Life History, Trophic ecology and Prey Handling by Cownose Rays from Chesapeake Bay

Cownose Ray (*Rhinoptera bonasus*)

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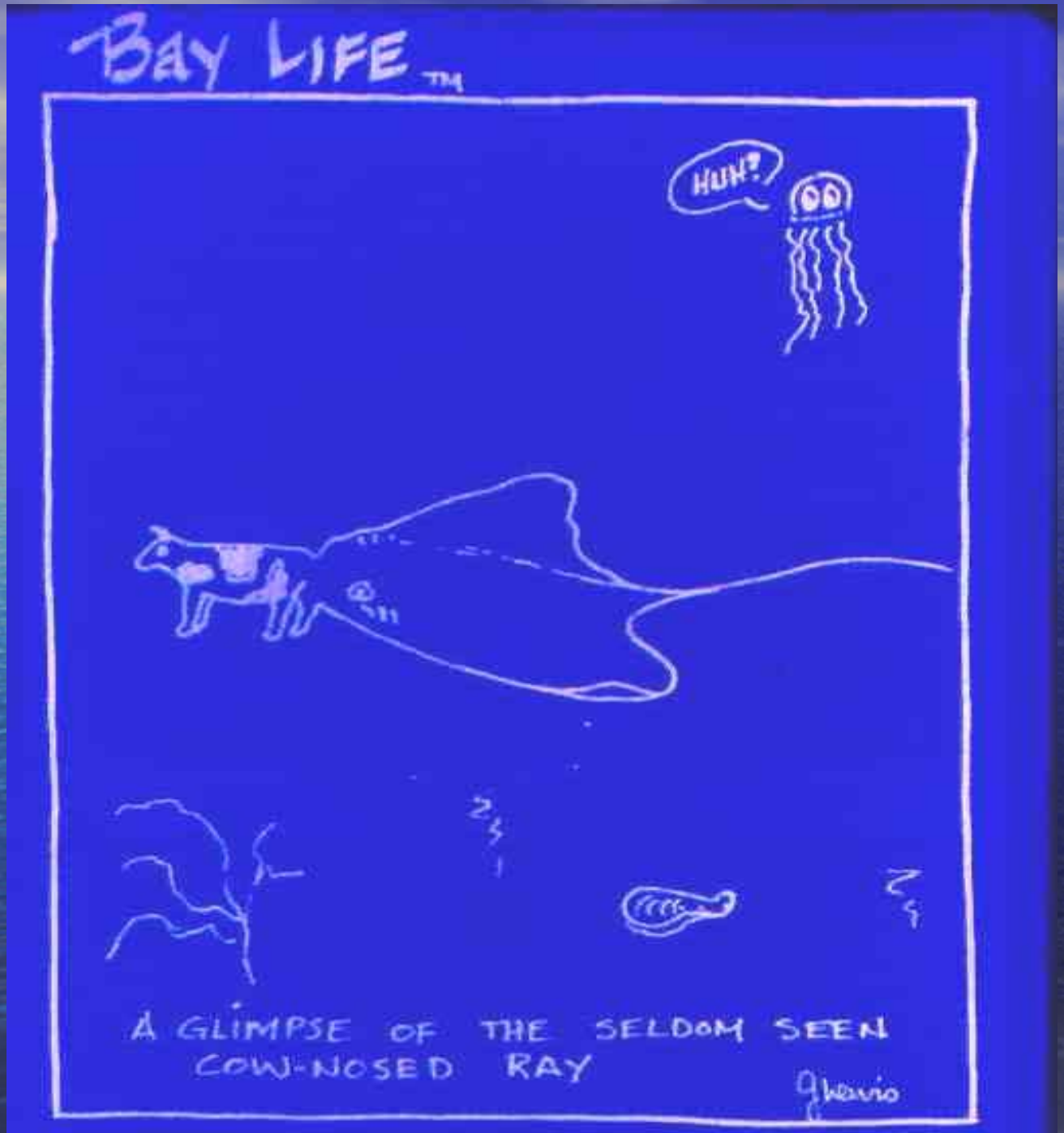
Bay Life™



Cownose Ray (Rhinoptera bonasus)

Elasmobranch: cartilage skeleton

Like a “flattened shark”

The genus name is derived from the Greek "rhinos" = nose and ”pteron“= wing.

The species name bonasus is from the Gree "bonasos" meaning bison

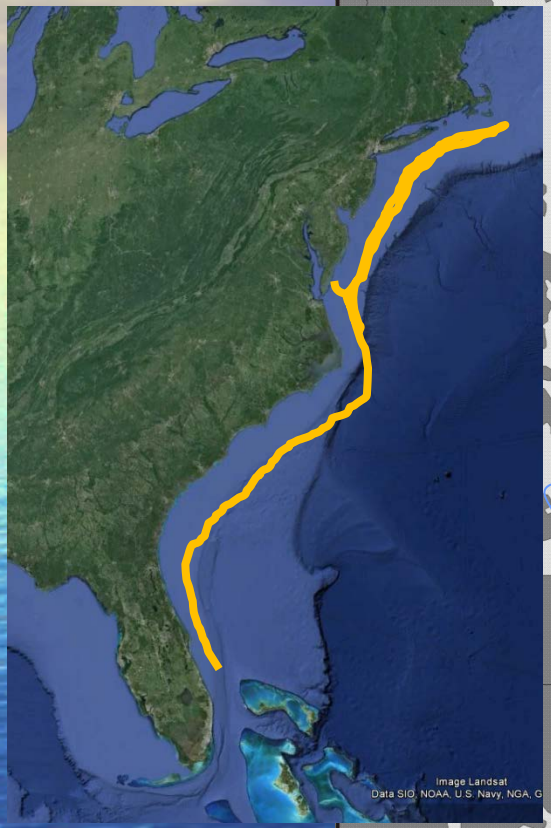
As with other Elasmobranches:

Cownose rays

-late maturity (males 6-7yrs, Females 7-8yrs)

-long gestation (11+ months)

-low fecundity (1 “pup” /female/year) ?



Chesapeake Bay

Atlantic

Ocean

Cape Henry

Migrating schools of Cownose rays enter the Chesapeake Bay in May and exit the Bay by mid October

Cape Hatteras

N

0 1000

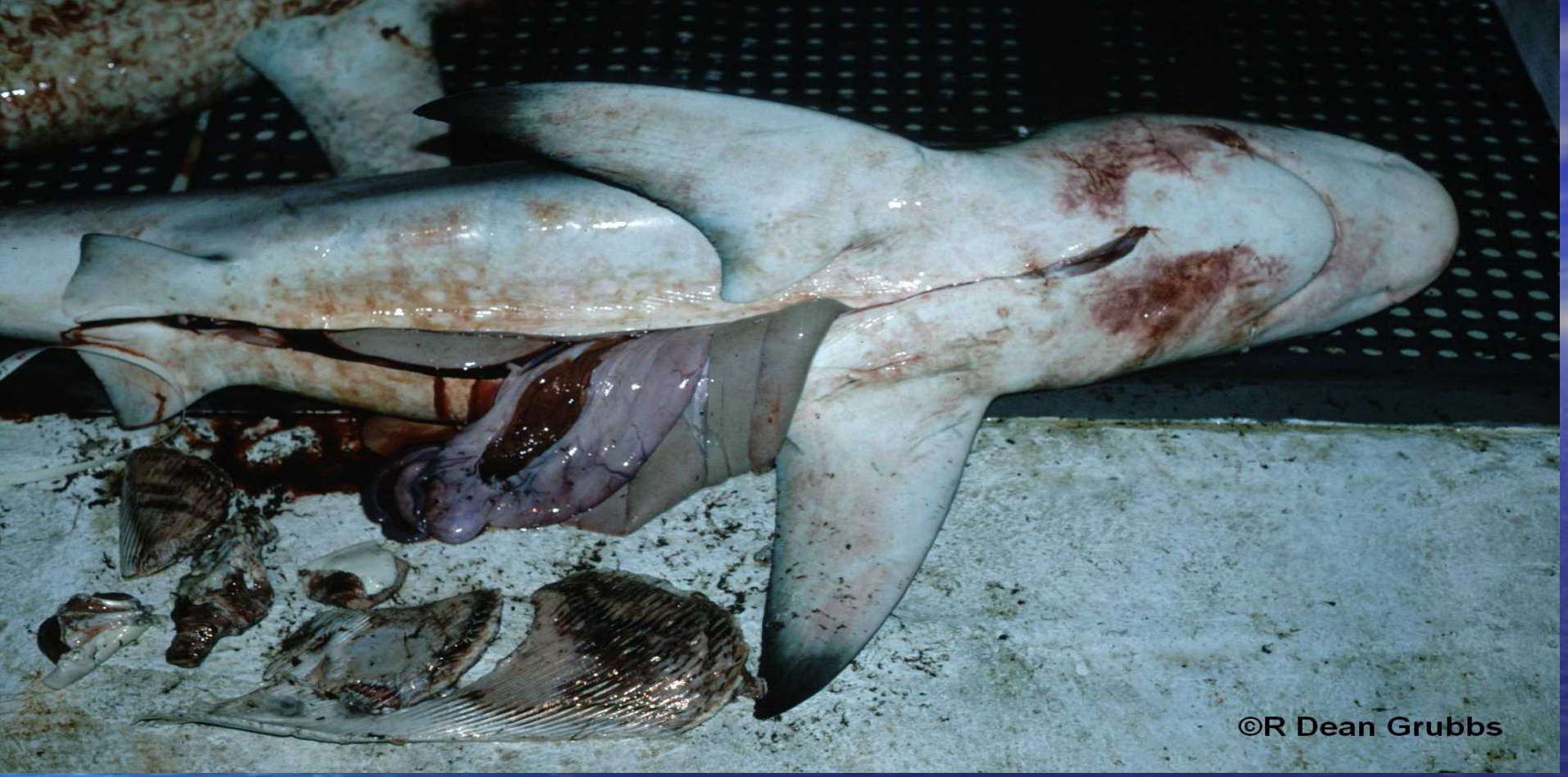
Kilometers

Mostly observed aggregated when foraging in shallow water or when mating

R.A. BLAYLOCK. 1989. A MASSIVE SCHOOL OF COWNOSE RAYS, *RHINOPTERA BONASUS* (RHINOPTERIDAE), IN LOWER CHESAPEAKE BAY, VIRGINIA. COPEIA 1989(3):744-748.

COVERED AN AREA OF ~1,129 ACRES.

Estimated over 5M rays in this one school



Cownose Ray Predators:

-Near-Shore shark species; Dusky, Sandbar

-Cobia

-Humans (In US, fishing gear interaction)

Cownose rays interact with traditional gear fished in the bay.

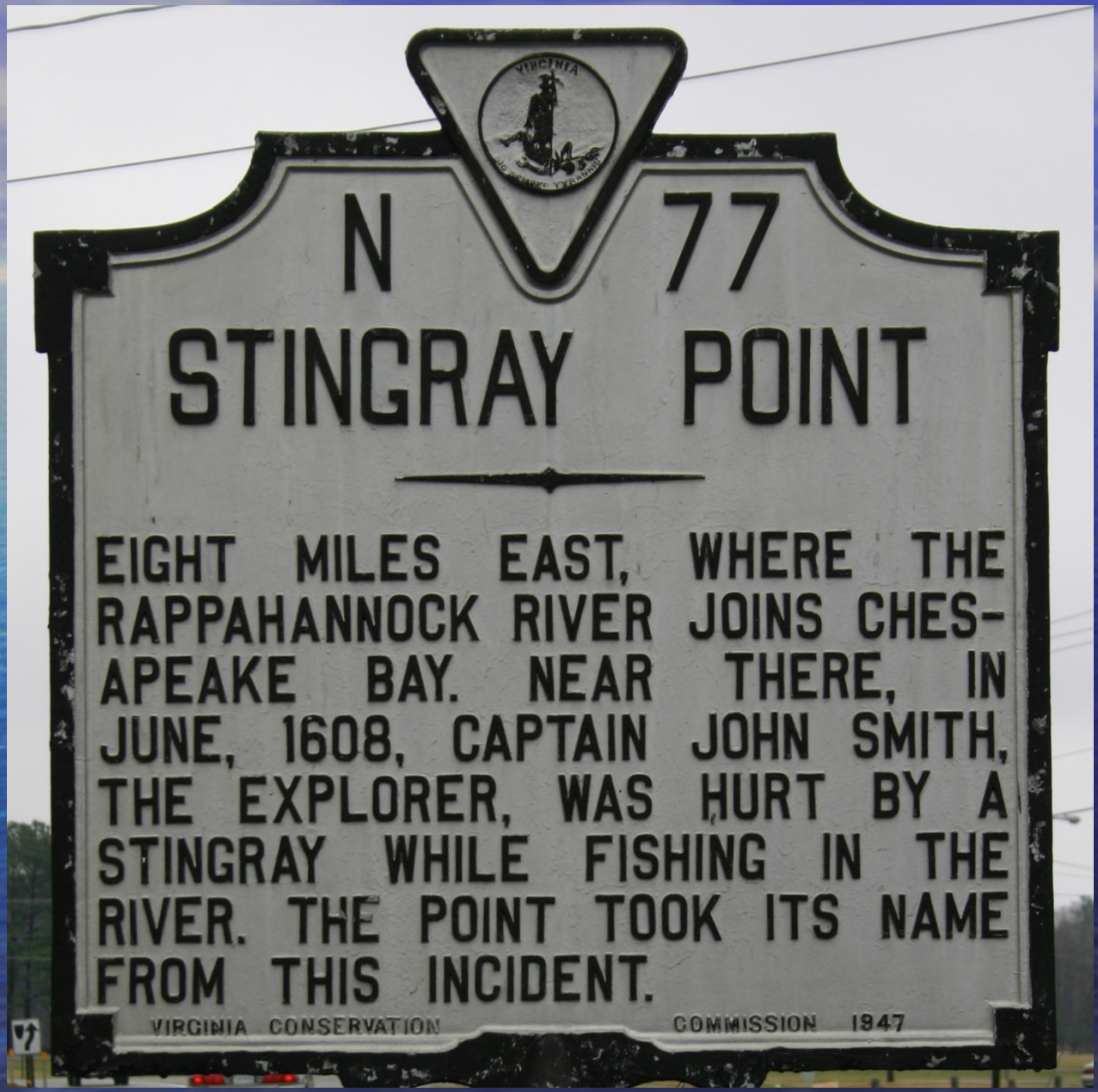
Problems Associated with cownose rays:

-migrate to Mid-Atlantic seaboard by the millions to feed, “pup”, feed, reproduce, and feed some more

-feed on the valuable shellfish in the Chesapeake Bay, scallops in NC, clams in NJ, MD, VA……impact to shellfish restoration efforts.

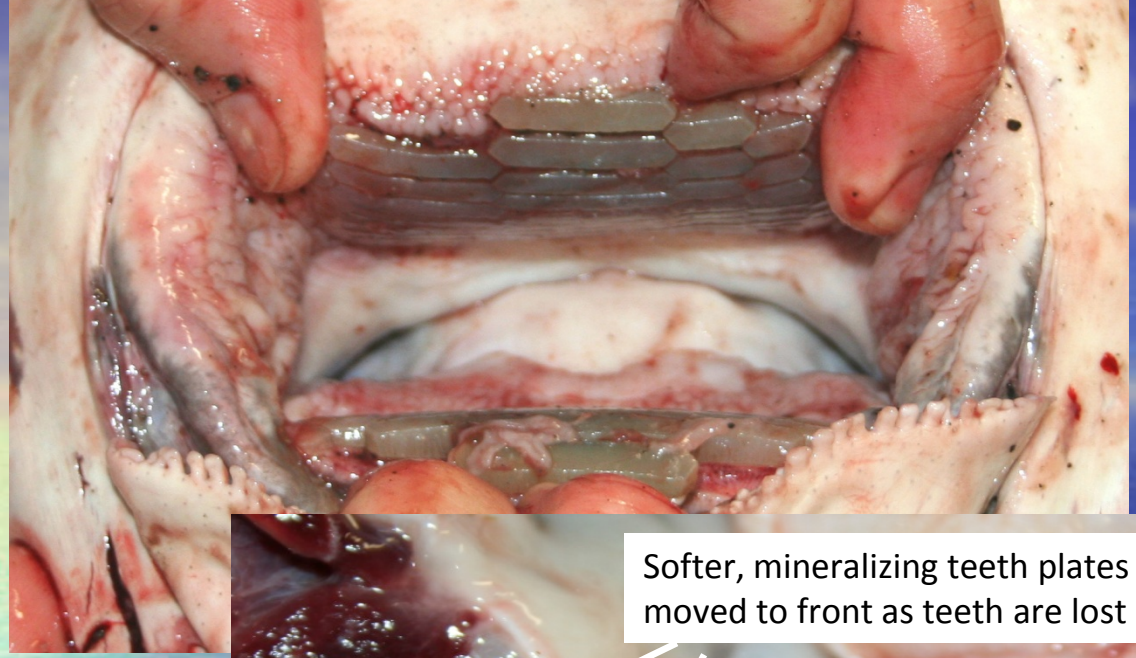
-destruction of submerged aquatic vegetation (SAV) during their foraging for food

-Interfere with traditional fisheries…..loss of catch, gear damage, injury


VIRGINIA
N 77
STINGRAY POINT
EIGHT MILES EAST, WHERE THE RAPPAHANNOCK RIVER JOINS CHESAPEAKE BAY. NEAR THERE, IN JUNE, 1608, CAPTAIN JOHN SMITH, THE EXPLORER, WAS HURT BY A STINGRAY WHILE FISHING IN THE RIVER. THE POINT TOOK ITS NAME FROM THIS INCIDENT.
VIRGINIA CONSERVATION COMMISSION 1947

