Is Cape Cod a Natural Delineation for Migratory Patterns in US and Canadian Spiny Dogfish Stocks?

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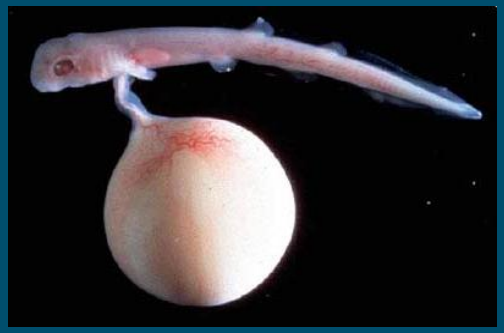
Spiny dogfish (*Squalus acanthias*)

http://www.sharkinfo.ch/SI2_99e/sacanthias.html

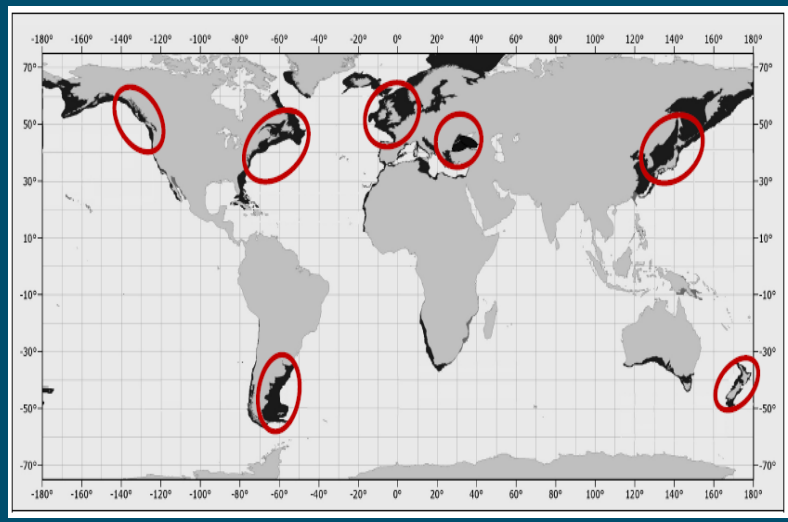
- Ovoviviparus: pups TL 18 – 33 cm at born
- Gonochoristic with sexual segregation:
  - ♀ larger, inshore shallower waters
  - ♂ smaller, deeper offshore waters



http://www.flmnh.ufl.edu

- K-selected:
  long gestation (≈ 2 years); slow growth rate;
  age at maturity 8-10 years for ♂ (> 60 cm)
  and12-15 for ♀ (> 80 cm)
- Cosmopolitan:
  from the surface to below 600 m
- Discussed for inclusion in CITES App.-II

(Jensen 1965; Nammack et al., 1982; Sheperd et al., 2002; Compagno et al., 2005; Fordham, 2009)



Source: CITES (CoP15 Prop. 18)

The Spiny Dogfish International Trade

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Iceland	31	73	67	48	32	70	107	221	150	95	45
Norway	3132	2416	1394	1065	1239	1447	1396	1108	1080	991	937
USA	7581	8938	8181	6817	6317	3761	1671	1664	909	753	720
Canada	469	145	228	370	599	1003	1569	1610	1540	1752	1484
Morocco	0	0	0	0	0	71	206	212	190	388	460
Mauritania	168	206	52	90	66	292	305	91	61	0	43
Argentina	204	313	68	256	253	232	310	263	341	119	315
New Zealand	29	5	18	15	71	152	195	448	319	244	250
Others	312	209	164	116	120	210	106	195	184	192	351
Total	11 926	12 305	10 171	8778	8696	7238	5863	5811	4774	4534	4605

European Commission (2006)

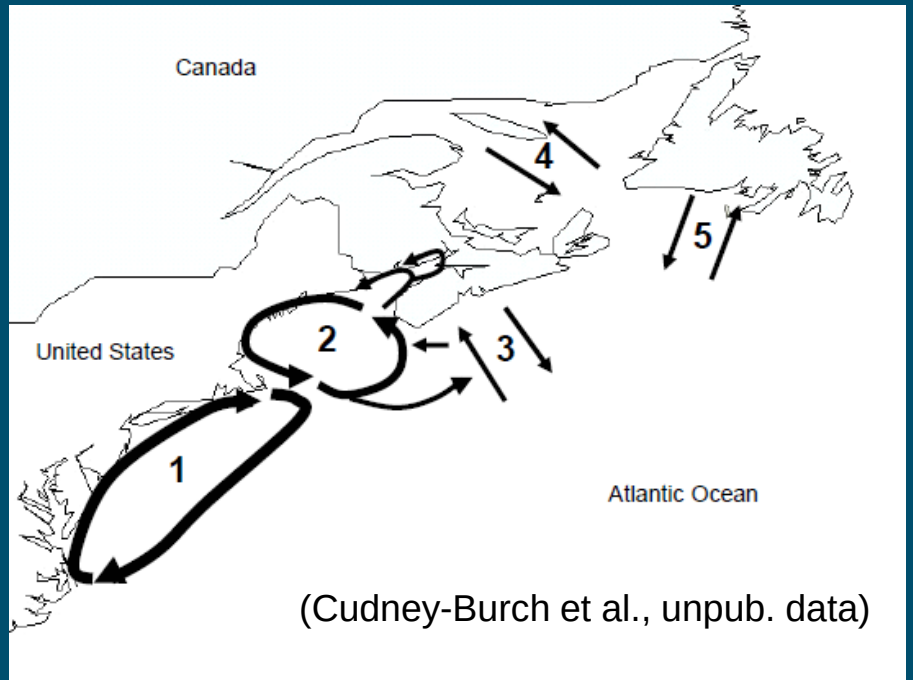
- The EU market demands for larger individuals (Lack, 2006)
- ♀ constituted 93% of US landings between 1998-2002, and 76% of estimated dead discards between 1989-2000 (NEFSC, 2003; Rago and Sosebee, 2010)
- Increased skewed sex ratio (7:1 M:F) and smaller sized reproductive females (that produce fewer, smaller offspring) due to low recruitment (SAW/SARC, 2006)

US Atlantic Spiny Dogfish FMP

- 1998, NMFS declared the US North Atlantic stock overfished
- 1999, NEFMC-MAFMC FMP in federal waters (3-200 miles offshore)
- 2002, ASMFC-FMP in state waters (0-3 miles offshore)
- 2010, NOAA declared the stock rebuilt
- TAC increased to 15 million lb for 2010/11 and to 30 million lb for 2012/13, with a 3,000 lb maximum possession limit per vessel trip
- Proposed TAC to 40.8 million lb for 2013, and 4,000 lb maximum possession limit per vessel trip for 2013/15 (MAFMC, 2012)

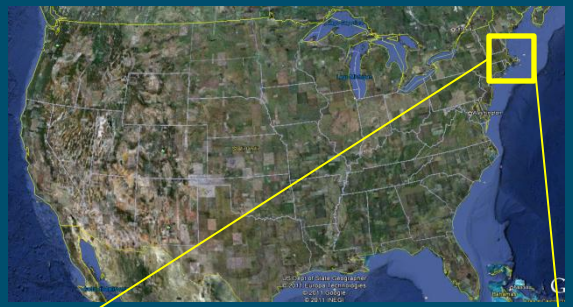
TAC Allocation for the US Atlantic

- TACs allocation system based on the species seasonal migration
- Fishery sustainability measured by SSB: adult female (> 80 cm) biomass estimate by NMFS-NEFSC spring trawl survey
- NMFS considers the NW Atlantic as a single population (NMFS, 2006)
- New paradigm suggests the presence of multiple stocks, with a limited rate of intermixing (≈10%) off New England and Cape Cod (Campana, 2010; Rulifson, 2010)



(Cudney-Burch et al., unpub. data)

Study Area



Source: Google Earth

- Longline fishers LEK: daily M:F ratio (R) changes throughout a normal fishing day
- Similar preliminary results by research survey conducted using commercial longlines (Rulifson, 2008; 2010)
- Male-only directed fishery???? (Rago and Sosebee, 2008)

