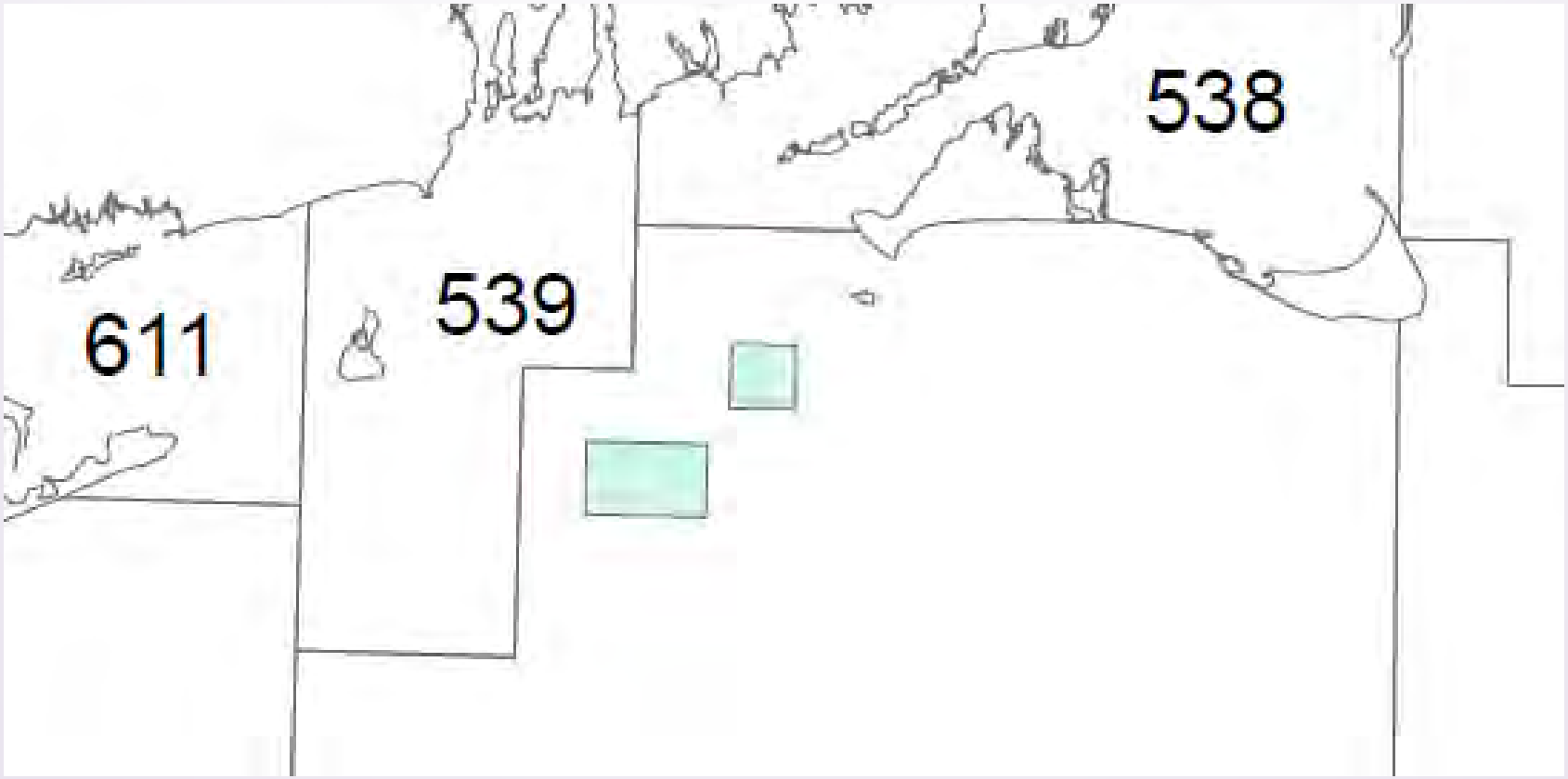

72°W
71°W
70°W
69°W
68°W
67°W
66°W
65°W
45°N
44°N
43°N
42°N
41°N
40°N
39°N
N
W
E
S
Shannon_and_Simpson_Index
Regulated Species Inverted Simpson
0.000000 - 0.200000
0.200001 - 0.400000
0.400001 - 0.600000
0.600001 - 0.800000
0.800001 - 1.000000
Fathoms_100
Fathoms_50
Nautical Miles
0 15 30 60 90 120


72°W
71°W
70°W
69°W
68°W
67°W
66°W
65°W
45°N
44°N
43°N
42°N
41°N
40°N
39°N
N
W
E
S
Shannon_and_Simpson_Index
Large Mesh Groundfish Inverted Simpson
0.000 - 0.200
0.201 - 0.400
0.401 - 0.600
0.601 - 0.800
0.801 - 1.000
Fathoms_100
Fathoms_50
Nautical Miles
0 15 30 60 90 120

Fishery net revenue mapping

- Application of fishery revenue less fishing costs applied to a probabilistic estimate of fishing location
- Used to estimate effect of proposed alternatives
- May allow modification of areas to minimize adverse economic and social impacts

Cox Ledge habitat alternative



VTR bands overlapping Cox Ledge