Severe internal burning sensation radiating from point of sting

Serrated barbs designed to go in but are not easily removed



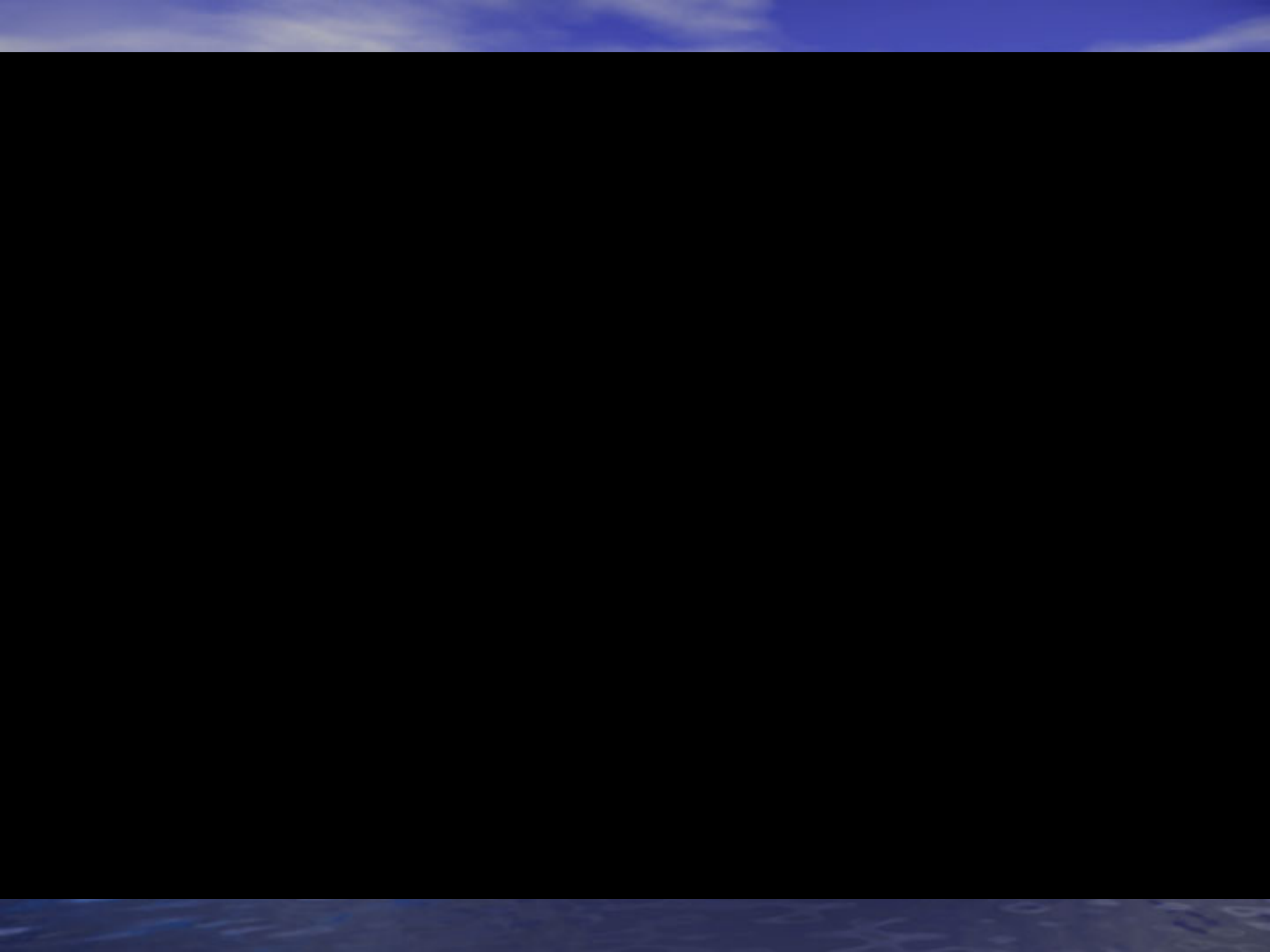
Durophagous predators

Mouth/Jaw/teeth morphology engineered for crushing shellfish

Softer, mineralizing teeth plates progressively moved to front as teeth are lost

Hardened (mineralized) teeth plates where crushing occurs

Re-enforcing struts in jaw cartilage at site of greatest crushing force.



Tropical and Subtropical Fisheries Technological Conference of the Americas

(Raleigh, NC 1991)

Product Development: Cownose Ray (*Rhinoptera bonasus*)

Robert Fisher, VIMS-VA Sea Grant
Patricia Lacey, VPI-VSAES

For this marketing attempt……Changed name from Cownose Ray to “Chesapeake Ray” (more market-friendly name)

No widespread interest in cownose rays….until shellfish restoration efforts…….

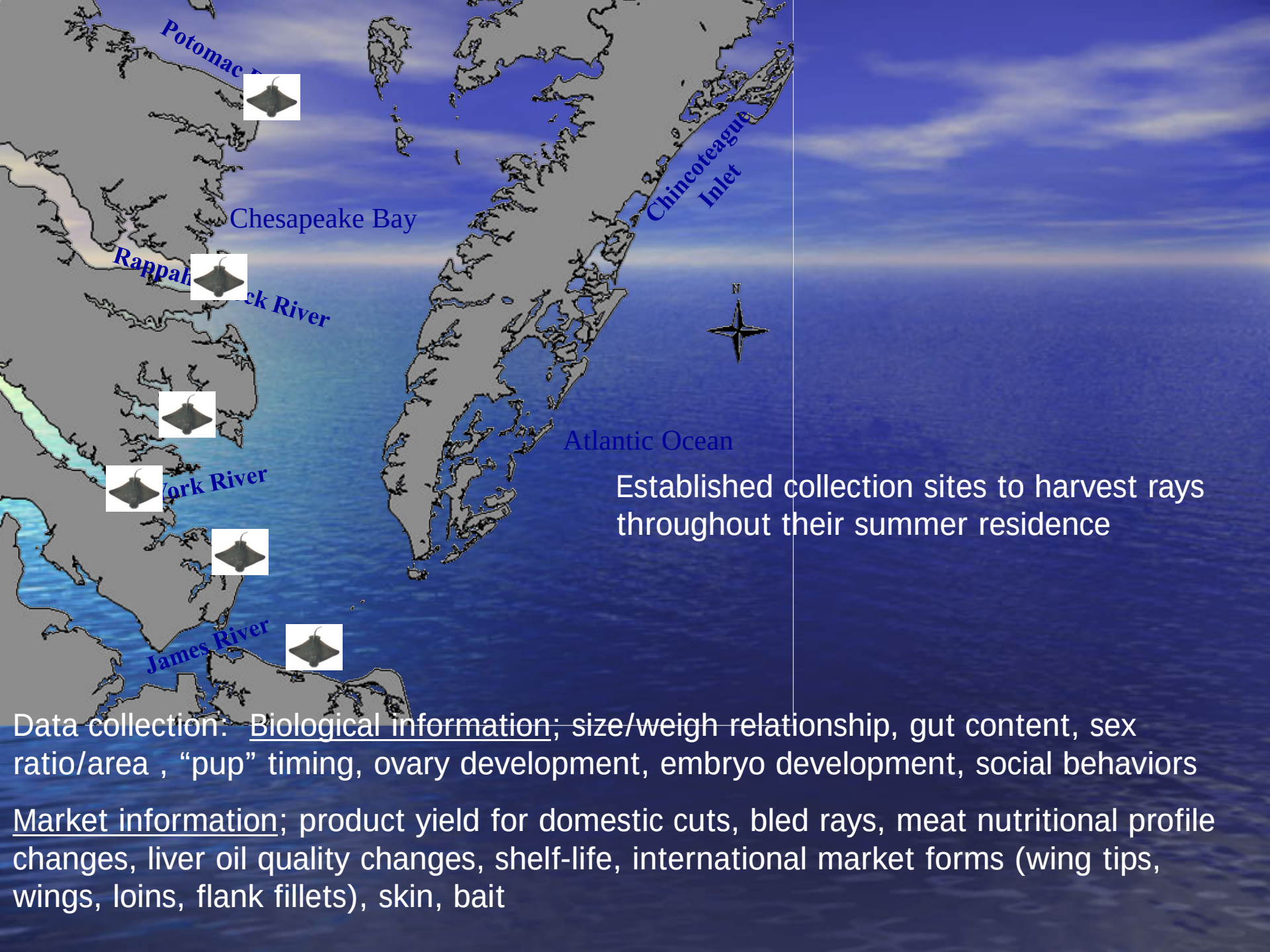
Oyster and Bay Scallop Restoration

- Oyster restoration efforts in Chesapeake Bay
  -Lessons learned???? Corp of Engineers, CBF....projects
    *2004...planted 1.2 million oysters on reef, Within 2 wks >95% eaten by rays
    *2006...775,500 oysters planted, within 5 days ~94% eaten by rays
  Scallop restoration efforts in North Carolina

- Political involvement
- Public awareness (perception) through media coverage
  Rays
    -menace.....get rid of them
    -morsel.....lets eat them
    -shark species.....we need to protect them

Cownose Ray Workshop 2006 Yorktown, VA
Develop commercial and recreational cownose ray fishery

The expected benefit of this work is to explore the potential for the development of a cownose ray fishery which could aid in shellfish restoration efforts in Virginia while also providing another fishery resource for Virginia fishermen to utilize. The proposed work will provide for the development of a new fishery in a **responsible manner**, given the species specific sensitivity to fishing pressure. A sustainable cownose ray fishery has the potential to relieve some ray predation on high valued shellfish, and reduce destruction on sub merged aquatic vegetation.

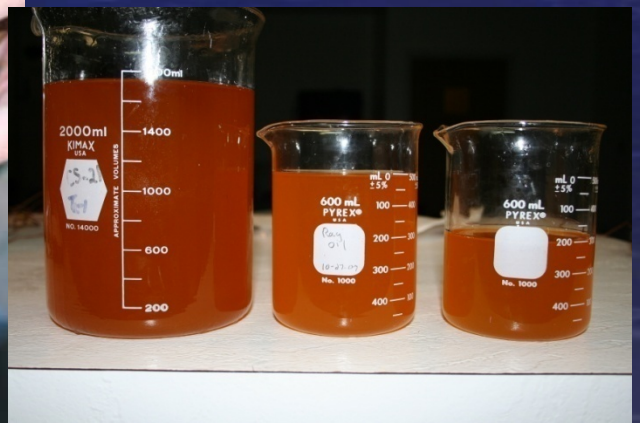


Established collection sites to harvest rays throughout their summer residence

Data collection: Biological information; size/weigh relationship, gut content, sex ratio/area , “pup” timing, ovary development, embryo development, social behaviors

Market information; product yield for domestic cuts, bled rays, meat nutritional profile changes, liver oil quality changes, shelf-life, international market forms (wing tips, wings, loins, flank fillets), skin, bait

Life History, Trophic ecology and Prey Handling by Cownose Rays from Chesapeake Bay



Ray processing for human consumption

Skin

Liver oil

Bait

Cownsose Ray Fishery:

Ray Specie Constraints

- Elasmobranch…….K-species
  - Age at sexual maturity..male 6-7, female7-8 ??
  - Long gestation…11+ month
  - Low fecundity…one “pup” per female per year ??
- Few predators….near-shore sharks, Humans
- Near-shore shark experience…..”caution”
- Brazilian effect…High fishing pressure in seine and pair trawl fisheries in Brazil have resulted in very large declines in the cownose ray (*Rhinoptera brasiliensis*) which is currently listed by the World Conservation Union’s Redlist of Threatened Species as “Endangered”

Initiating a ray fishery

The Good.....

The Bad.....

The Ugly.....

The Good.....

- Reduce pressure on natural and cultured shellfish (?)
- Enhance restoration efforts (?)
- Supplemental fishery for waterman
- New culinary opportunity
- **Focus on the species....develop pop est., environmental req., social behavior**

The Bad.....

- K-species....potential for over-exploitation

  -no ray population estimates...fishery without science??? (sustainability)
- Public perception...segment of pop against
- Marketing “red meat” seafood item

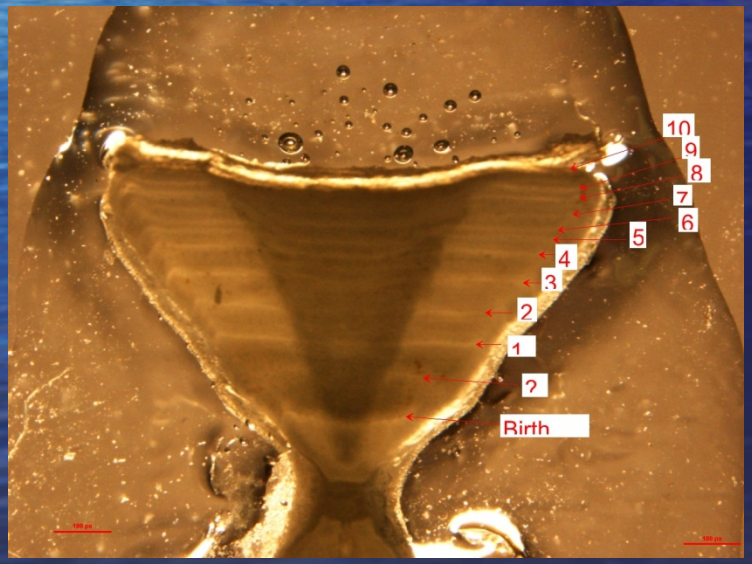
  -success lies in an extensive education component

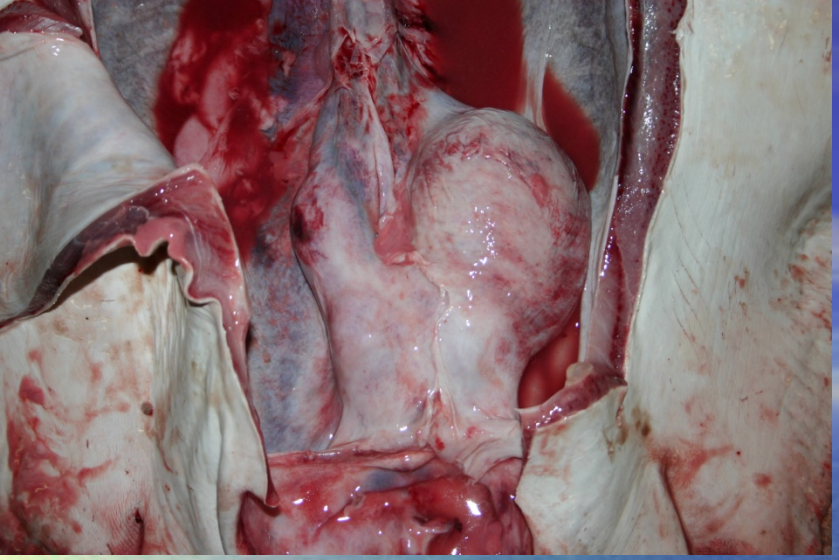
  -rays are not skates
- Ray processing...Labor intense (irregular shape)
  - Bait market; low value, unstable
  - Human consumption market; need to create value, high waste volume

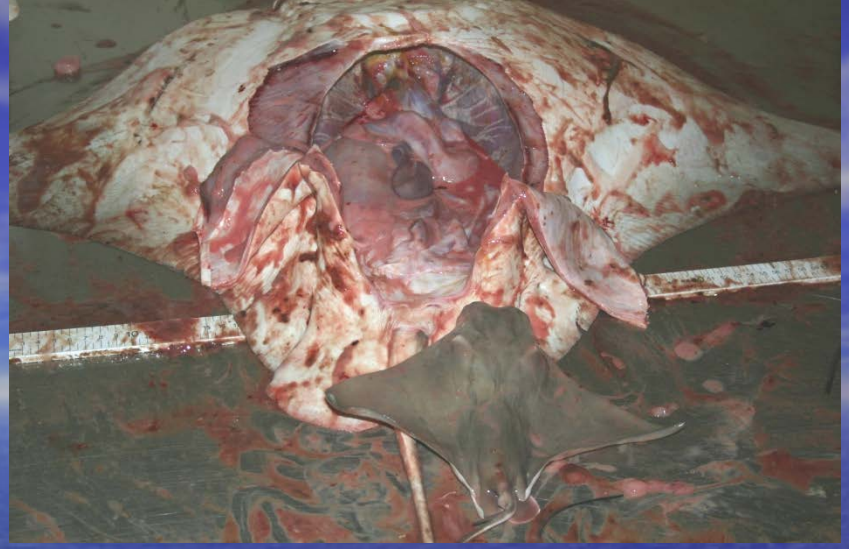
The Ugly.....

Not Really!!!!