Goal and Objectives

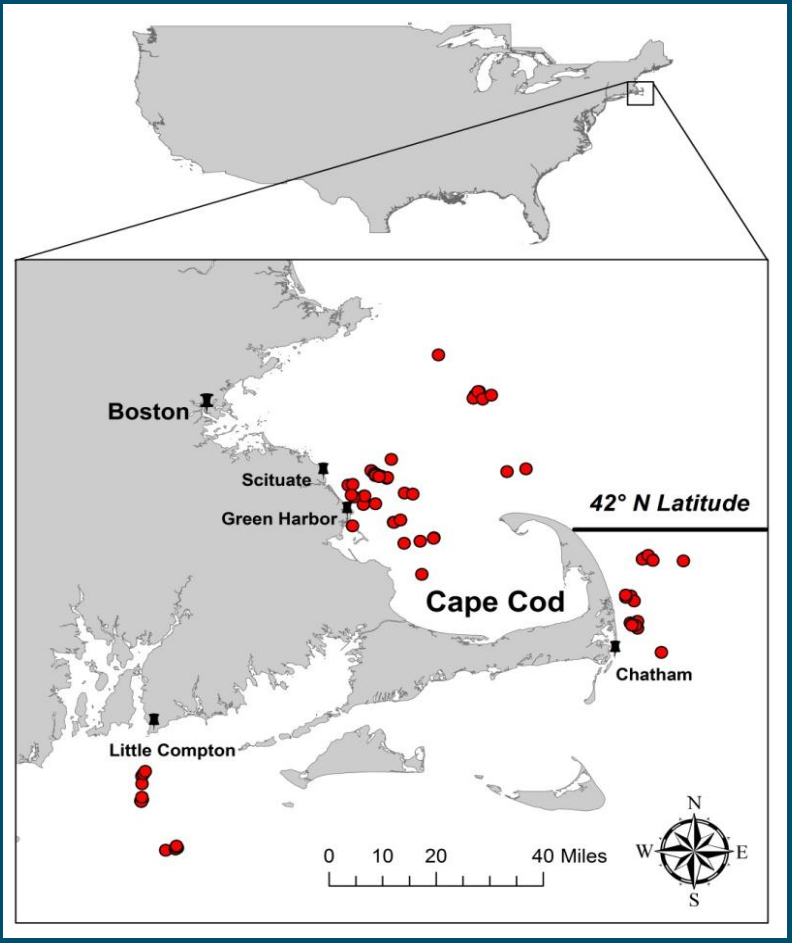
- To estimate the amount of mixing between US and Canadian spiny dogfish stocks
- To conduct fishery-dependent surveys in the study area to test for the occurrence of changes in the male:female ratio (R) reported by local fishers
- To determine the relationships between R, geographic location, environmental conditions, and local fishery characteristics

Goal and Objectives

- Multiple tagging techniques (external and acoustic tags) to assess dogfish migratory behavior
- Analyses of sex ratio composition throghout a typical commercial fishing day and assessment of changes in R by season and fishing gear

Methods

- Commercial Gillnets (10 panels, 6.5 cm stretch mesh size x 300 ft = 3,000 ft line) and longline (4 bundles x 1,500 ft = 6,000 ft line. 300 hooks x bundle = 1,200 hooks. Squid as bait)



- October 7-13, 2010; May 9-17, 2011; June 22-28, 2011; August 14-17, 2011
- STAR-ODDI DST Centi TD: average T (°C) at gear depth and average gear depth (m)

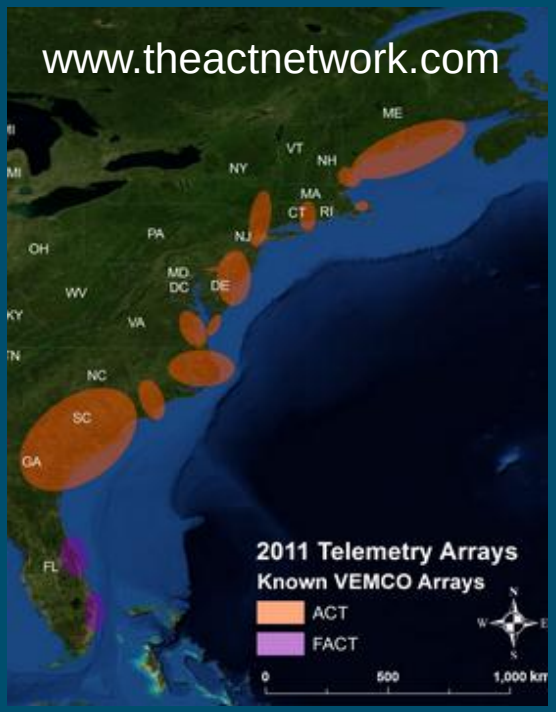
  Data NA for October, 2010
- YSI Model 85: surface water T (°C), salinity (ppt)
- 42° N Lat. for dividing N and S area

Methods

- Sex, length (TL in mm), tagged and released
- External tags (FLOY SS-94)

  external red button tags (FLOY Oval tag) and internal acoustic tags (VEMCO V16)
- $$IR = \frac{\left[\left(\frac{Xrs}{Ntotn}\right)+\left(\frac{Xrn}{Ntots}\right)\right]}{2}$$

Methods


www.theactnetwork.com
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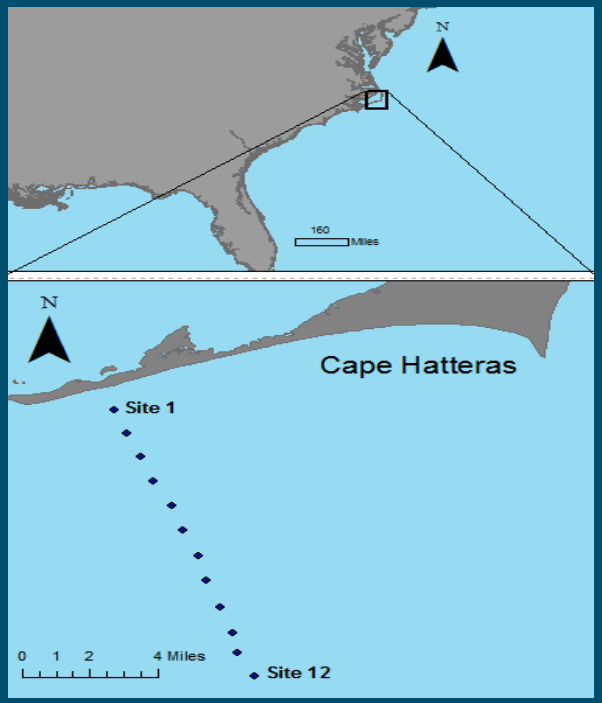
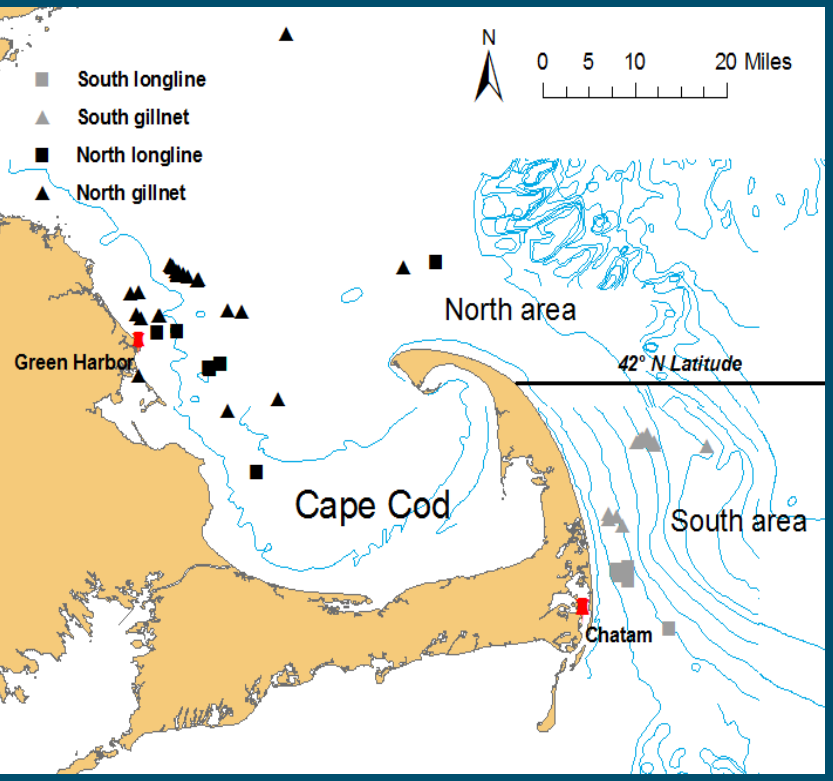

N
160
Miles
N
Cape Hatteras
Site 1
0 1 2 4 Miles
Site 12

Methods for Sex Ratio Study

- 59 surveys conducted at N (n = 39) and S (n = 20) of Cape Cod (42° N Lat)



- Spearman's rank correlation coefficient (ρ)
- Kruskal-Wallis single factor ANOVA

  R , ♂ and ♀ total No

  depth strata:

  0 = 0-29.9 m, 1 = 30-44.9 m, 2 > 45 m

  time strata:

  "morning" 0 = 6:00 AM - 12:59 AM
  "afternoon" 1 = 1:00 PM - 6:59 PM
  "night" 2 = 7:00 PM – 5:59 AM
- Wilcox non-parametric t.test
- Chi-squared test or G-test – changes in R, and in ♂ and ♀ total No and avg TL throughout a fishing day

Results

	Fall 2010		
	Males	Females	Subtotal
North			
Gillnet	33	678	711
Longline	5	660	665
South			
Gillnet	30	558	588
Longline	573	94	667
Subtotal	*641*	*1990*	*2631*
	Spring 2011		
	Males	Females	Subtotal
North			
Gillnet	0	570	570
Longline	4	599	603
South			
Gillnet	30	561	591
Longline	8	584	592
Subtotal	*42*	*2314*	*2356*
	Summer 2011		
	Males	Females	Subtotal
North			
Gillnet	196	473	669
Longline	143	551	694
South			
Gillnet	474	245	719
Longline	650	26	676
Subtotal	*1463*	*1295*	*2758*
Total	**2146**	**5599**	**7745**

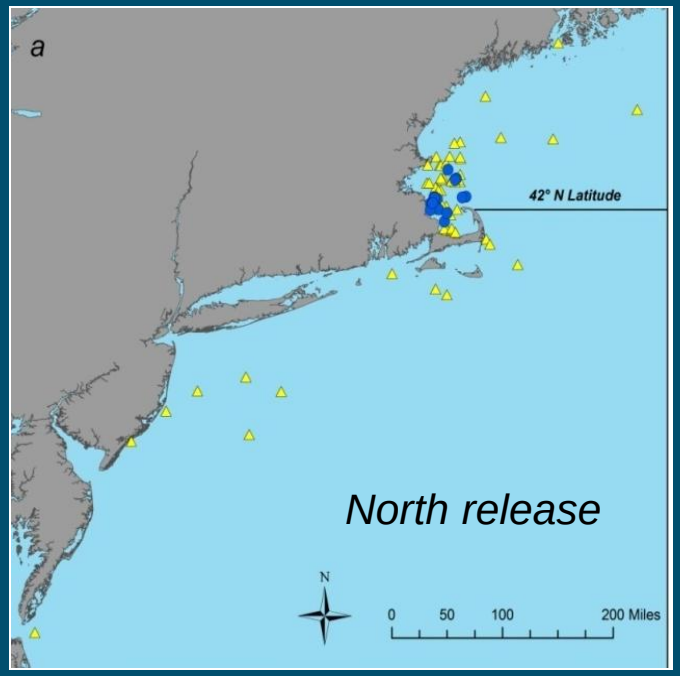
External Tags:

- 89 sets (54 in the N and 35 in the S)
- Catch composition: 72.3% ♀; 27.7% ♂
- Catch by area: 3,912 at N and 3,833 at S

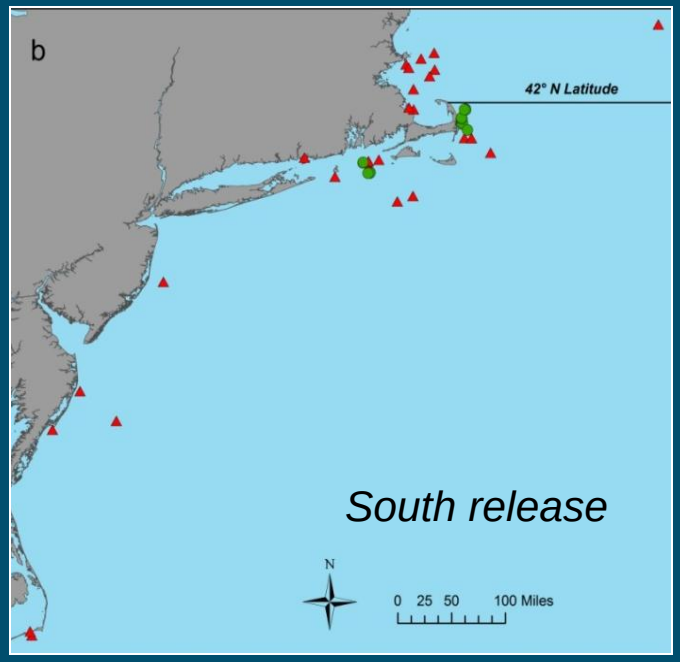
Acoustic Tags:

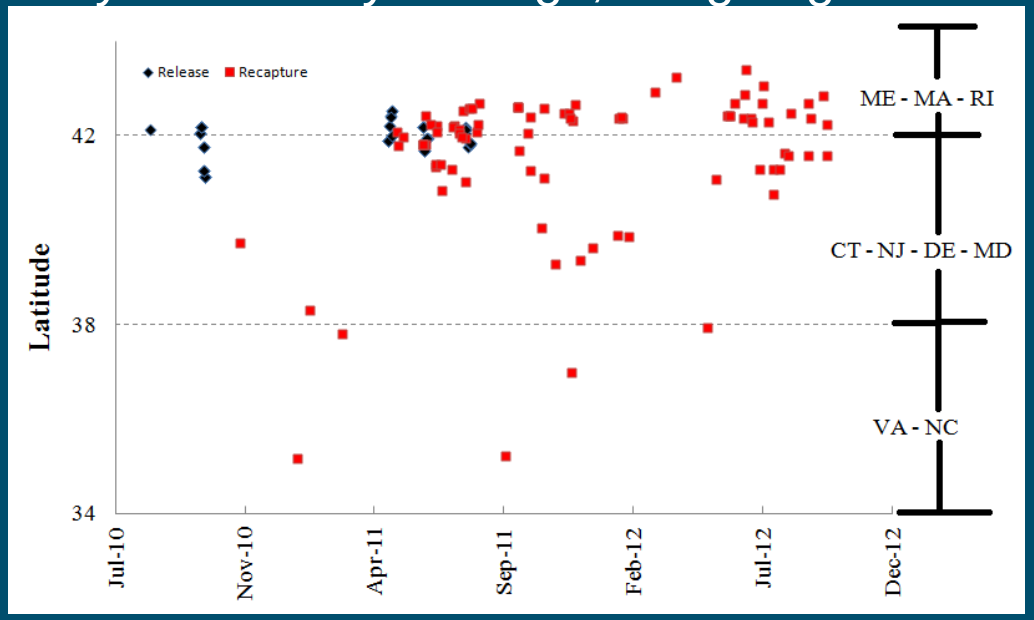
	Males	Females	Subtotal
North	18	42	60
South	24	36	60
Total	**42**	**78**	**120**

External Tags

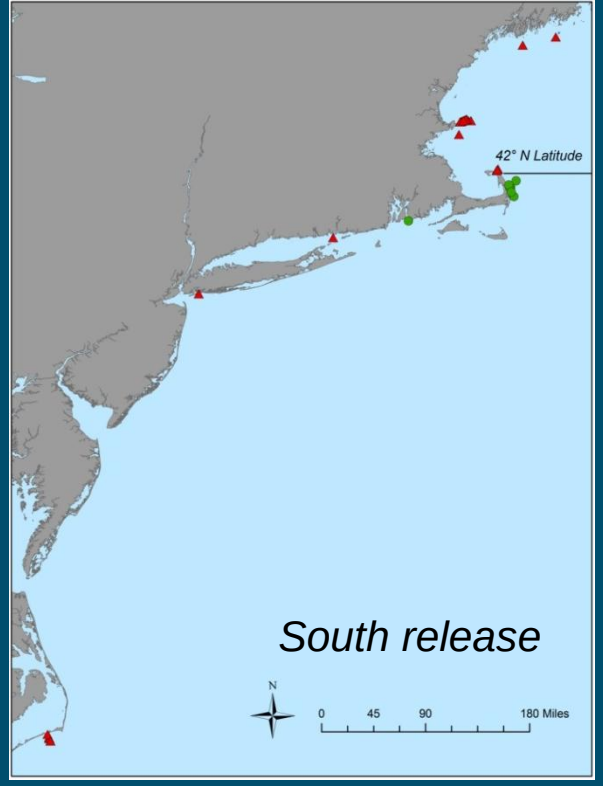


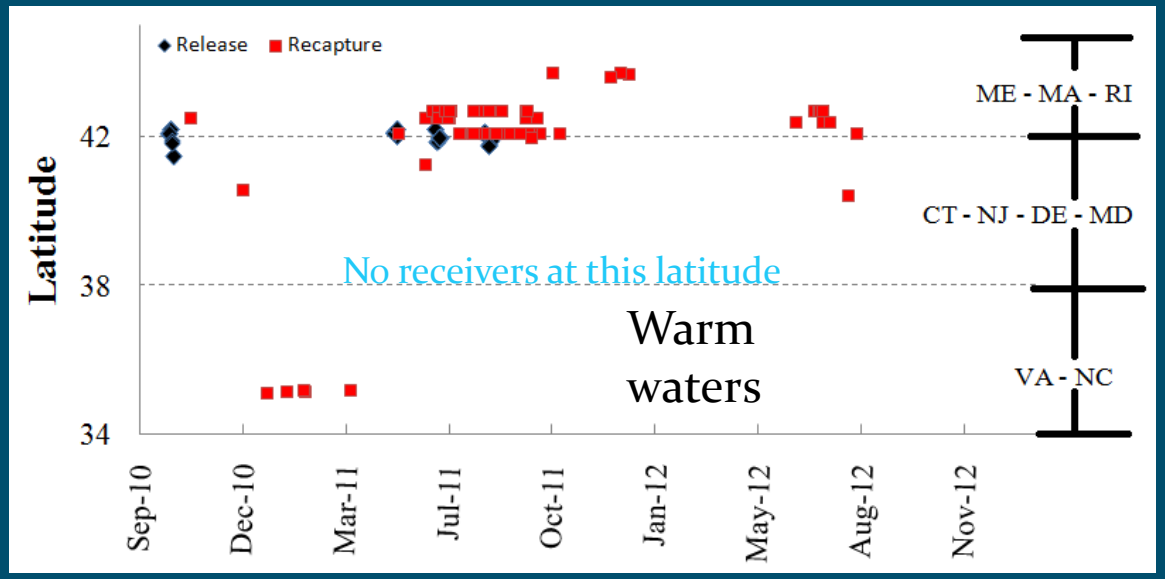
- n=90 (3 ♂ and 87 ♀)
- 1% recapture rate
- North: 79% (n=49) recapture within the N area
- South: 64.3% (n=18) recapture within the S area
- Average IR=28.4% (but no recaptures from Canada)
- This year – many old tags; long migration?