Processed ray for biological assessment

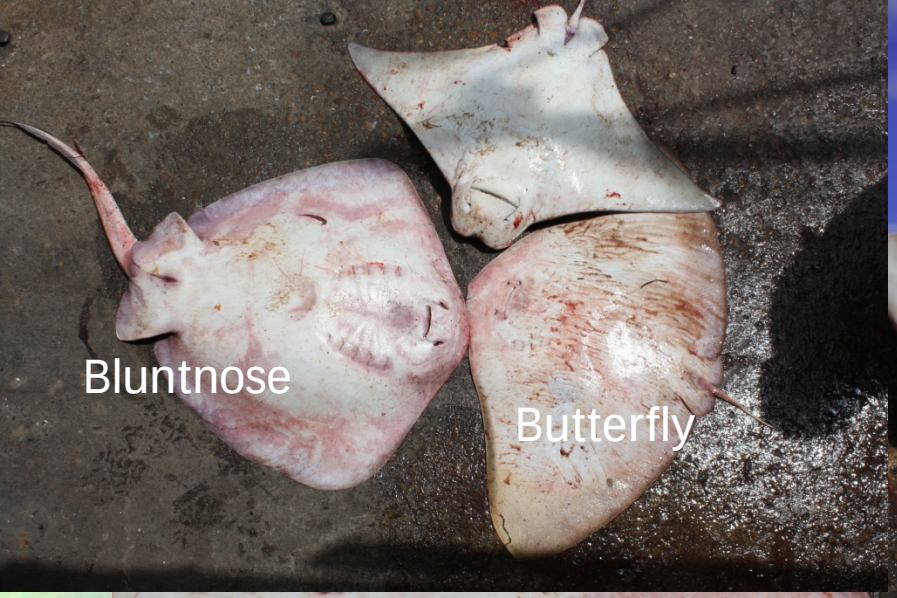






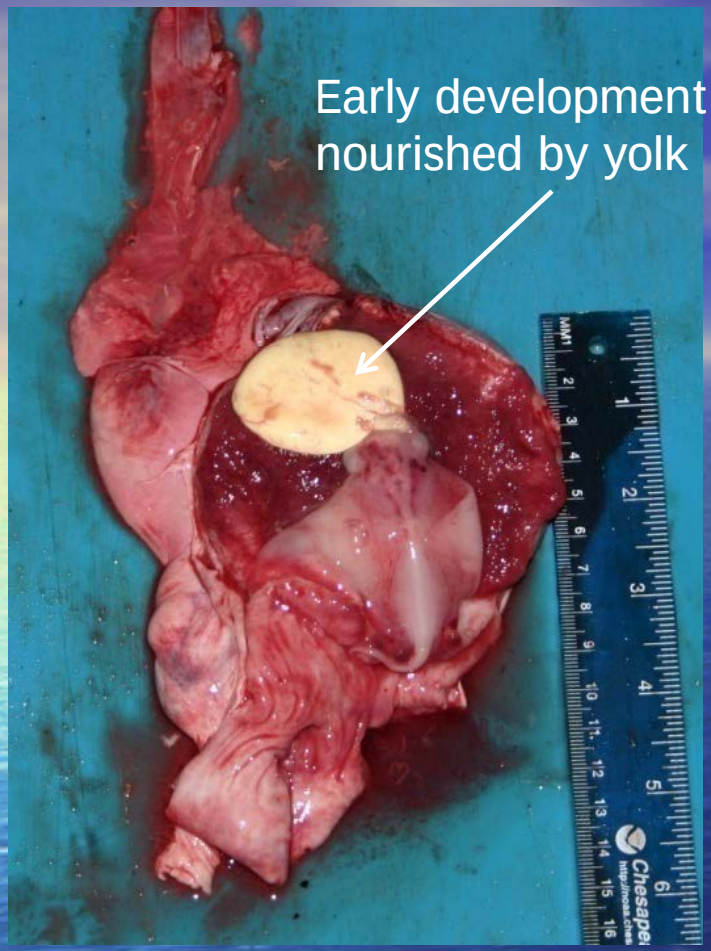
Cownose ray: paired uterus, but only left uterus functional; one pup per female (generally)

Bluntnose rays (Dasyatis say) with multiple pups, small mouth, weak jaw structure



Cownose ray

These other species, which give birth to multiple pups, have weak dentition relative to cownose rays and are not able to feed on commercial shellfish of any significant size

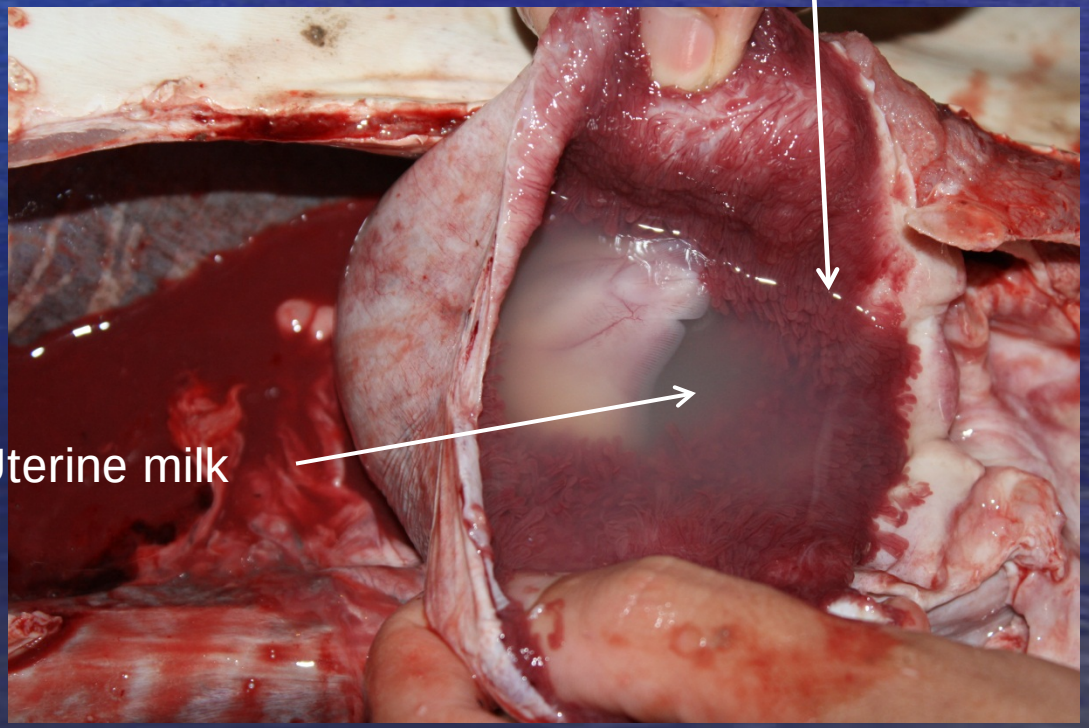


Cownose ray reproductive strategy:

Ovoviviparity = aplacental viviparity

Nourishment from yolk first, then from uterine milk

Trophenemata: finger-like projections produce histotroph



Histotroph = Uterine milk

Cownose ray in Chesapeake Bay
(May) pre-term 28-32cm (11-12.5”)
(June) term birth, 33-37cm (12-15.5”)

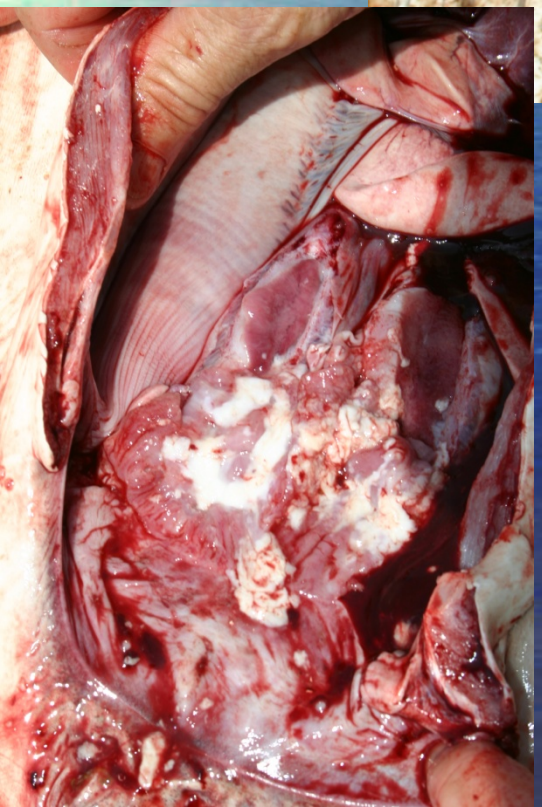
September 7: yolk nearly depleted

Cownose ray embryo
development during summer

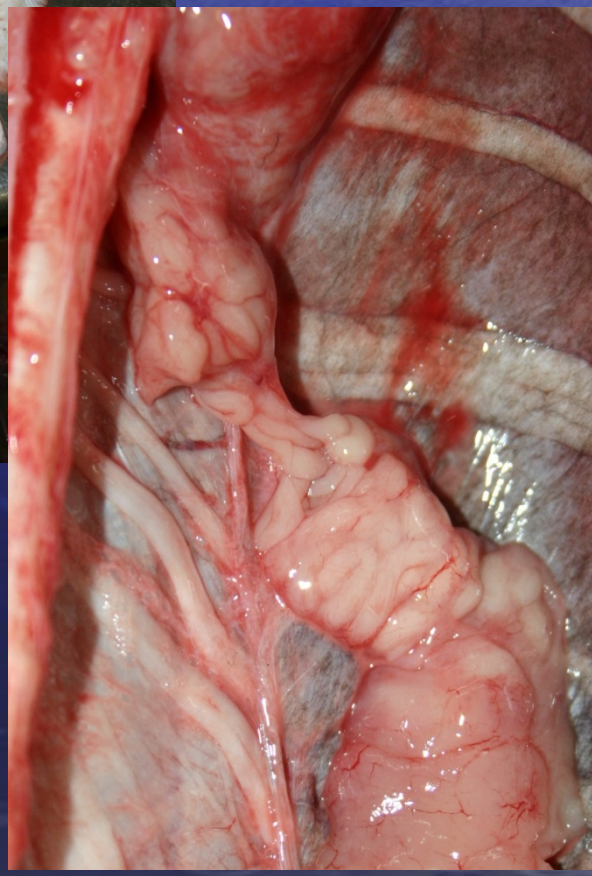
Rays leaving the Bay in October
embryo ~ 20-22cm (~8”)

June 20, 2008

Female rays are at term, pupping, and quickly mated with



From 26 females rays collected, half were at term and ready to pup, the other half had already pupped and had mated....11++++ month gestation



Male maturity: besides calcification, articulation, and length of claspers, coiling of vas deferens and expression of seminal fluid from sperm sacs at urogenital papilla were used to determine maturity

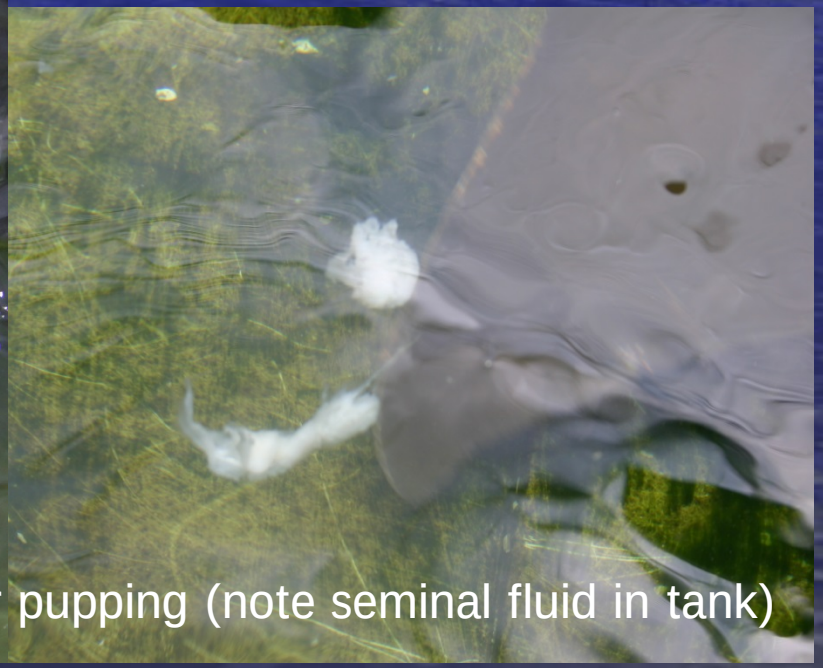
Figure 15. Older mating mark in state of tissue repair.

Mating marks on trailing edge of females pectoral fin. Males bite down on females fin to hold on during copulation

First reported case of multiple embryos in cownose rays: live birth of twins

Adult Female			Neonates			
Tag #	Weight (kg)	Disc Width (cm)	Tag #	Sex	Weight (g)	Disc Width (cm)
93	13.5	98	001	F	628	33.5
95	17.0	98.50	002	F	805	26.2
96	19.6	98	003	M	460	30.5
			004	F	807	35.7
			005	M	1560	43.7

Adult female and newborn cownose rays which resulted from multiple births. 8 July 2008



Mating occurred in holding tank within 2 days after pupping (note seminal fluid in tank)

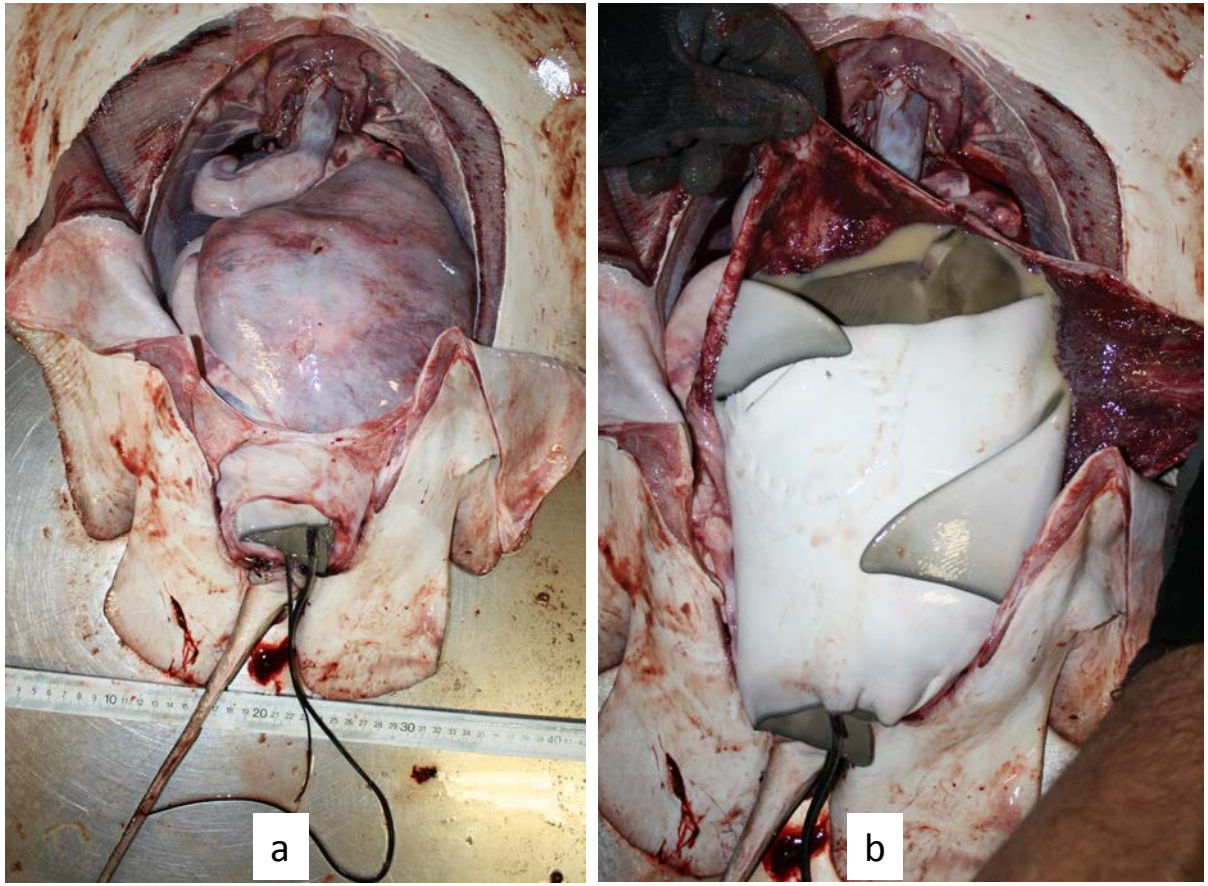


Figure 1. Twin embryo cownose rays: a) in uterus with tails extending out of female; b) twins positioned in uterus with heads facing same direction (cranially). Note histotroph in uterus near embryo heads.

Subsequent reporting of multiple embryos in cownose rays (Fisher, 2010, 2013)

Multiple Embryos

Adult female cownose rays and corresponding multiple embryos (twins) sampled from May and June 2009 as gestation of embryos reach term.