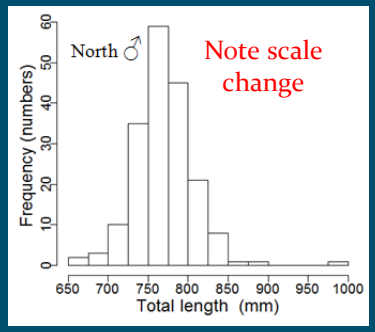
Acoustic Tags

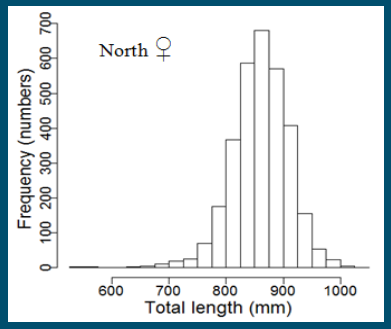


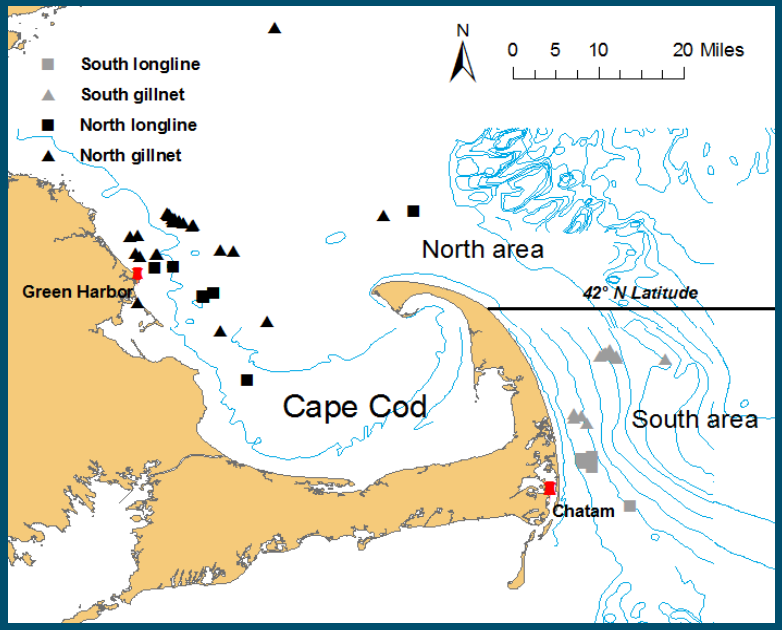


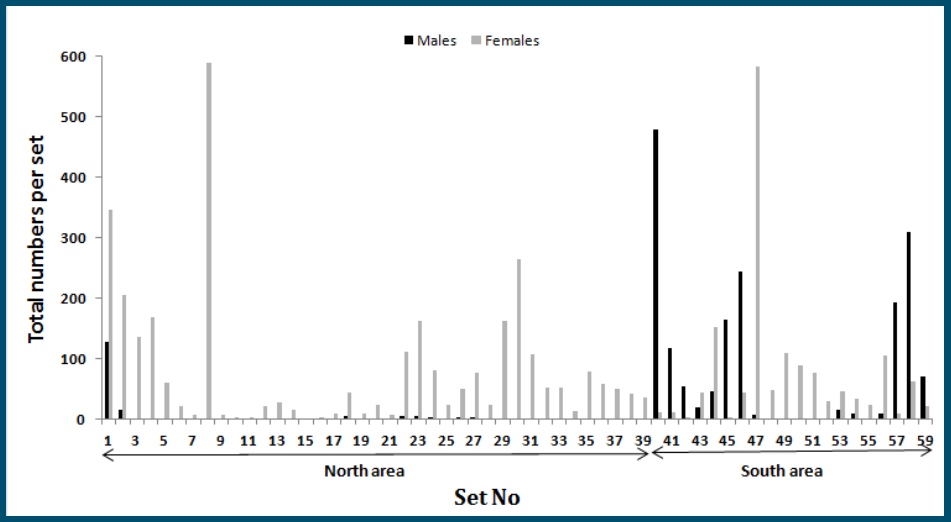
- n=58 (12 ♂ and 46 ♀)
- 48.3% recapture rate
- 63.8% (n=37) released at N and 36.2% (n=21) released at S
- North: 94.6% (n=35) redetected in the N area. South: 28.6% (n=6) redetected in the S area.
- Average IR=38.4%
- More females redetected than males (χ^2 =10.1, P=0.01) with and Odd Ratio=3.59

M:F Ratio (R)









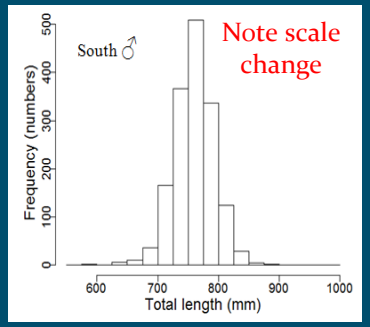
♀ 91.2% of adult size; ♂ 99.9% of adult size (♀ >80 cm; ♂ >60 cm; Nammack et al., 1985)

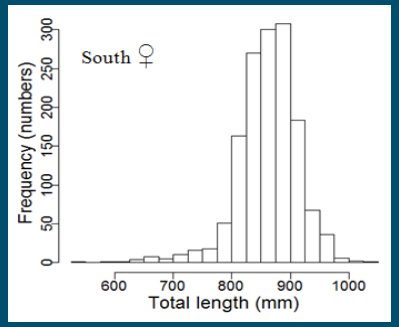
♀ always caught; ♂ in 62.7% (n = 37) of sets

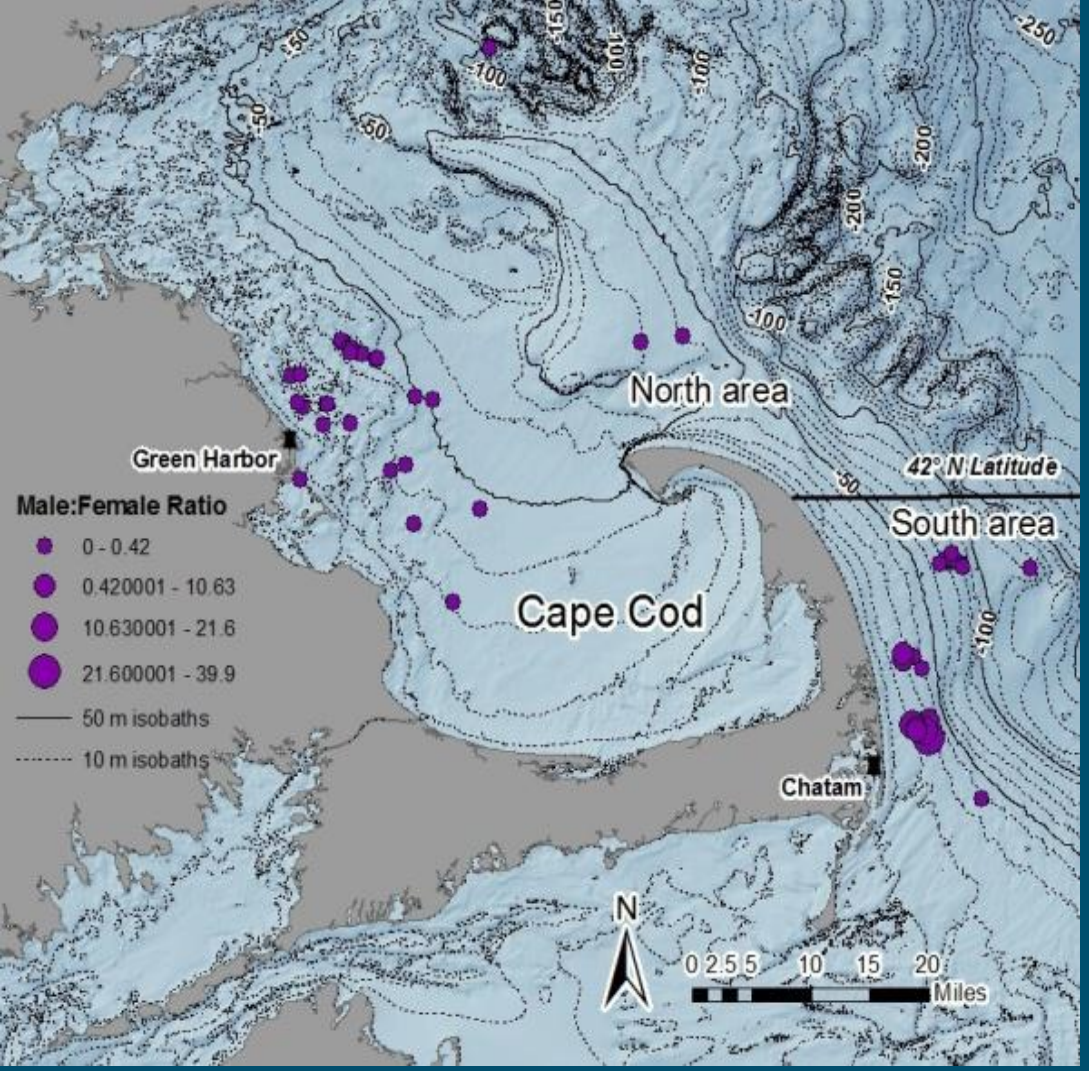
86.4% (n = 51) of sets with R < 1

13.6% (n = 8) of sets with R > 1 ALL SOUTH

No apparent influence of season (summer and fall) and type of gear (longline or gillnet)







Source: NOAA National Geophysical Data Center (NGDC)

M:F Ratio (R)

Temp for North (n = 19) ???
Unusual cold bottom water on May (n=7) mean= 4.9 °C, range 4.7- 5.8 °C at depths between 40-50 m

Gear Temp and SWS
ρ = 0.505; P = 0.016

South
Gear Depth and Gear Temp
ρ = -0.89; P < 0.001

M:F Ratio	Gear Depth	Gear T	Surface Water Temperature	Surface Water Salinity
North	-0.05	0.310	0.092	0.396*
South	-0.810*	0.774*	-0.190	0.308

M:F Ratio (R)

Environmental parameter	North	South	Statistic
Bottom temperature (°C)	4.7 - 10.9; 7.9 ± 2.1	5.8 - 10.5; 7.3 ± 1.7	W = 185.5; P = 0.27
Surface temperature (°C)	8.9 - 19.2; 14.4 ± 3.5	14.5 - 19.6; 17.4 ± 1.5	W = 70.5; P = 0.003*
Water depth (m)	10.1 - 51.8; 33 ± 10.4	20.7 - 77.7; 46.5 ± 23	W = 308; P = 0.19
Surface salinity	29.4 - 31.4; 30.3 ± 0.7	29.3 - 30.8; 30.2 ± 0.4	W = 162.5; P = 0.74

- The two areas differed in SST, with the South warmer than the North area
- The South is characterized by a steep decline in sea bottom depth within ≈ 10 miles from shore that is not a characteristic of the North area

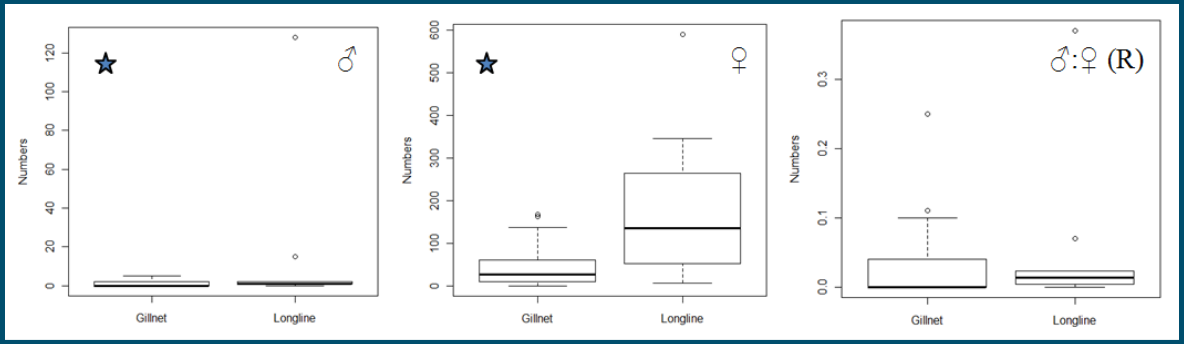
Date	Season	Gear	Area	Settime	Pulltime	Depth (m)	M:F Ratio	Males No	Females No
10/11/2010	Fall	Gillnet	S	7:30	8:30	5.8	0	0	30
10/11/2010	Fall	Gillnet	S	9:15	10:30	6.1	0.2	4	20
10/11/2010	Fall	Gillnet	S	11:24	12:30	5.8	0.064	3	47
10/11/2010	Fall	Gillnet	S	13:17	14:15	5.9	0.059	3	51
10/12/2010	Fall	Gillnet	S	15:00	8:11	6.4	0.014	1	70
10/12/2010	Fall	Gillnet	S	7:37	9:40	5.4	0.250	6	24
10/12/2010	Fall	Gillnet	S	9:23	10:55	NA	0	0	2
10/12/2010	Fall	Gillnet	S	10:07	12:58	NA	0.3	3	10
10/12/2010	Fall	Gillnet	S	11:41	12:58	NA	0	0	2
10/13/2010	Fall	Gillnet	S	5:22	8:07	NA	0.052	7	135
10/13/2010	Fall	Gillnet	S	6:02	9:30	NA	0.043	2	46
10/13/2010	Fall	Gillnet	S	9:17	11:27	NA	0	0	11
10/13/2010	Fall	Gillnet	S	10:14	12:27	5.7	0	0	51
10/13/2010	Fall	Gillnet	S	11:45	14:49	6	0.042	1	24
10/13/2010	Fall	Gillnet	S	13:06	15:19	5.8	0	0	35

Rhode Island (Oct 2010)

- R<1 (more females)
- Shallow waters, mean depth = 5.9 m and range between 5.4 and 6.4 m

Results – North Area

Fishing Gear (n = 10 for longline and n = 29 for gillnet)

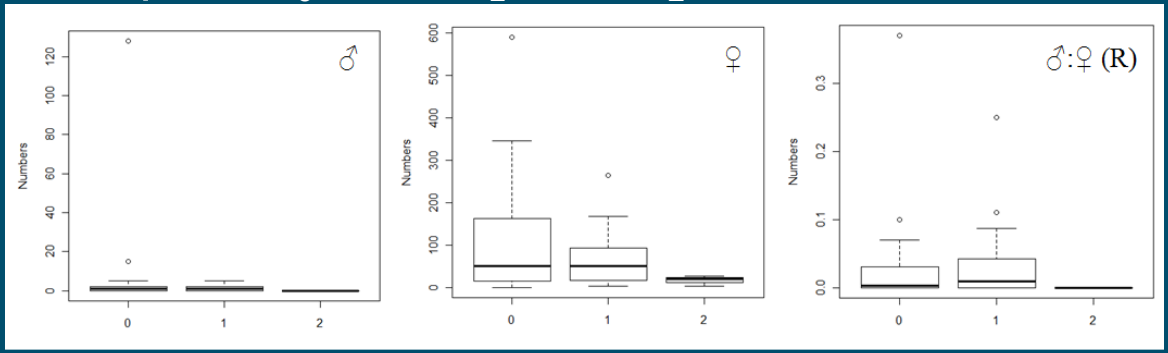


Wilcox t.test

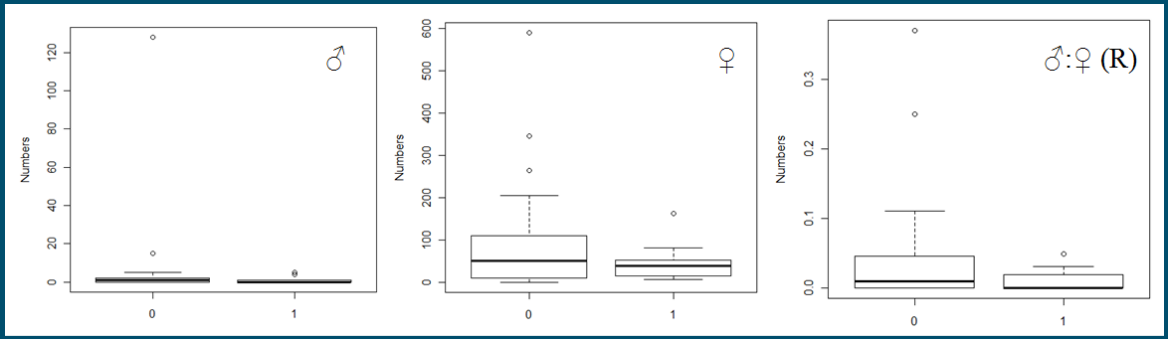
♂ W = 84.5; P = 0.04

♀ W = 68; P = 0.014

Depth (n_0 = 13, n_1 = 23, n_2= 3)



Time (n_0 = 29, n_1 = 10)



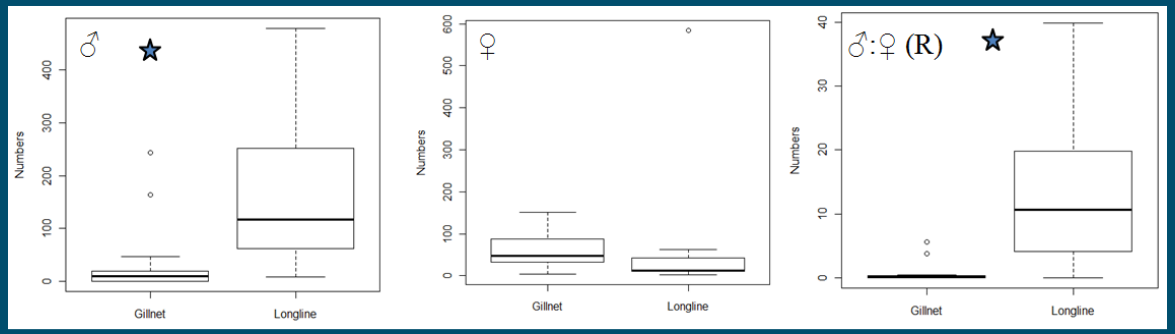
Wilcox t.test

♂:♀ (R) W =193; P = 0.1

one longline set on August 2011: 128 ♂ and 346 ♀

Results – South Area

Fishing gear (n = 7 for longline and n = 13 for gillnet)