Date	Stage	Adult Female		Twin Embryos		
		Weight (kg)	DW (cm)	Sex	Weight (g)	DW (cm)
May 26, 2009	pre-term	19.55	103	F	249.48	24.8
				M	340.19	27.5
May 28, 2009	pre-term	17.01	98	F	476.27	30.4
				M	272.16	25.5
May 29, 2009	pre-term	19.64	98	F	453.59	31.0
				M	294.84	26.0
June 23, 2009	term	18.55	98	F	1,043.26	40.0
				M	839.20	39.0
July 2, 2009	term	16.47	96.5	M	771.11	36.0
				M	907.18	38.0
July 2, 2009	term	19.01	102	F	1,542.21	43.5
				M	1,451.50	43.5

one of 10 female rays randomly sub-sampled from 156 females

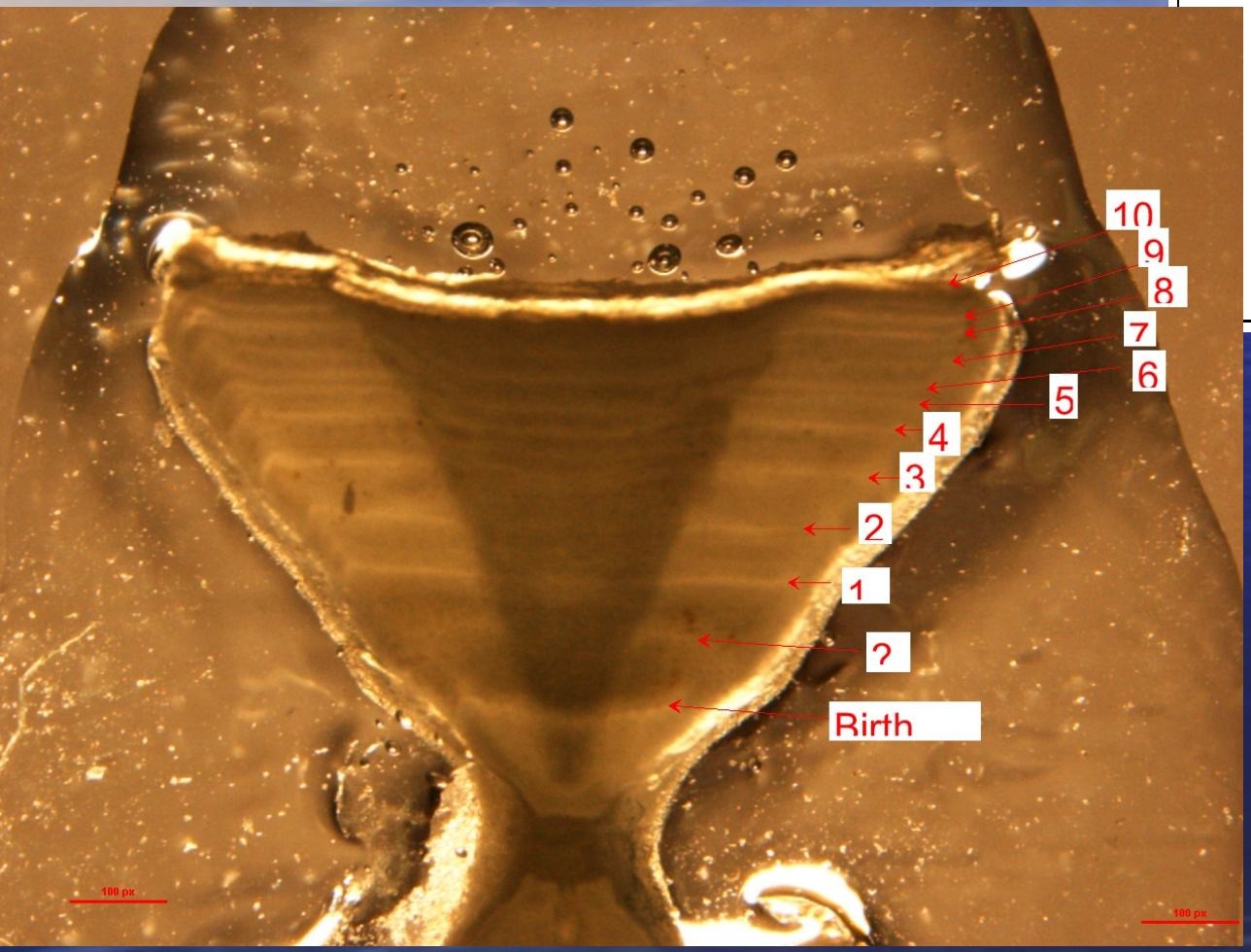
one set of twins in 60 adult females (1.6%)

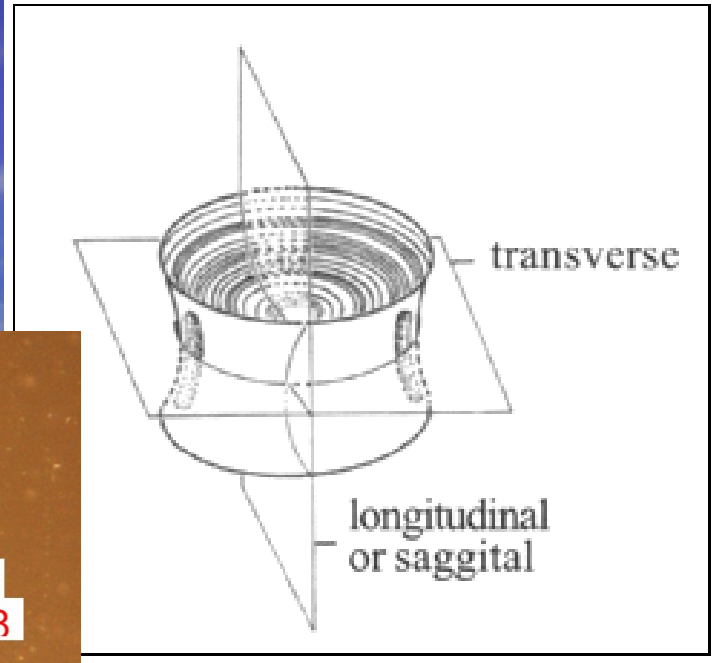
one set of twins in 77 adult females (1.3%)

one set of twins in 42 adult females (2.4%)

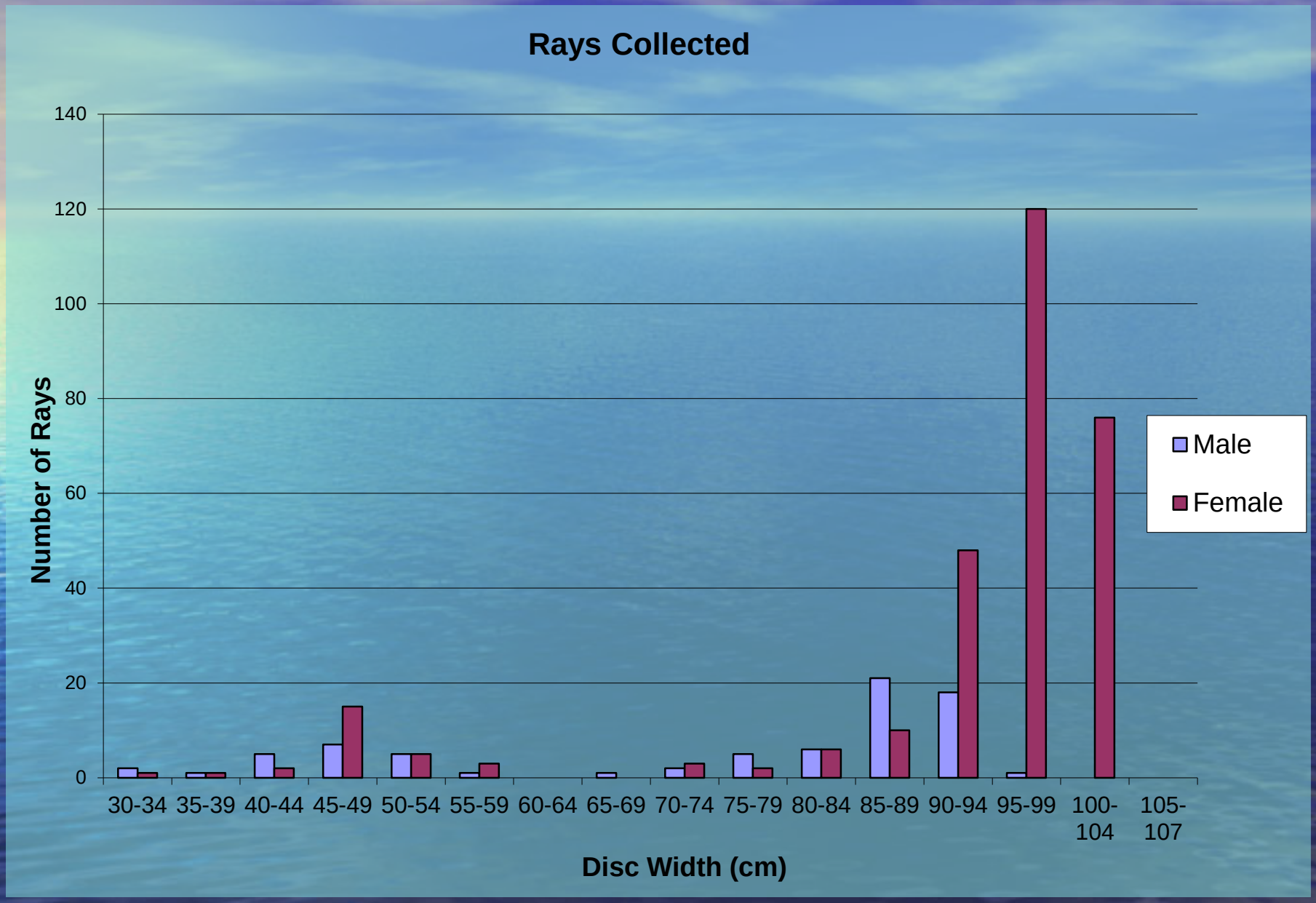
two sets of twins found in a long-line sample of 16 adult females (12.5%).

Age estimation:





vertebral centra annuli rings:
narrow and wide band pairs representing successive winters and summers of life



Rays used in age and growth study. Note lack of teenage rays available for sampling

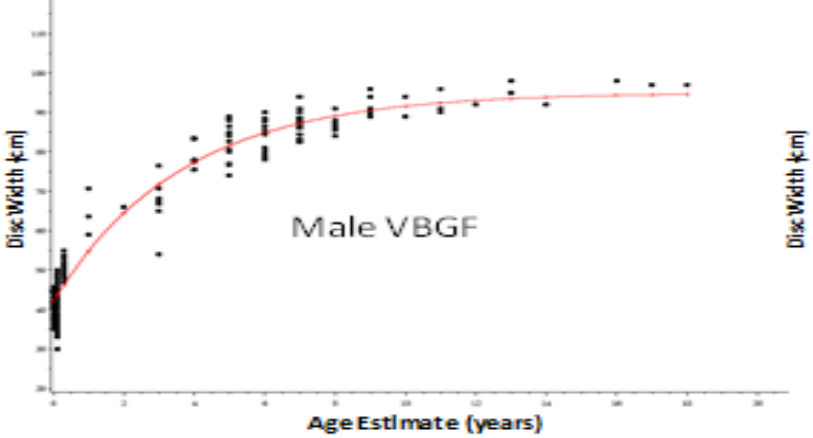
	Age (years)										
	0	0.12	0.3	1	2	3	4	5	6	7	8
Males											
Avg DW (cm)	41.9	41.7	50.9	64.5	66.0	67.0	79.5	82	83.6	86.3	87
SD	2.45	4.05	2.06	5.92	na	6.82	3.61	4.14	3.90	2.47	2.07
Predicted	42.1	43.9	46.3	54.8	64.5	71.7	77.3	81.6	84.8	87.2	89
N	51	58	20	3	1	7	5	16	14	14	9
Females											
Avg DW (cm)	42.4	42.3	50.5	62.8	-	70.7	75.4	79.1	83.3	85.8	92.4
SD	2.75	3.78	3.78	na	-	2.94	5.49	3.18	3.60	1.18	2.21
Predicted	42.2	43.6	46.5	53.2		69.9	76.1	81.2	85.5	89	91.8
N	63	51	9	1	0	3	5	8	7	13	10

Table 3a. Mean size-at-age for male and female cownose rays ages 0 to 8 from Chesapeake Bay. DW=disc width, SD=standard deviation

	Age (years)												
	9	10	11	12	13	14	15	16	17	18	19	20	21
Males													
Avg DW (cm)	91.7	92.8	92.3	92	96.5	92	-	98	97	97	-	-	-
SD	2.67	2.50	3.21	na	2.12	na	-	na	na	na	-	-	-
Predicted	90.5	91.5	92.4	93	93.5	93.8		94.3	94.5				
N	6	4	3	1	2	1	0	1	1	1	0	0	0
Females													
Avg DW (cm)	94.4	97.8	99.7	98.8	99.8	100.1	101.6	100.5	103	103	110.5	-	107
SD	3.36	3.29	2.96	2.86	2.84	2.99	2.99	2.49	na	3.31	na	-	na
Predicted	94.2	96.2	97.8	99.1	100.2	101.1	101.8	102.4	103	103.4	103.7		104.2
N	15	25	22	23	23	17	11	6	1	4	1	0	1

Table 3b. Mean size-at-age for male and female cownose rays ages 9 to 21 from Chesapeake Bay. DW=disc width, SD=standard deviation

Cownose ray Age Estimation table



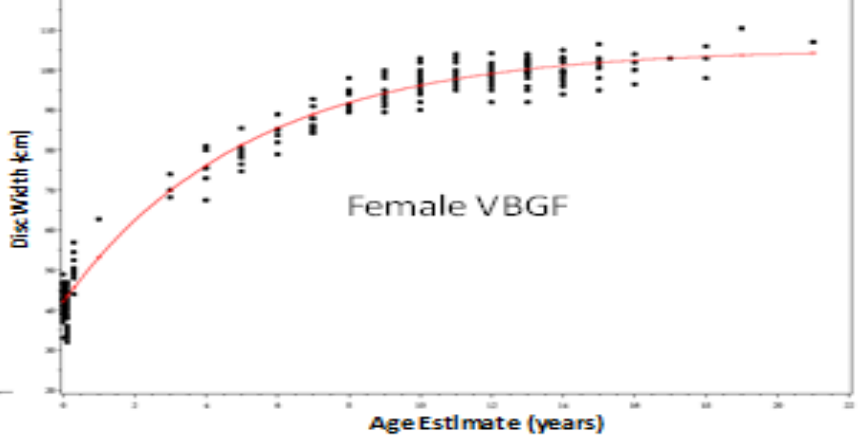


Figure 4. The von Bertalanffy growth model for cownose rays from the Chesapeake Bay using fractional age 0 observations.

three-parameter von Bertalanffy growth model had the lowest residual mean square errors (MSE) and the lowest Akaike's Information Criteria (AIC) values suggesting they provided the best fit to the observed size-at-age data

	Model	DW_∞	K (year^{-1})	t_0	L_o	AIC	MSE
Males	2ParmVB	96.446(±1.57)	0.2422(±0.019)	na	45	808.5	17.072
	VBGF	95.685(±1.34)	0.2622(±0.018)	na	42	785.6	15.122
	VBGFmod	**95.685(±1.33)**	**0.2622(±0.018)**	**-2.22**	**na**	**785.6**	**15.122**
	Gompertz	94.920(±1.33)	0.3125(±0.020)	na		811.7	18.482
	Logistic	93.061(±1.04)	0.4253(±0.023)	0.411	na	798.5	16.585
Females	2ParmVB	105.99(±0.82)	0.1814(±0.007)	na	45	1388.2	11.921
	VBGF	105.48(±0.71)	0.1911(±0.007)	na	42	1350.3	10.223
	VBGFmod	**105.48(±0.71)**	**0.1911(±0.007)**	**-2.69**	**na**	**1350.3**	**10.223**
	Gompertz	104.09(±0.62)	0.2387(±0.007)	na		1383.7	11.716
	Logistic	102.36(±0.46)	0.3207(±0.008)	1.052	na	1351.4	10.269

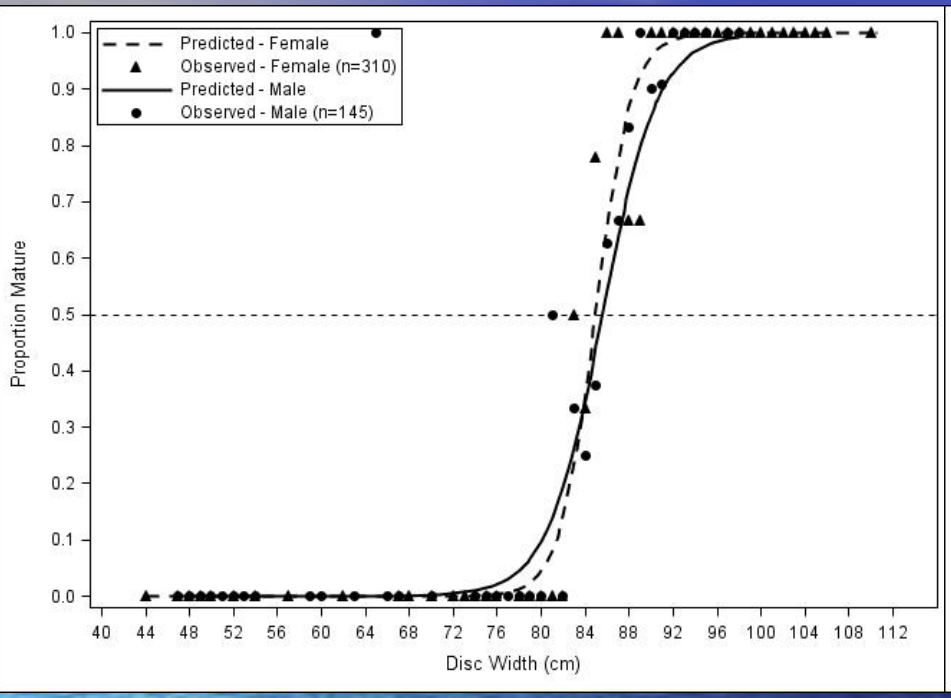
Table 2. Five growth models used to evaluate cownose rays (with fractional age estimates for young-of-year rays). Females N=319; Males N=218

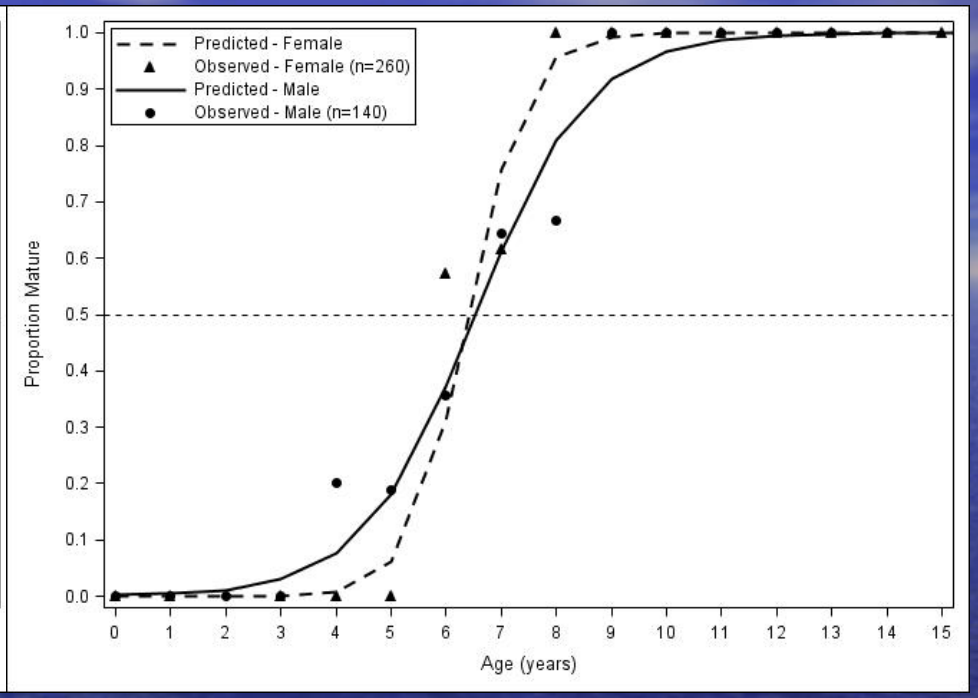
	Species	k (combined sexes)	k (female)	k (male)
This study (2012)	Rhinoptera bonasus		0.19	0.26
Smith & Merriner (1987)	Rhinoptera bonasus		0.119	0.126
Neer & Thompson (2005)	Rhinoptera bonasus	0.075, 0.133[1]		
Martin & Cailliet (1988)	Myliobatis californicus		0.0995	0.229
Jacobsen & Bennet (2010)	Neotrygon annotata		0.20	0.31
White et al. (2002)	Trygonoptera mucosa		0.241	0.493

Table 5. Comparison of model-derived growth coeffients (k) across multiple studies of cownose rays and other batoids indicates k can be highly variable across species and between sexes. [1]determined with Gompertz model, other k values for Rhinoptera bonasus reflect von Bertalanffy model.