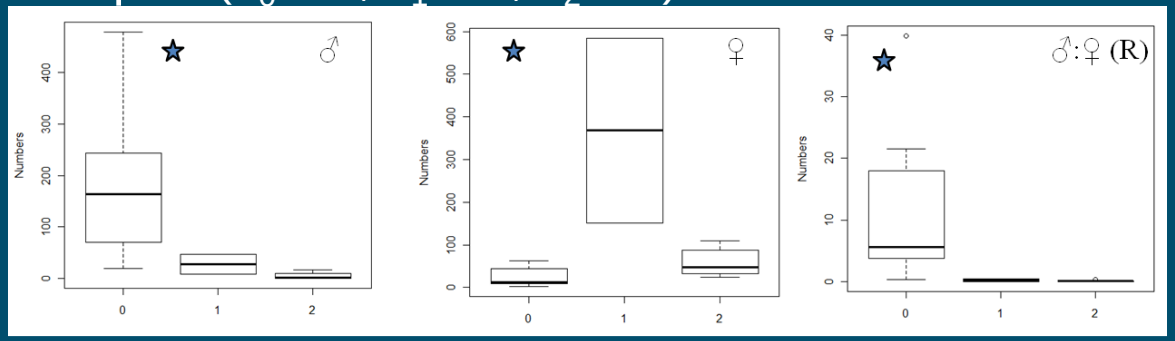


Wilcox t.test

♂ W = 14; P = 0.01

♂:♀ (R) W = 12; P = 0.009

Depth (n_0 = 9, n_1 = 2, n_2 = 9)



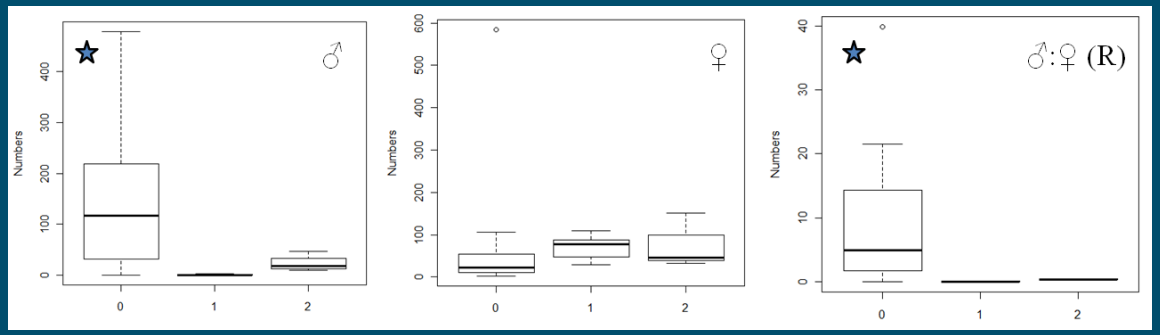
KW-ANOVA
Bonferroni pairwise

♂ F = 14.5; P < 0.001

♀ F = 10.7; P = 0.0048

♂:♀ (R) F = 13.5; P < 0.001

Time (n_0 = 11, n_1 = 5, n_2= 4)



KW-ANOVA
Bonferroni pairwise

♂ F = 9.8; P = 0.007

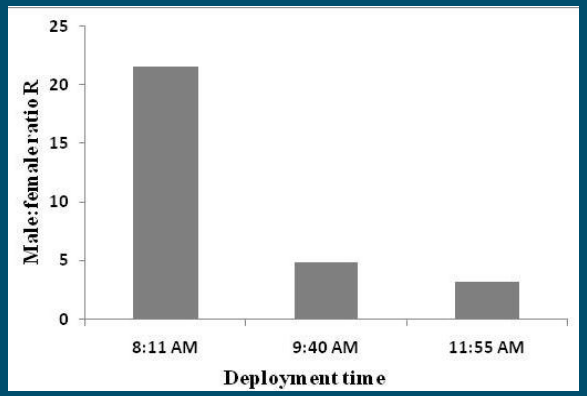
♀ F = 4.1; P = 0.1

♂:♀ (R) F = 8.6; P = 0.01

October 11, 2010 avg time 12.3 min

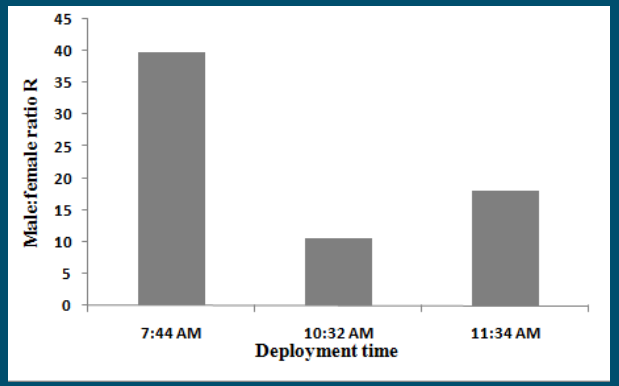
August 14, 2011 avg time 14.3 min

Longline – related to feeding behavior



G = 19.1

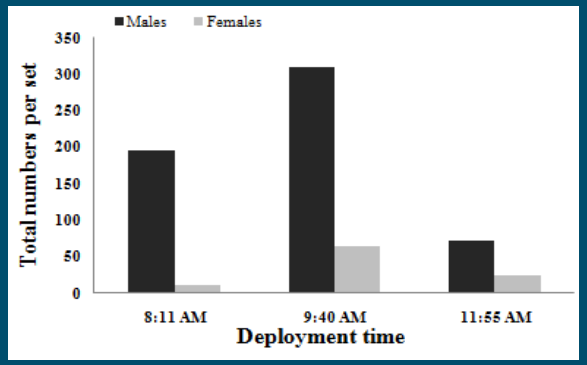
P < 0.001



χ^2 = 20.3

P < 0.001

♂



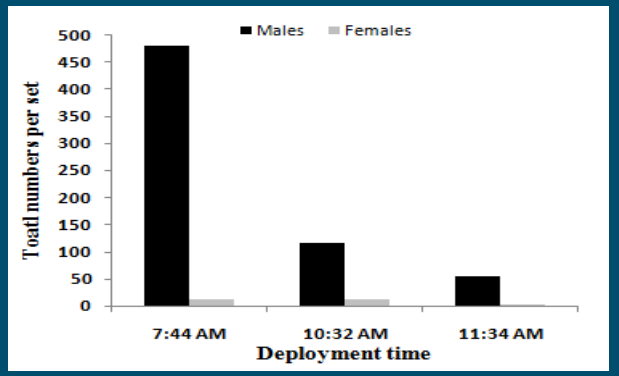
χ^2 = 149.6

P < 0.001

♀

χ^2 = 50.7

P < 0.001



♂

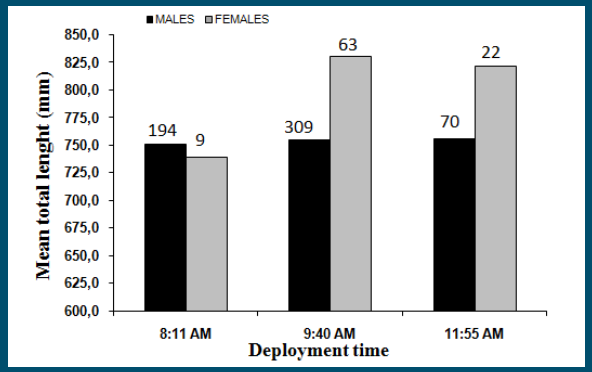
χ^2 = 485.6

P < 0.001

♀

G = 6.5

P = 0.038

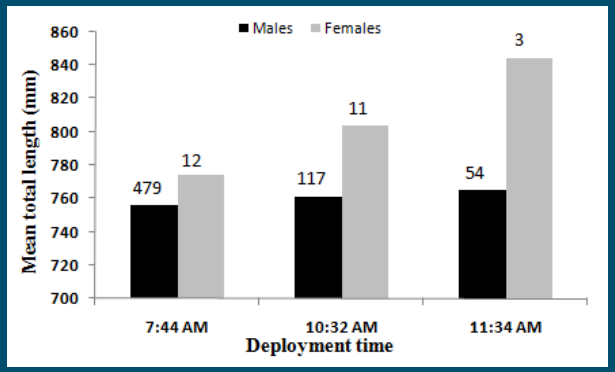


♀

F = 10.4

P = 0.005

Bonferroni pairwise

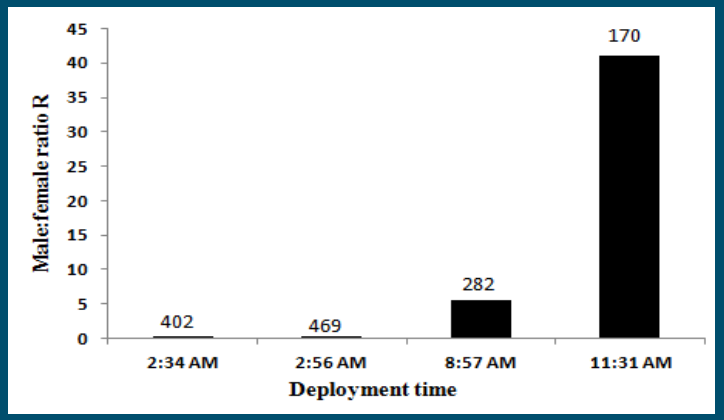


♀

F = 1.72

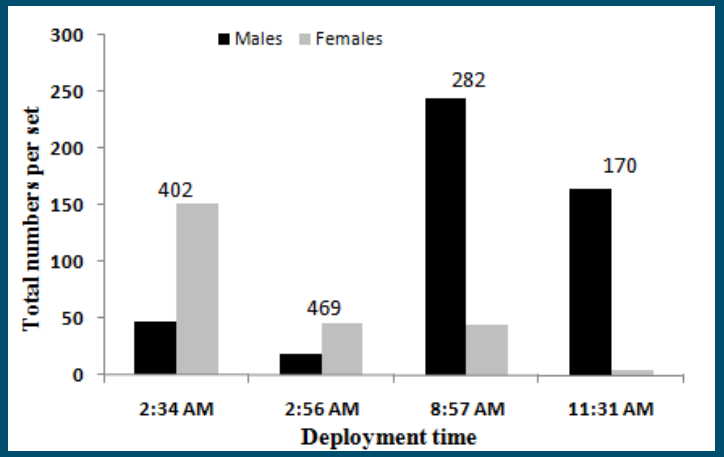
P = 0.4

Bonferroni pairwise



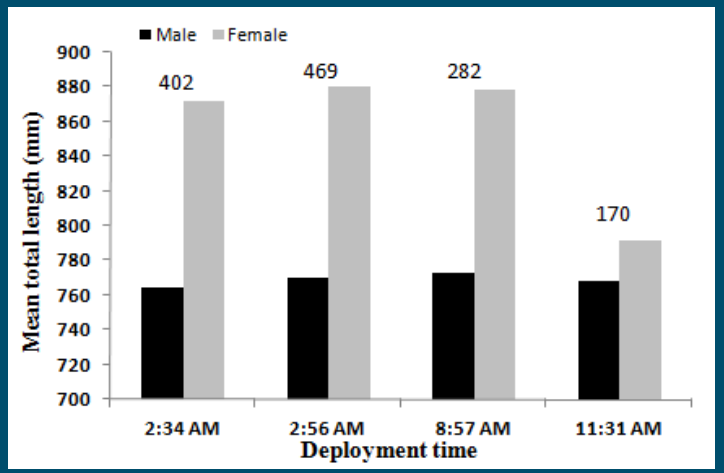
August 17, 2010 avg time 331 min

G = 87; P < 0.001



♂ χ^2 = 277; P < 0.001

♀ G = 197; P < 0.001



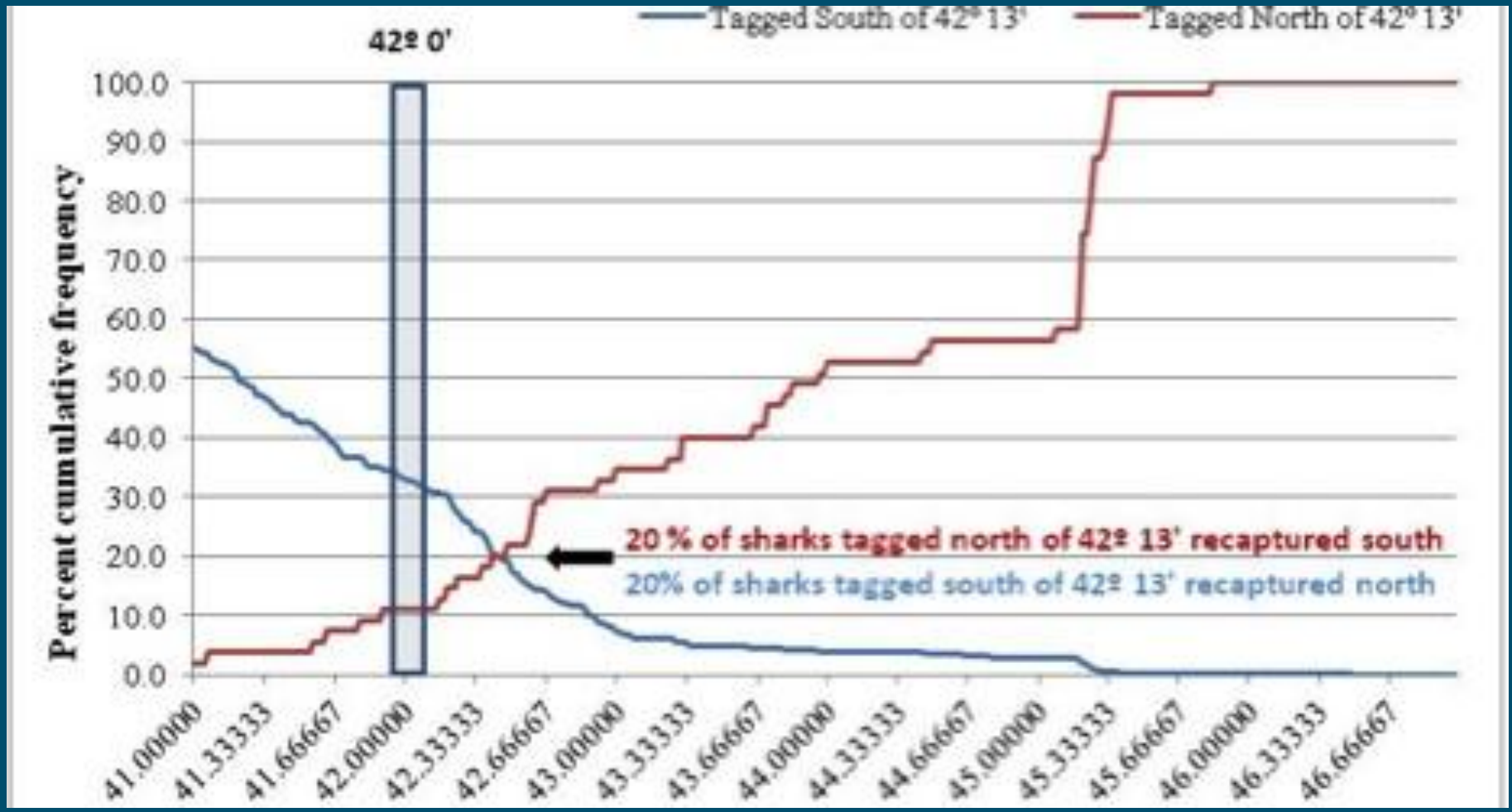
♀ F = 16.5; P < 0.001
Bonferroni pairwise

Gillnet not necessarily related to feeding behavior

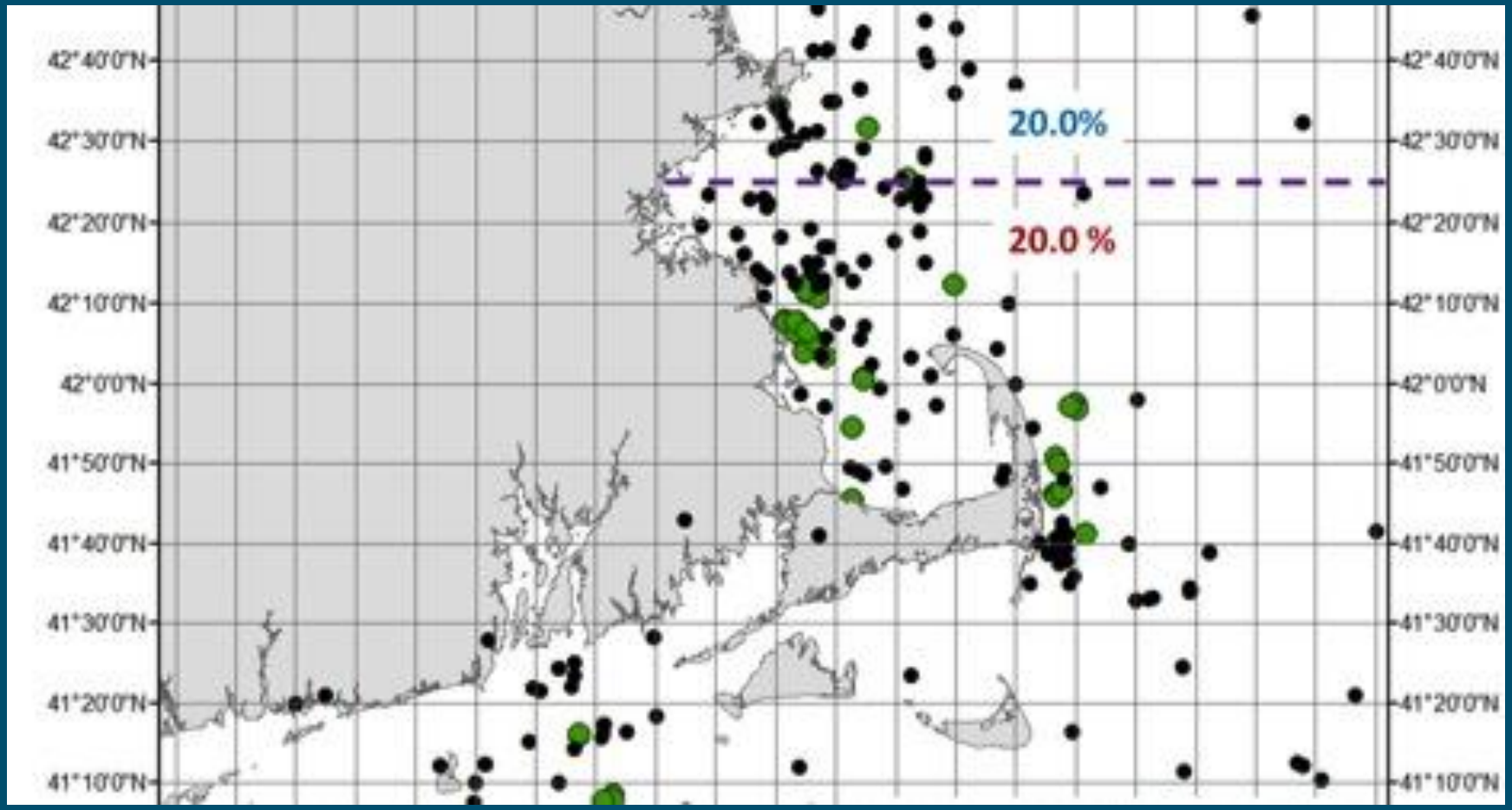
Discussion

- Presence of two main stocks (US and Canadian stocks) with NE as the natural intermixing ground and IR between 28.4%-38.4% but NO recaptures from Canada itself.
- Consistency in seasonal North-South migratory behavior (temp. regulated)
- Behavior and habitat-use in Cape Cod differ by location and sex
- R in the South is related to depth: feeding (♂) or mating behavior (♀)
- ♀ in the North inhabit inshore waters but can move to deeper waters
- Higher numbers of dogfish caught with longline