Sexual maturity of male cownose rays was determined using the following criteria: (1) clasper calcification (uncalcified, partially calcified, and calcified); (2) vas deferens coiling (none, partial, complete; Neer & Caillliet 2001); (3) presence/absence of seminal fluid (sperm-containing secretion) from the vas deferens and/or expressed through the urogenital papilla; (4) ratio of clasper length to disc width (Smith & Merriner, 1986); and (5) histological sampling (selected individuals, n= 24) of testes and vas deferens for presence/absence of mature sperm in relationship to vas deferens coiling and presence of seminal fluid. Males with calcified claspers, enlarged testis, and fully coiled vas deferens were considered mature.

Female maturity was largely determined by diameter of the largest ova, or if pregnant. Diameters of the largest three ova within the ovary were measured (mm) to obtain mean maximum ovum diameter (MOD). Rays with ova greater than 10mm were considered to be mature (advanced vitellogenic oocytes) per Smith & Merriner (1986). Histological sampling of ovaries was performed to document stage of vitellogenesis and ova development. Females have one functional and one non-functional oviduct, with the left typically serving as the functional oviduct (Fisher 2010). The uteri are well-developed and expanded in females that have recently given birth and in a transitional development stage in those rays preparing to gestate for the first time. Left uterus width (UW, widest point), qualitative assessment of uterine wall thickness, and trophenemata development and color were also used as indications of sexual maturity. Maturing females undergo a rapid expansion in uterine width, thickening of the uterine wall, and elongation and darkening (pink to red) of trophenemata.





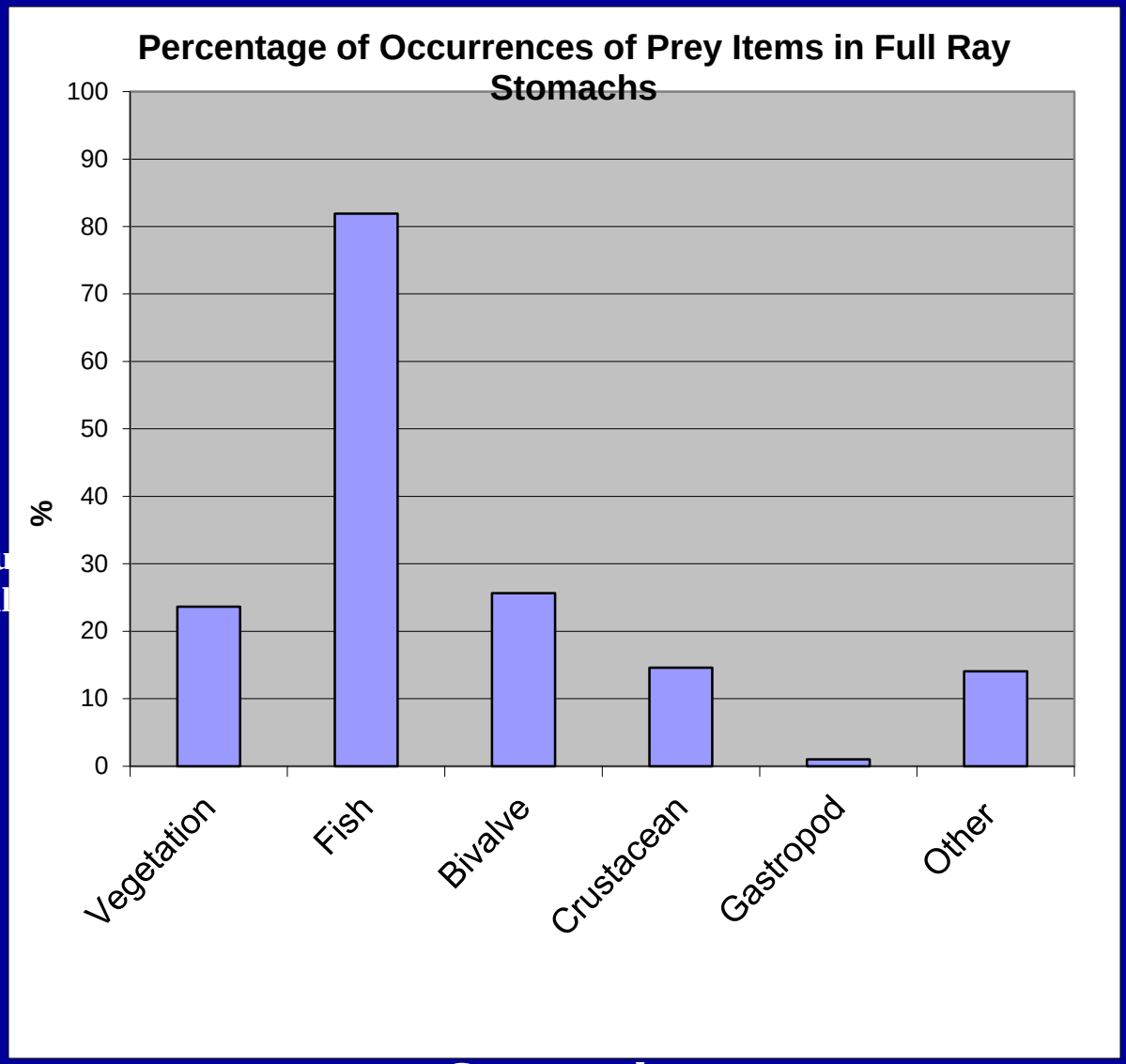
Cownose ray maturity Ogive
Males and Females 85-86cm DW
Males 6-7yrs, Females 7-8yrs

Maturity ogives were used to estimate the size at maturity (DW at which 50% of the individuals are mature) following Mollet et al. (2000). The ogives were fitted to a logistic model using binomial maturity determinations (0=immature, 1=mature)

Vegetation
Eudendriums sp.
Macro algae
Seagrass
Zostera sp.
Unid Vegetation

Fish
Anchoa mitchilli
Anchoa sp.
Brevoortia tyrannus
Cynoscion regalis
Leiostomus xanthuru
Micropogonias undul
Peprilus sp.
Unid Fish
Unid flatfish

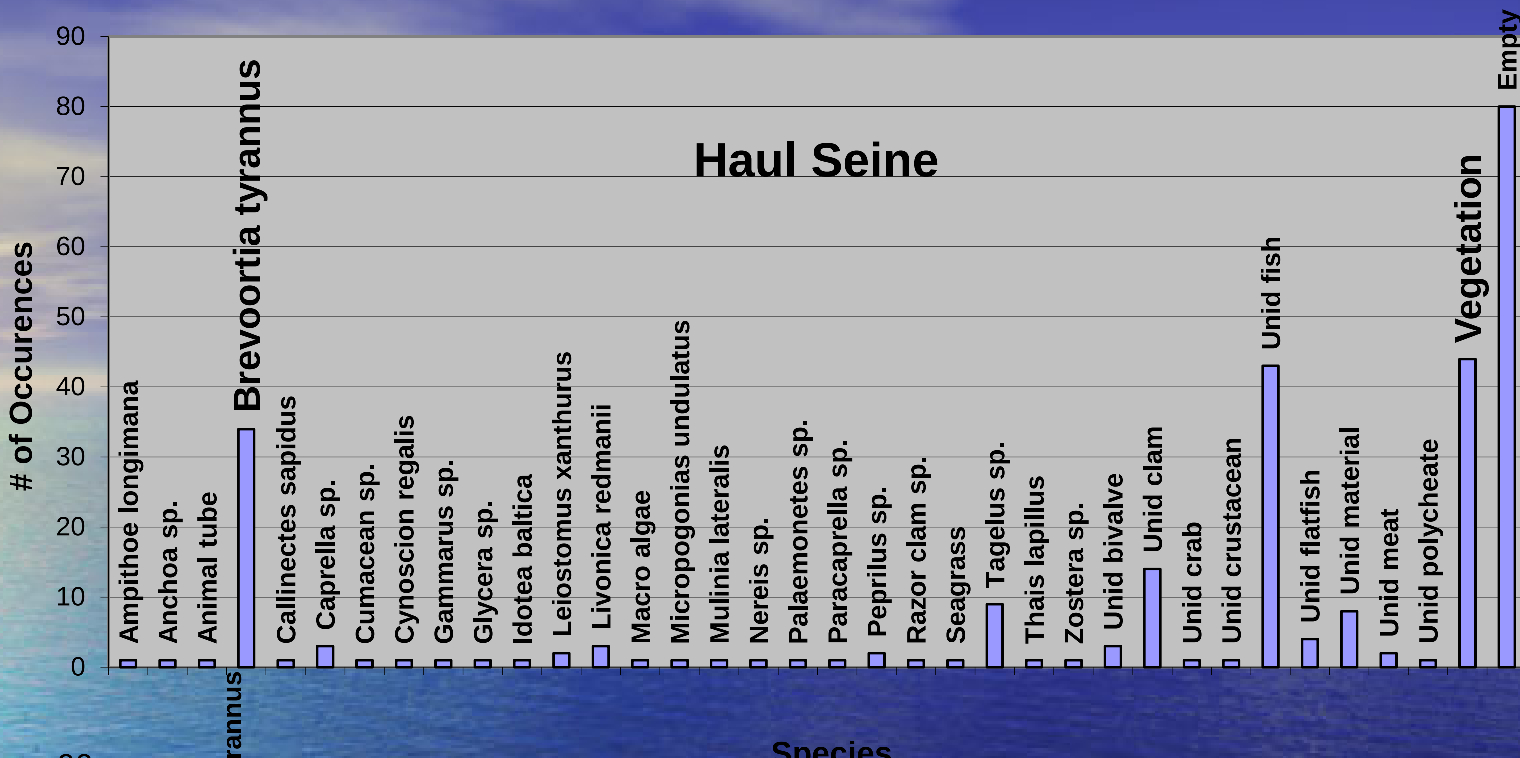
Other
Animal tube
Glycera sp.
Nereis sp.
Rock
Unid material
Unid meat
Unid polycheate
Worm tubes

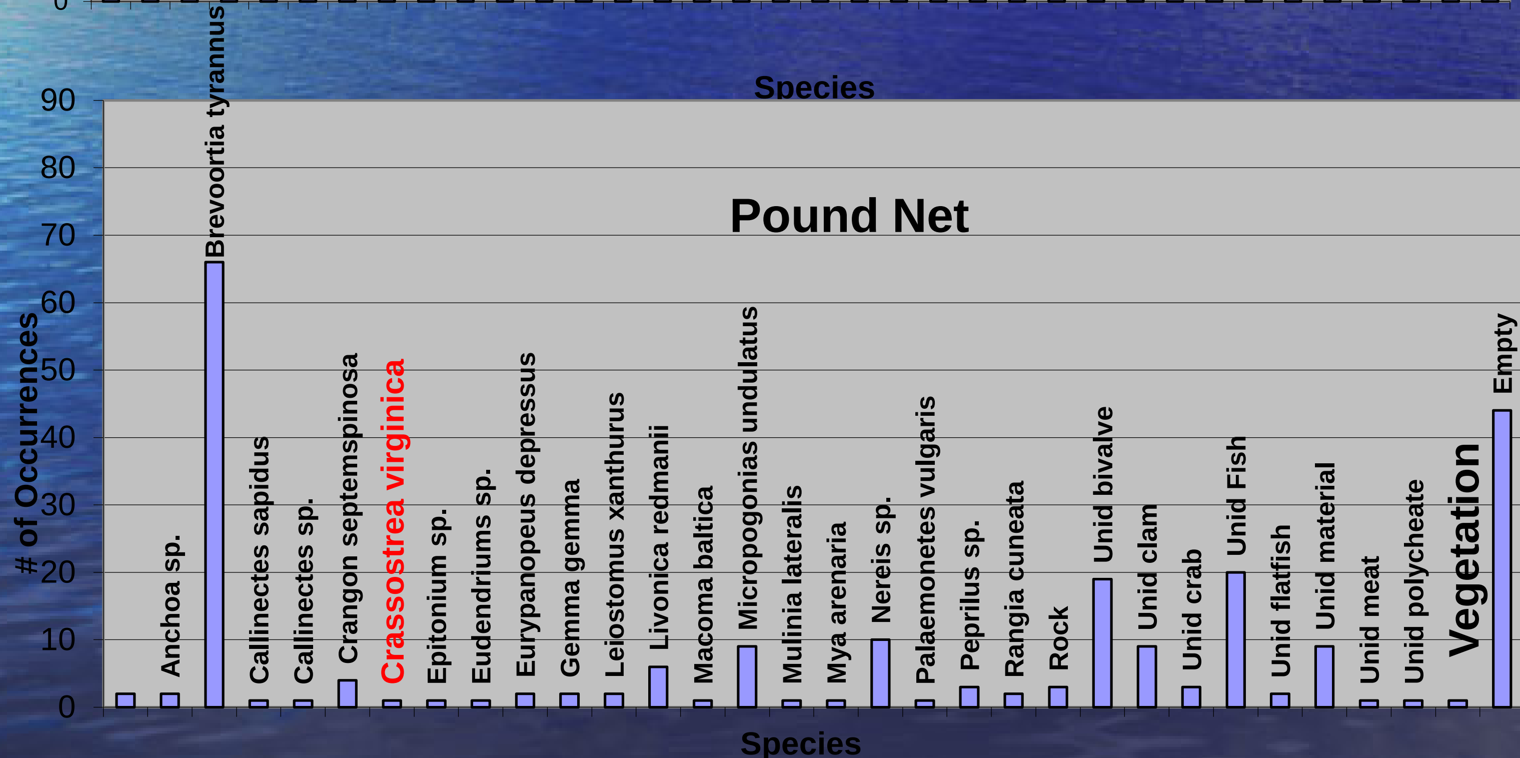


Gastropod
Epitonium sp.
Thais lapillus

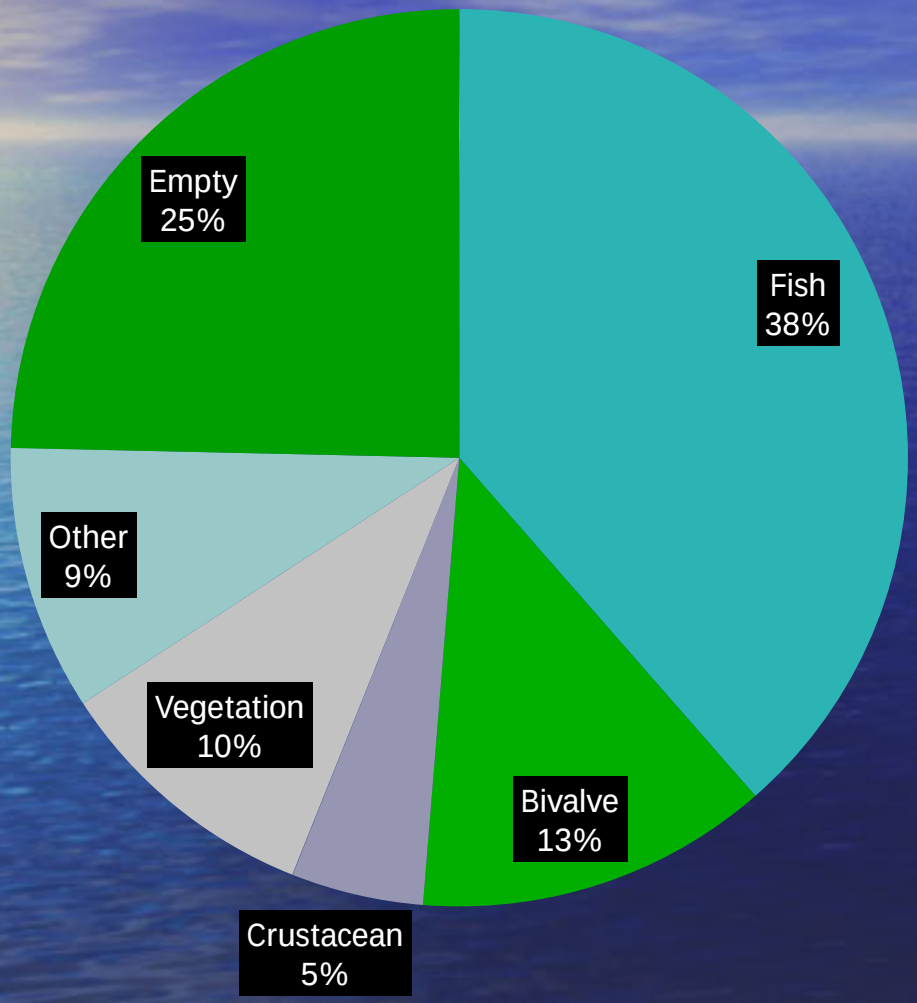
Bivalve
Crassostrea virginica
Gemma gemma
Macoma baltica
Mulinia lateralis
Mya arenaria
Rangia cuneata
Razor clam sp.
Tagelus sp.
Unid bivalve
Unid clam
Unid mollusc meat

Crustacean
Ampithoe longimana
Callinectes sapidus
Callinectes sp.
Caprella sp.
Crangon septemspinosa
Cumacean sp.
Eurypanopeus depressus
Gammarus sp.
Idotea baltica
Livonica redmanii
Palaemonetes sp.
Palaemonetes vulgaris
Paracaprella sp.
Unid crab

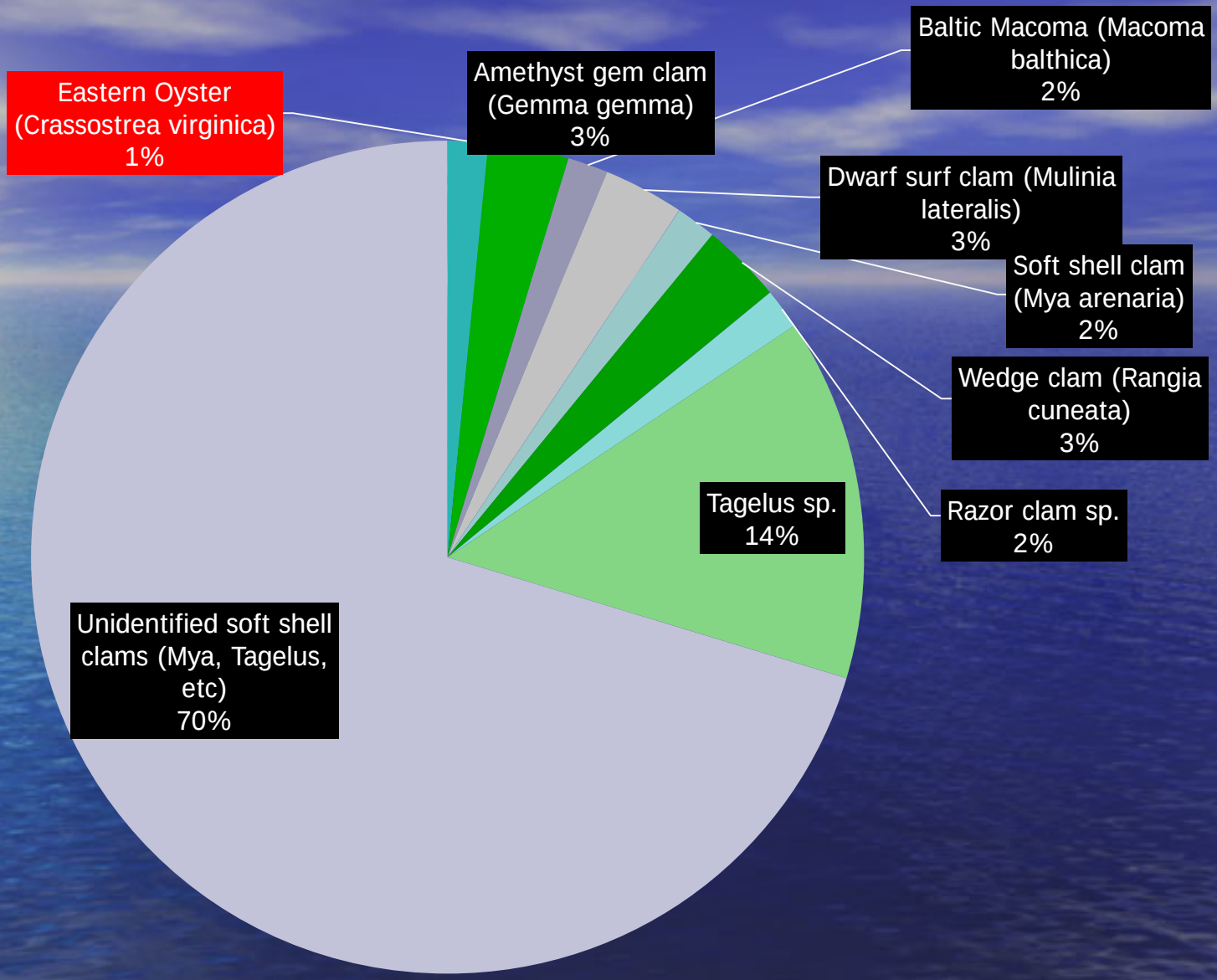

Haul Seine
# of Occurences
Species
0
10
20
30
40
50
60
70
80
90
Ampithoe longimana
Anchoa sp.
Animal tube
Brevoortia tyrannus
Callinectes sapidus
Caprella sp.
Cumacean sp.
Cynoscion regalis
Gammarus sp.
Glycera sp.
Idotea baltica
Leiostomus xanthurus
Livonica redmanii
Macro algae
Micropogonias undulatus
Mulinia lateralis
Nereis sp.
Palaemonetes sp.
Paracaprella sp.
Peprilus sp.
Razor clam sp.
Seagrass
Tagelus sp.
Thais lapillus
Zostera sp.
Unid bivalve
Unid clam
Unid crab
Unid crustacean
Unid fish
Unid flatfish
Unid material
Unid meat
Unid polycheate
Vegetation
Empty


Pound Net
# of Occurrences
Species
0
10
20
30
40
50
60
70
80
90
Anchoa sp.
Brevoortia tyrannus
Callinectes sapidus
Callinectes sp.
Crangon septemspinosa
Crassostrea virginica
Epitonium sp.
Eudendriums sp.
Eurypanopeus depressus
Gemma gemma
Leiostomus xanthurus
Livonica redmanii
Macoma baltica
Micropogonias undulatus
Mulinia lateralis
Mya arenaria
Nereis sp.
Palaemonetes vulgaris
Peprilus sp.
Rangia cuneata
Rock
Unid bivalve
Unid clam
Unid crab
Unid Fish
Unid flatfish
Unid material
Unid meat
Unid polycheate
Vegetation
Empty

Fishery Dependent Prey ofCownose Ray



Fishery dependent sampling for natural prey species was biased due to the fishing method and the highly opportunistic nature of cownose rays. Pound nets and haul seins employ a period of time where captured rays are held in a confined area for considerable amount of time with an assemblage of entrapped marine species, enabling rays to feed on prey they may not do otherwise. Note the amount of finfish reported.



Fishery Dependent Cownose Ray Prey: Bivalves

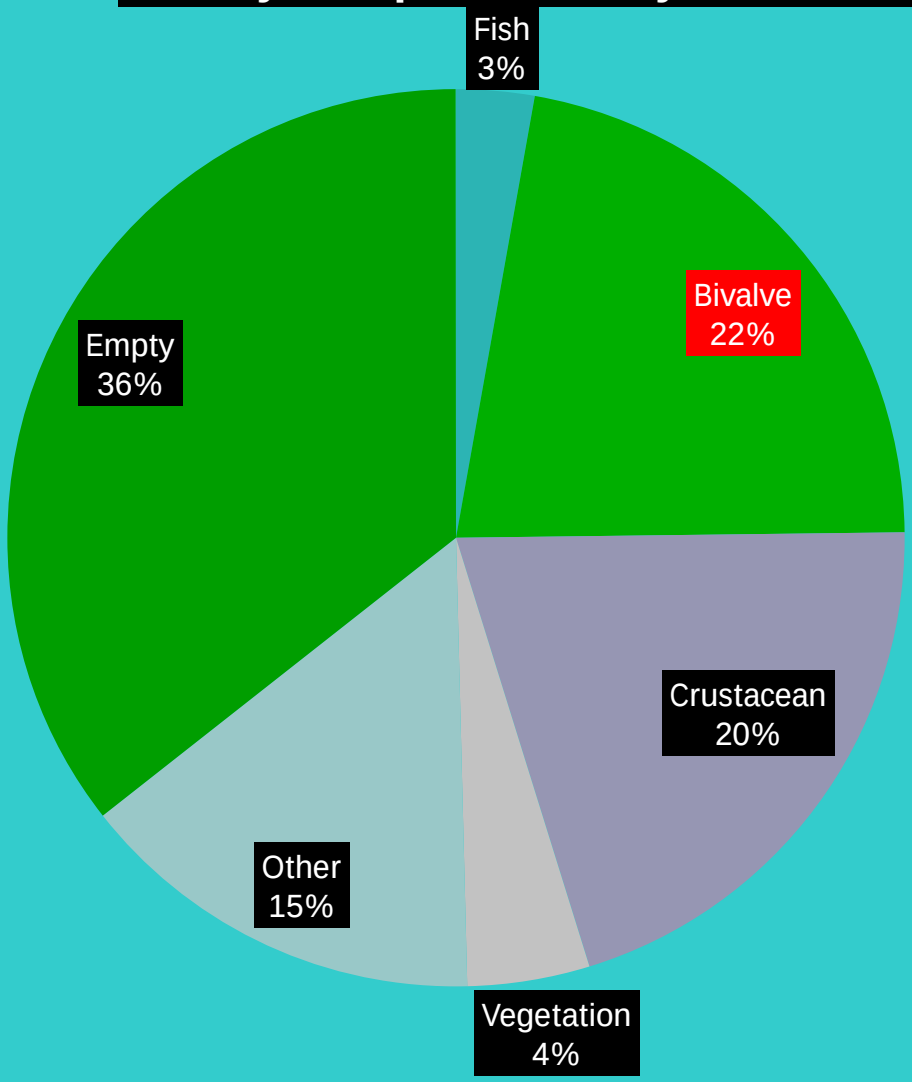
Need for Fishery independent sampling of rays to better observe natural prey species. Methods that remove rays from the water with prey captured from foraging still in digestive track

Modified Danish seine (FRG Project)

Bow Fishing

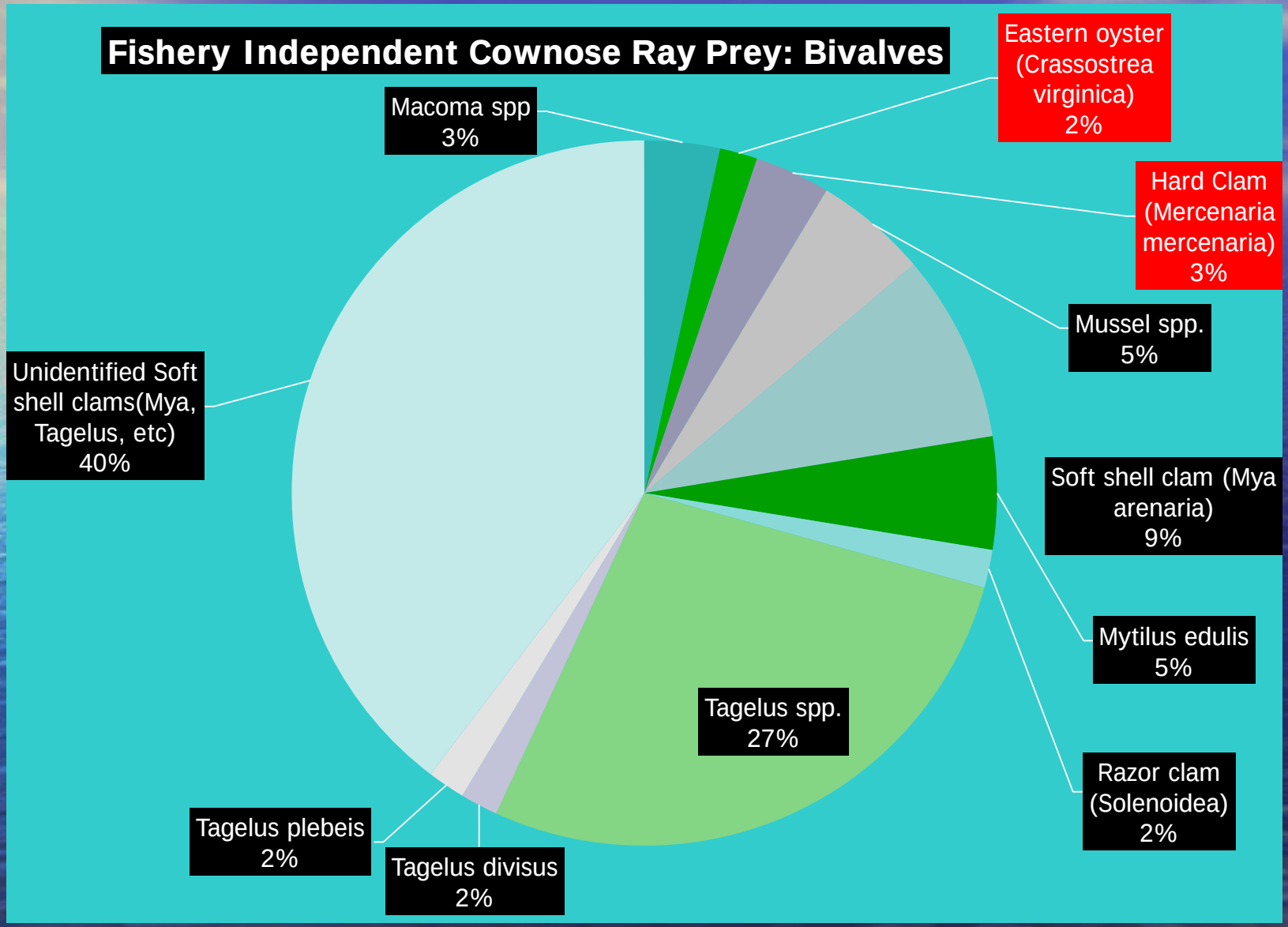
Longline (VMRC support)
Fished 2x/day

Fishery Independent Prey of Cownose Ray

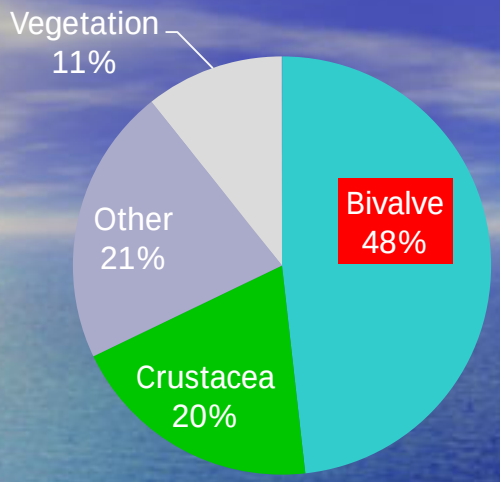


Fish was only recorded from long line sampling method and identified as bait used

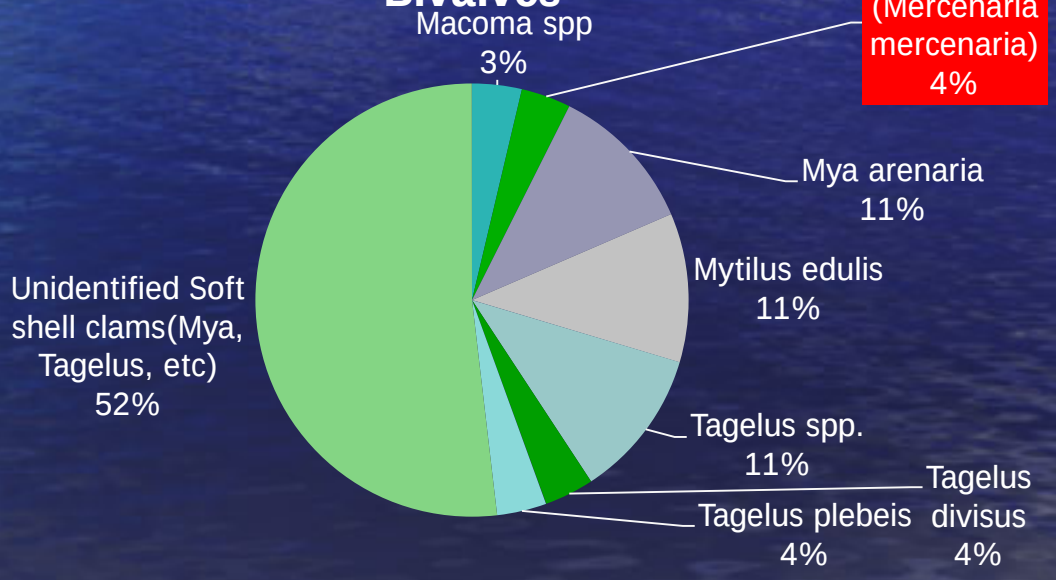
Fishery Independent Cownose Ray Prey: Bivalves