External Tag Recovery

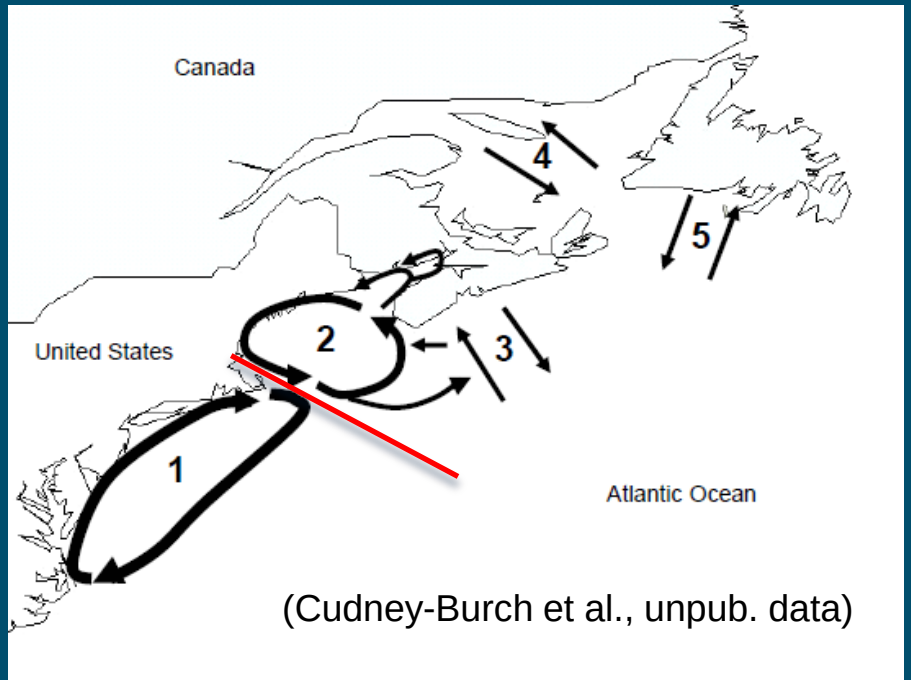


What is so Important about 42° 13’ ?



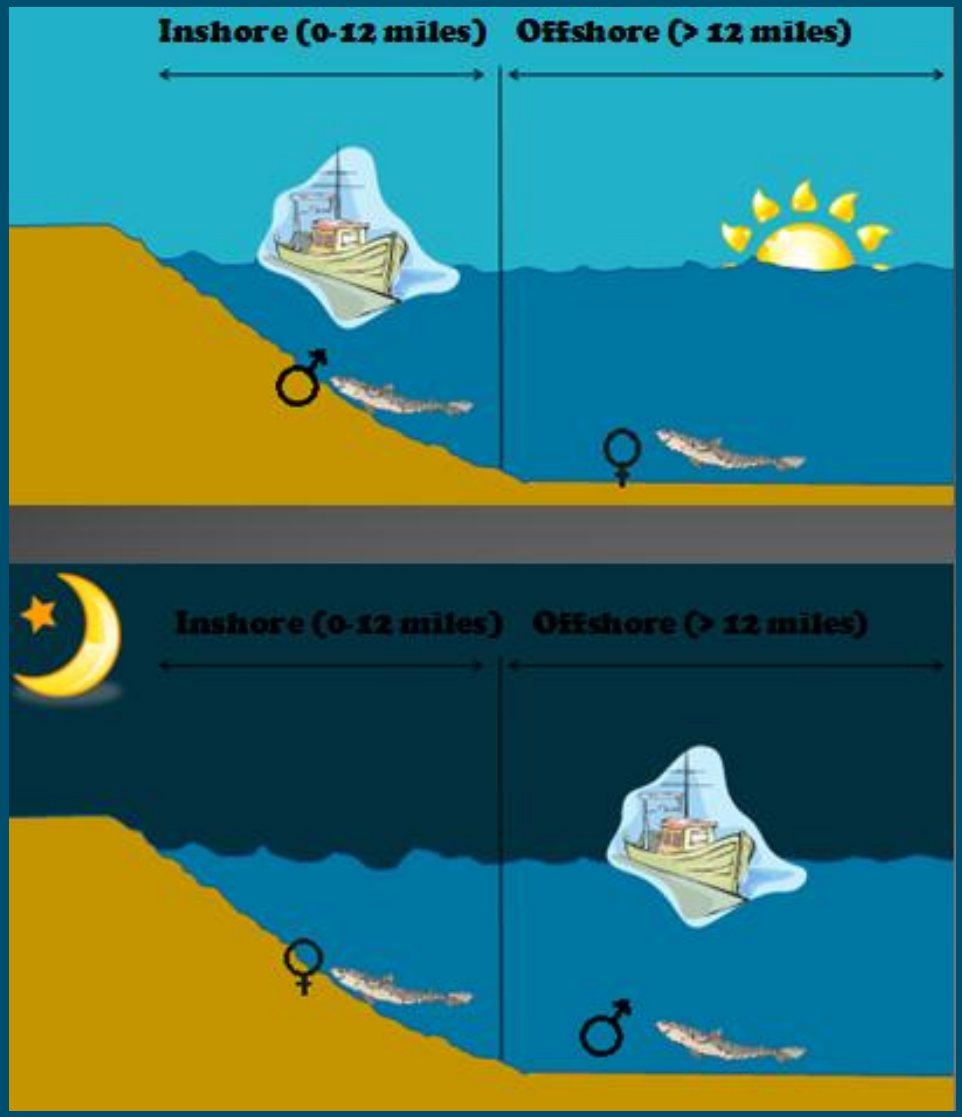
Management Recommendations

- Differentiate stock assessment for US and Canadian dogfish
- Intergration of tag-returned information for enhancing TAC allocation by state (consider allocation by temp. forecasting)
- Extend existing acoustic lines further offshore (i.e. continental shelf) and/or develop new acoustic arrays for uncovered areas

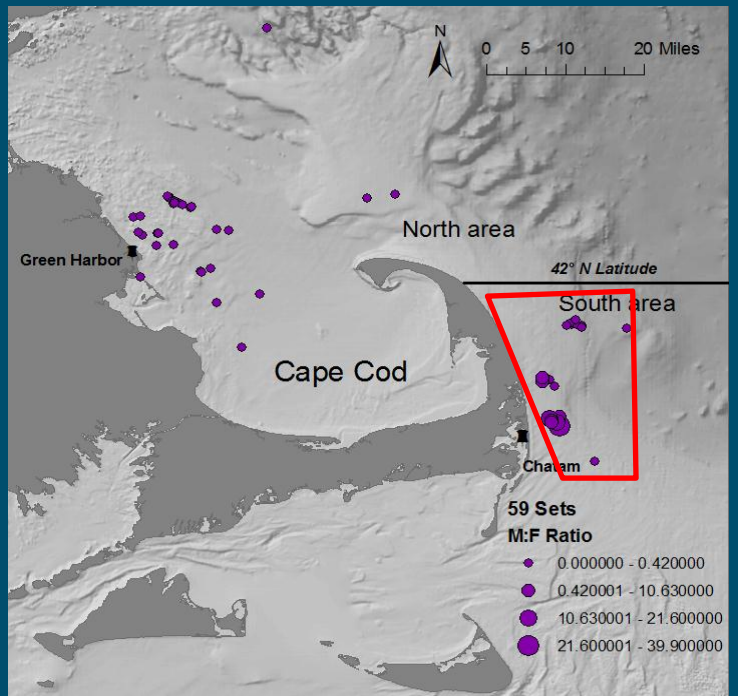


(Cudney-Burch et al., unpub. data)

Management Recommendations



- Male-only directed fishery at 10 miles NE of Chatham, MA, based on time of the day
- Promote longline employment instead of gillnet in Cape Cod



Future Developments and Directions

- Fine scale monitoring of dogfish behavior patterns in the Cape Cod area (manual acoustic tracking) and specific diet by sex
- M:F ratio changes between gillnet and longline surveys conducted simultaneously at same location
- Results will be relevant for the NMFS, ASMFC, the NEFMC, the MAFMC, and Fisheries and Oceans Canada in revising current management plans for spiny dogfish

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