Modified Dutch Seine Cownose Ray Prey

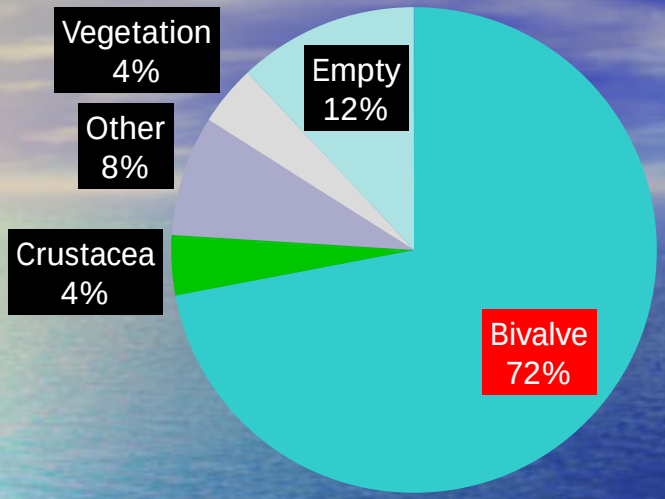


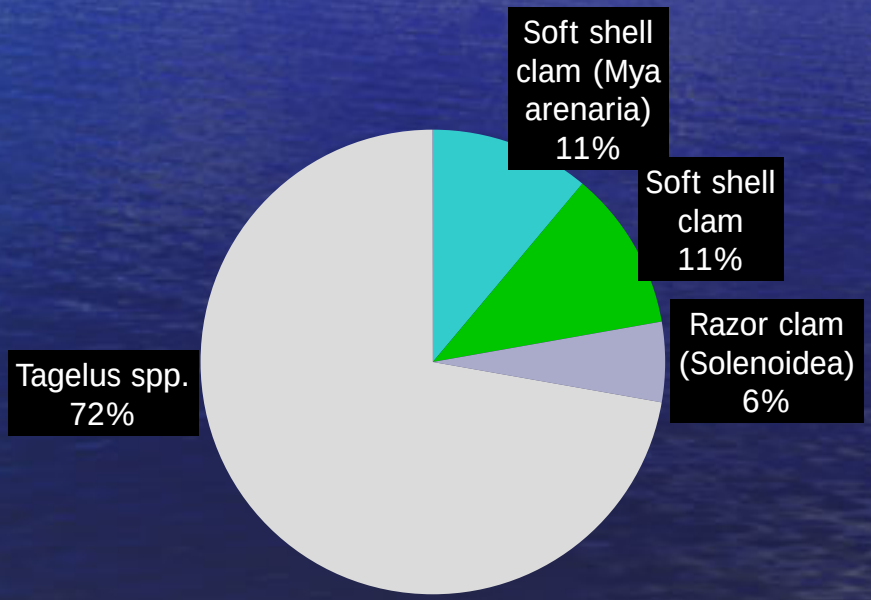
Modified Dutch Seine Cownose Ray Prey: Bivalves



No Oysters

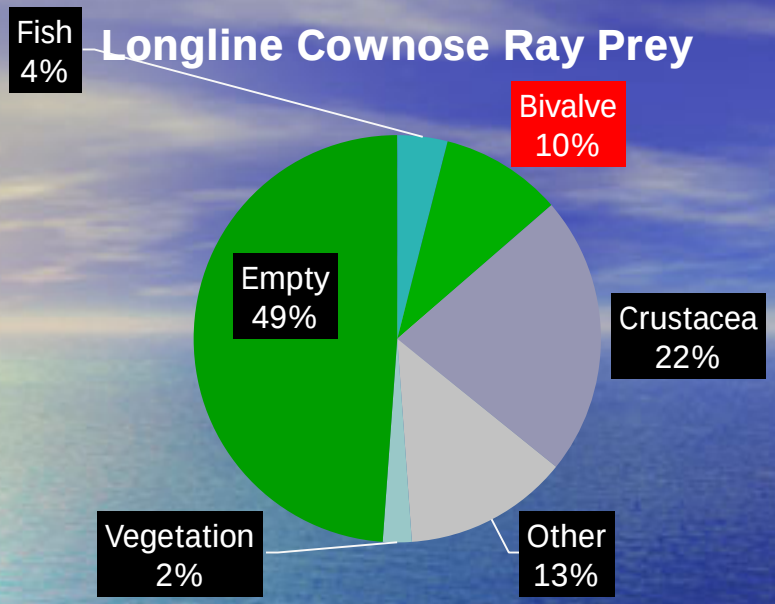
Bow Cownose Ray Prey





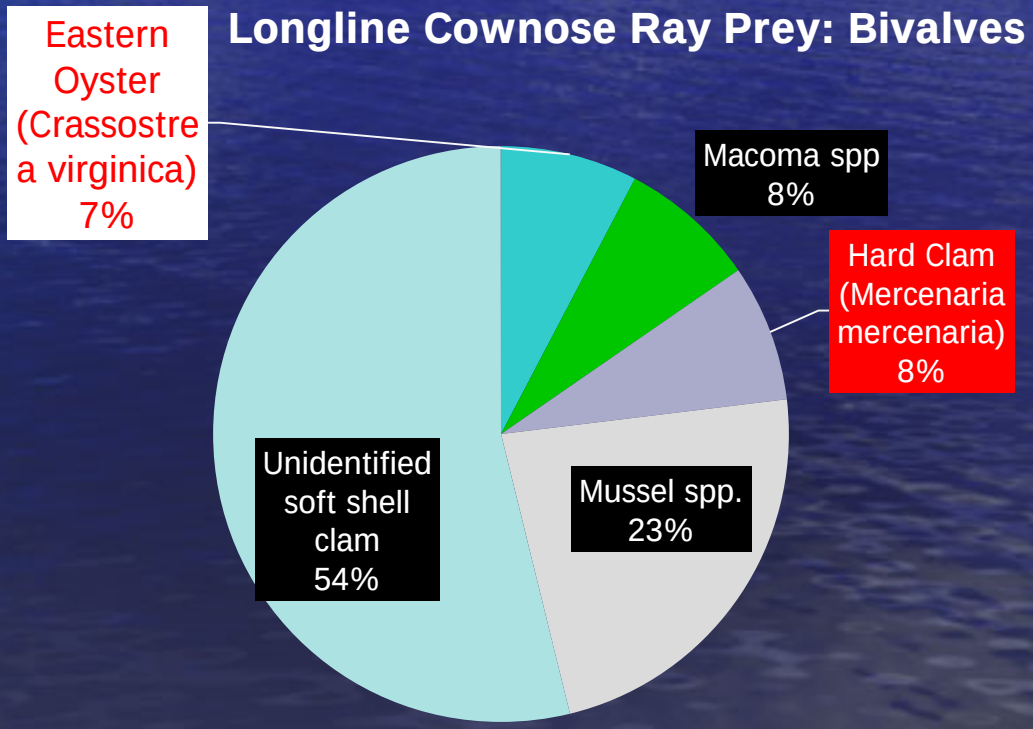
No Oysters or Hard clams

Bow Cownose Ray Prey: Bivalves

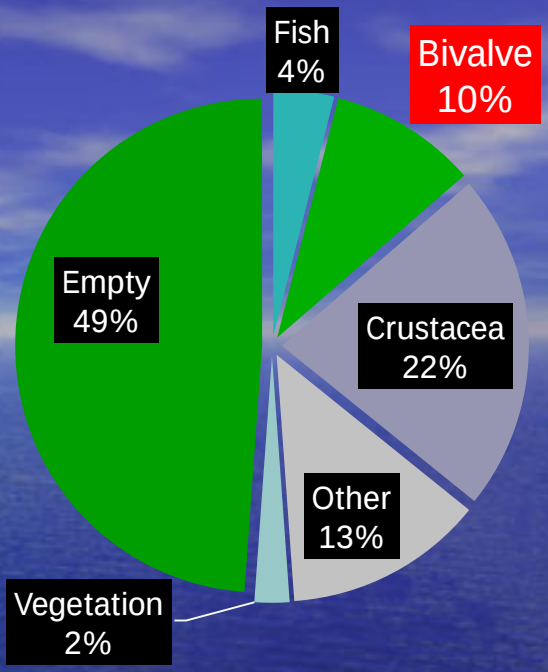


Fishing adjacent to commercial oyster grounds

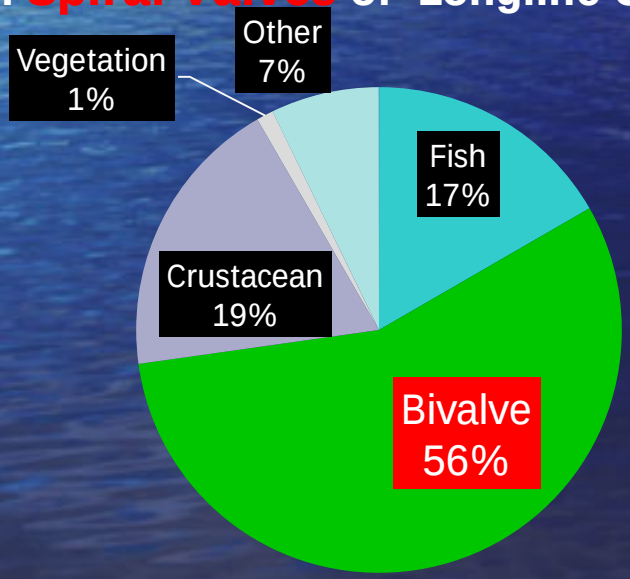
Rays seem to target prey that associates with structure, as oyster grounds provide. From personal observation and implied from other studies conducted by this author, rays seem to target weak-valved bivalves and crustaceans (mud crabs) associated with oyster grounds , but will feed on available oysters of size when these other prey items are exhausted



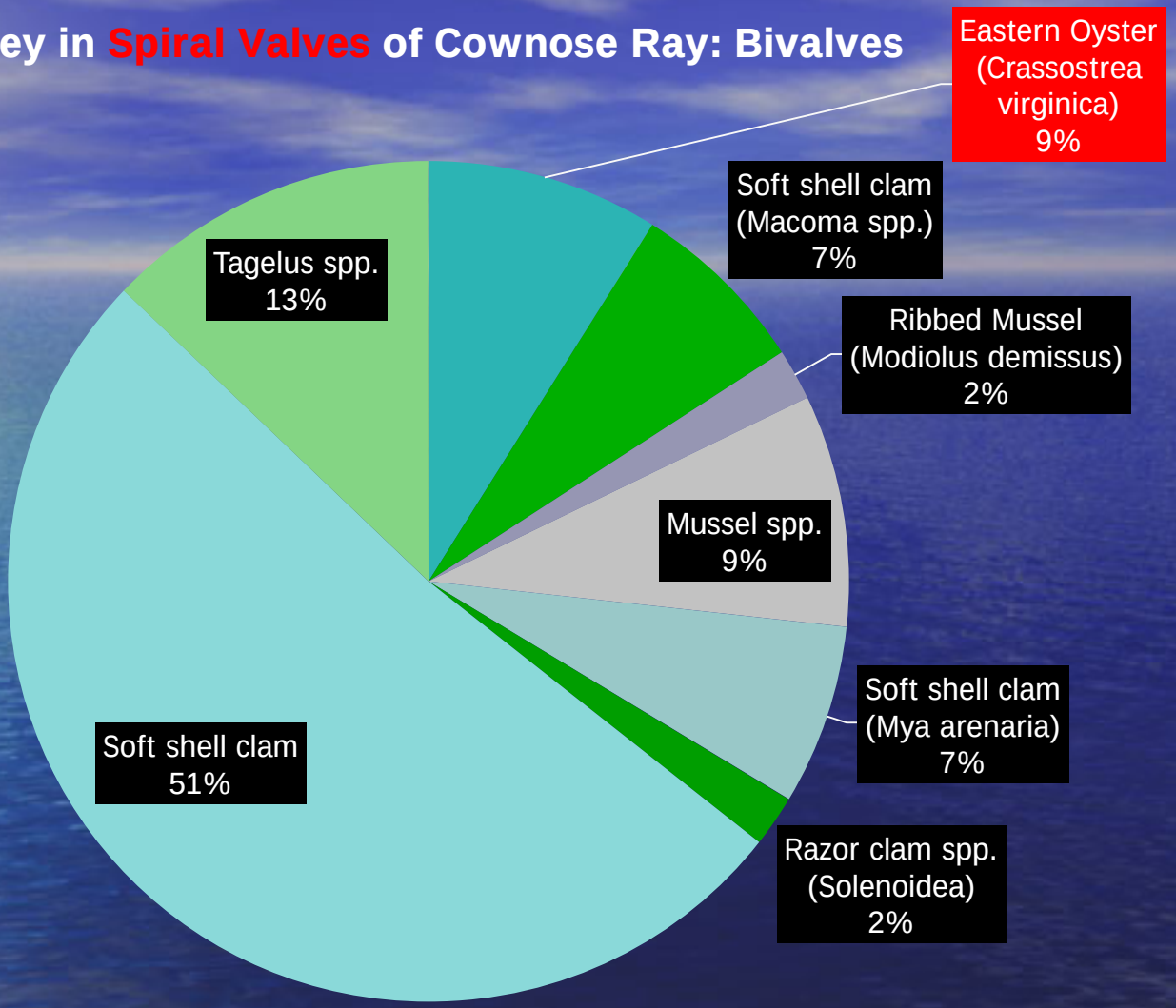
Prey in Stomachs of Longline Cownose Ray



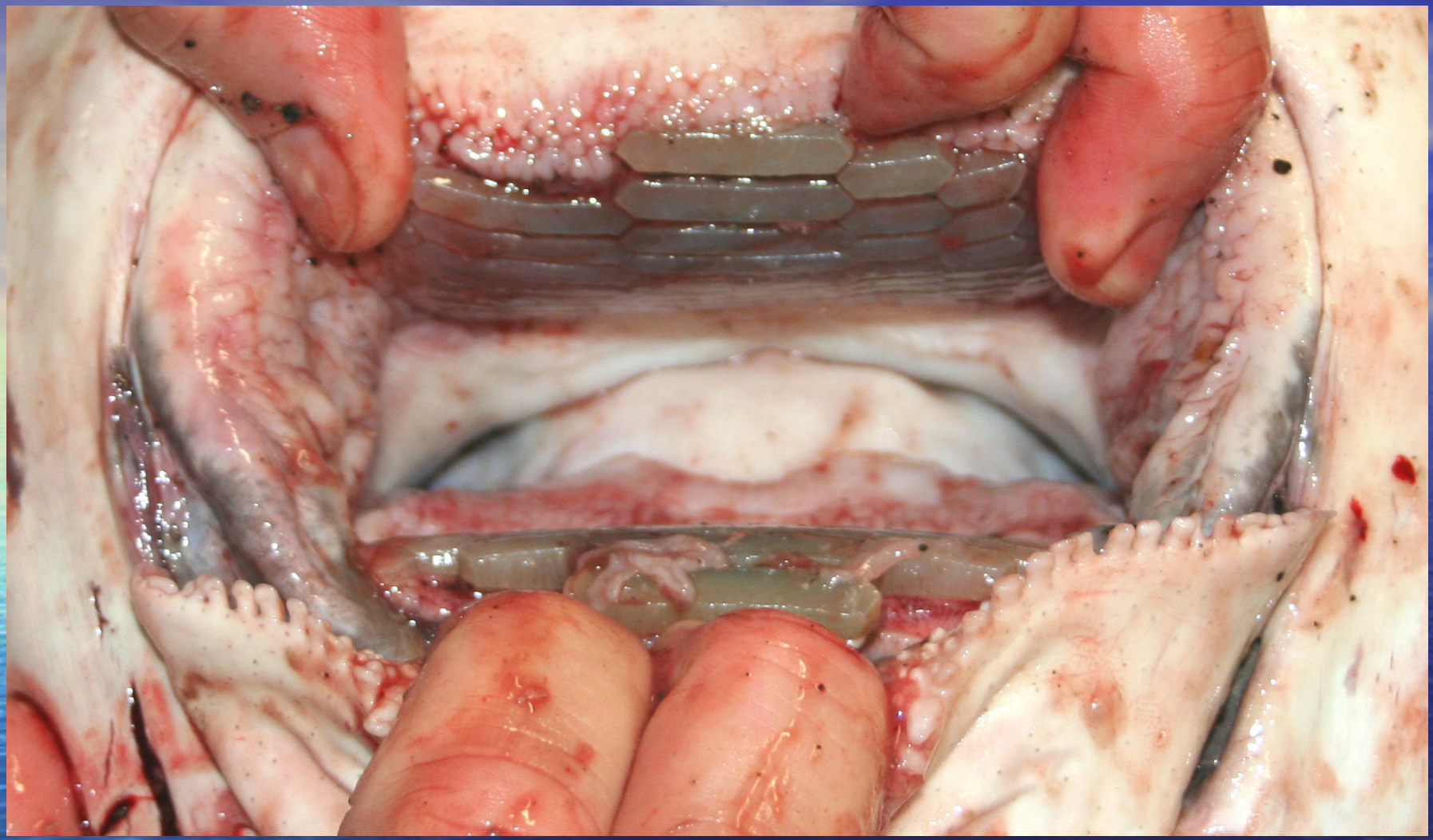
Prey In Spiral Valves of Longline Cownose Ray



Prey in Spiral Valves of Cownose Ray: Bivalves




Cownose Ray Predation on
Oysters: Yes, Including
Spat-on-Shell Oysters

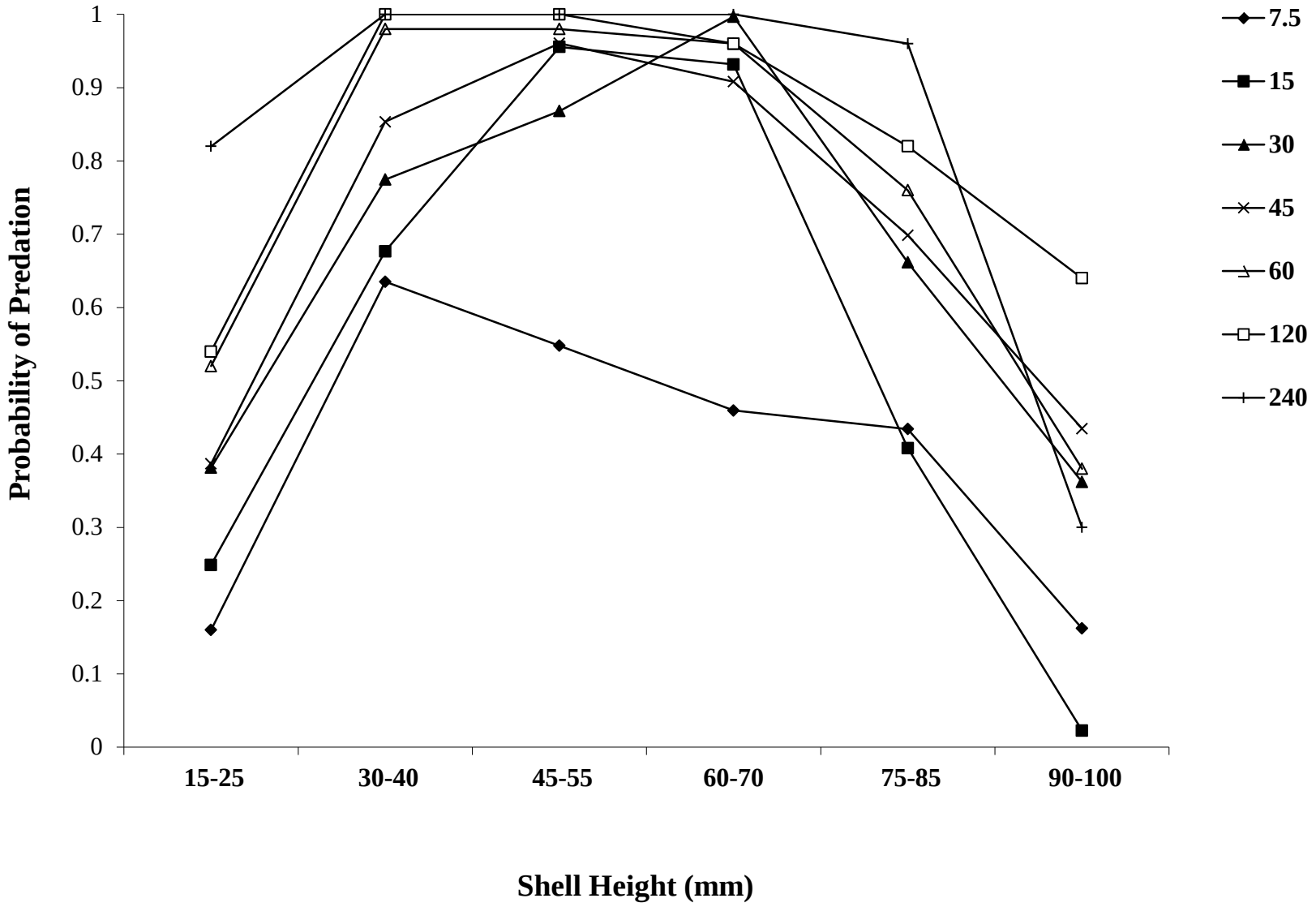


Mouth/Jaw/teeth morphology engineered for crushing shellfish: but are limited by jaw gape and crushing force

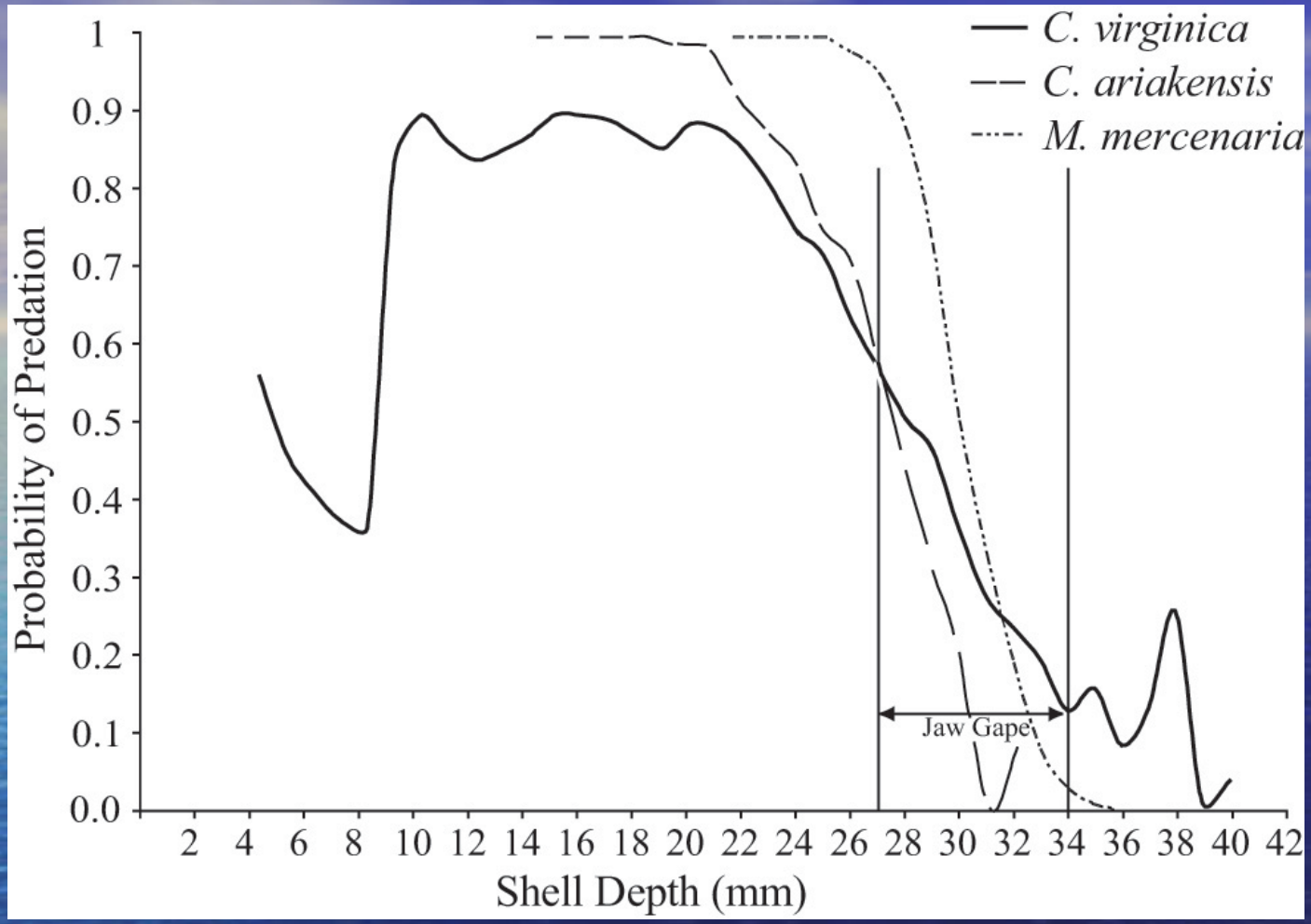
Investigating ray predation relative to bivalve ontogeny

Pre-trial Co-mingled oysters

Post-trial Co-mingled oysters

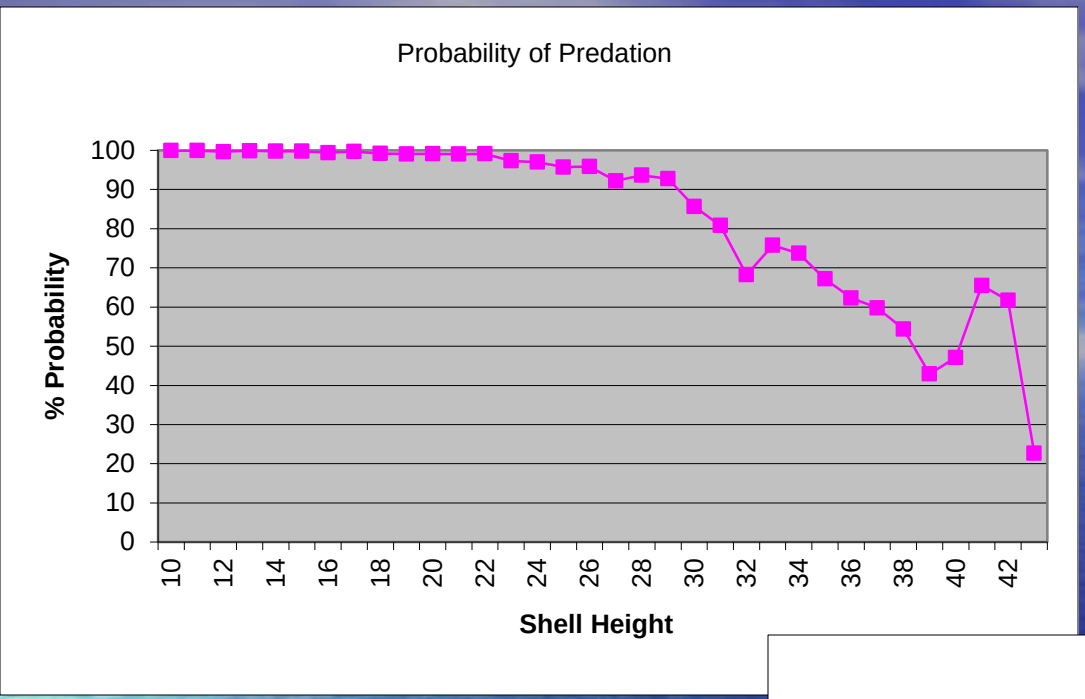


30-40, 45-55, and 60-70 mm were the most highly preyed upon

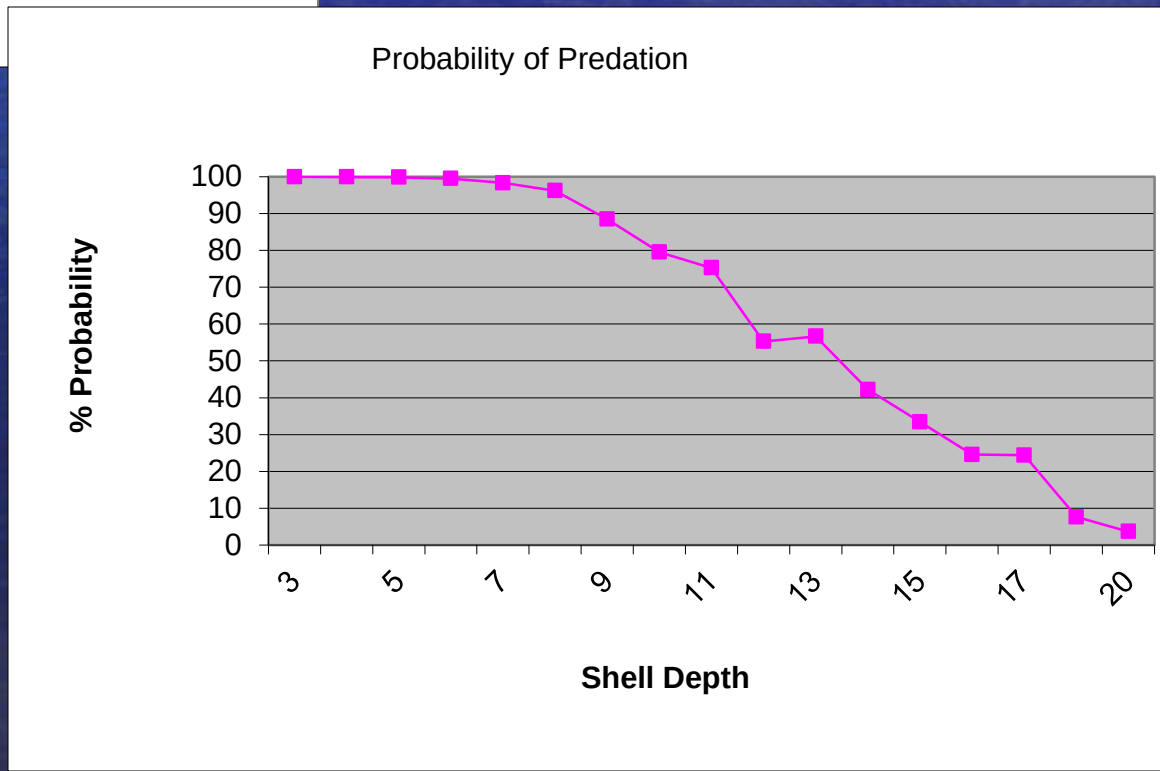


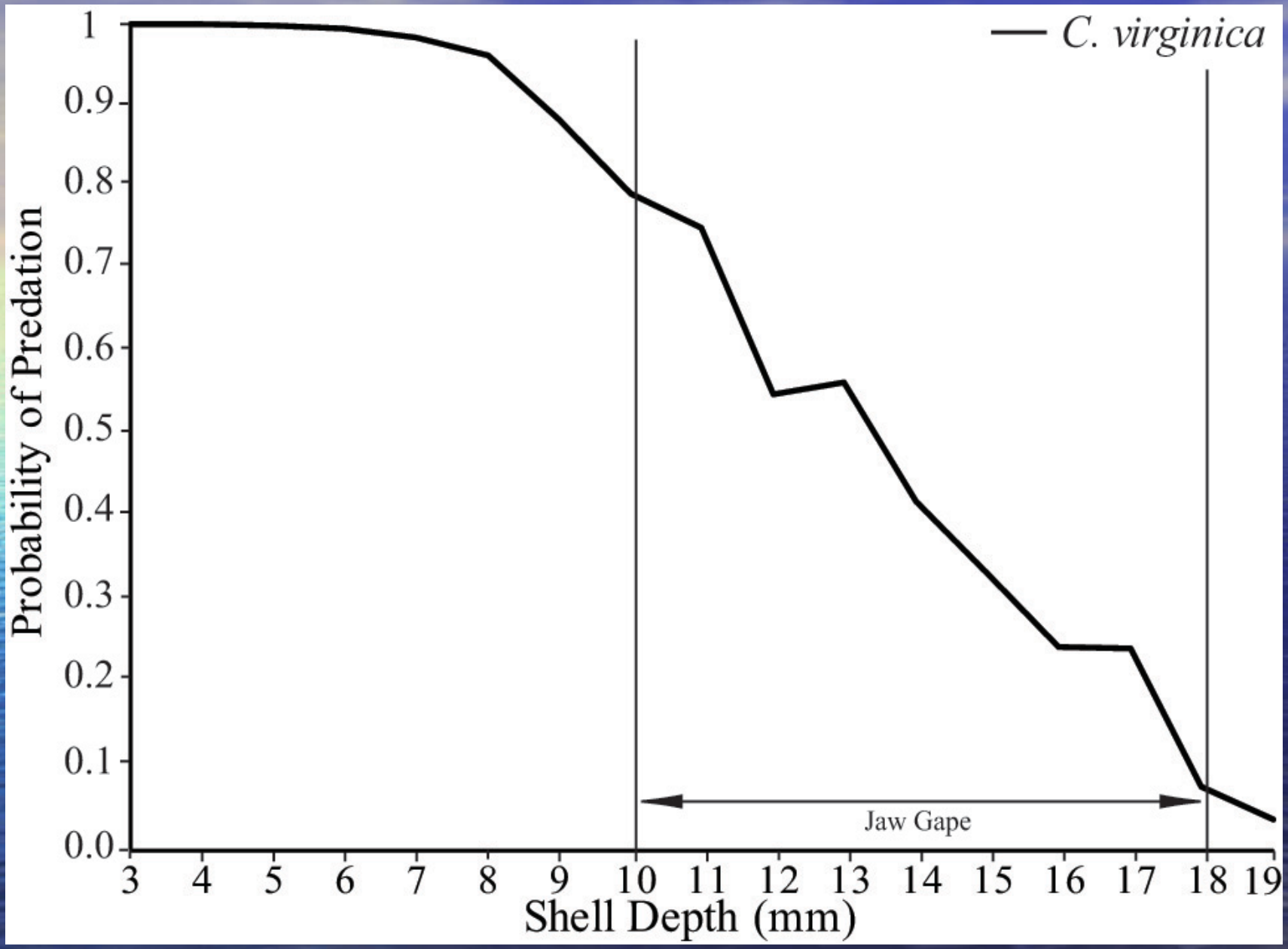
Mean predicted probability of predation from logistic regression models of *C. virginica, C. ariakensis,* and *M. mercenaria* as related to shell depth.

Predation declined with increasing shell depth. The lowest predation success recorded in oysters with shell depths greater than 32 mm.

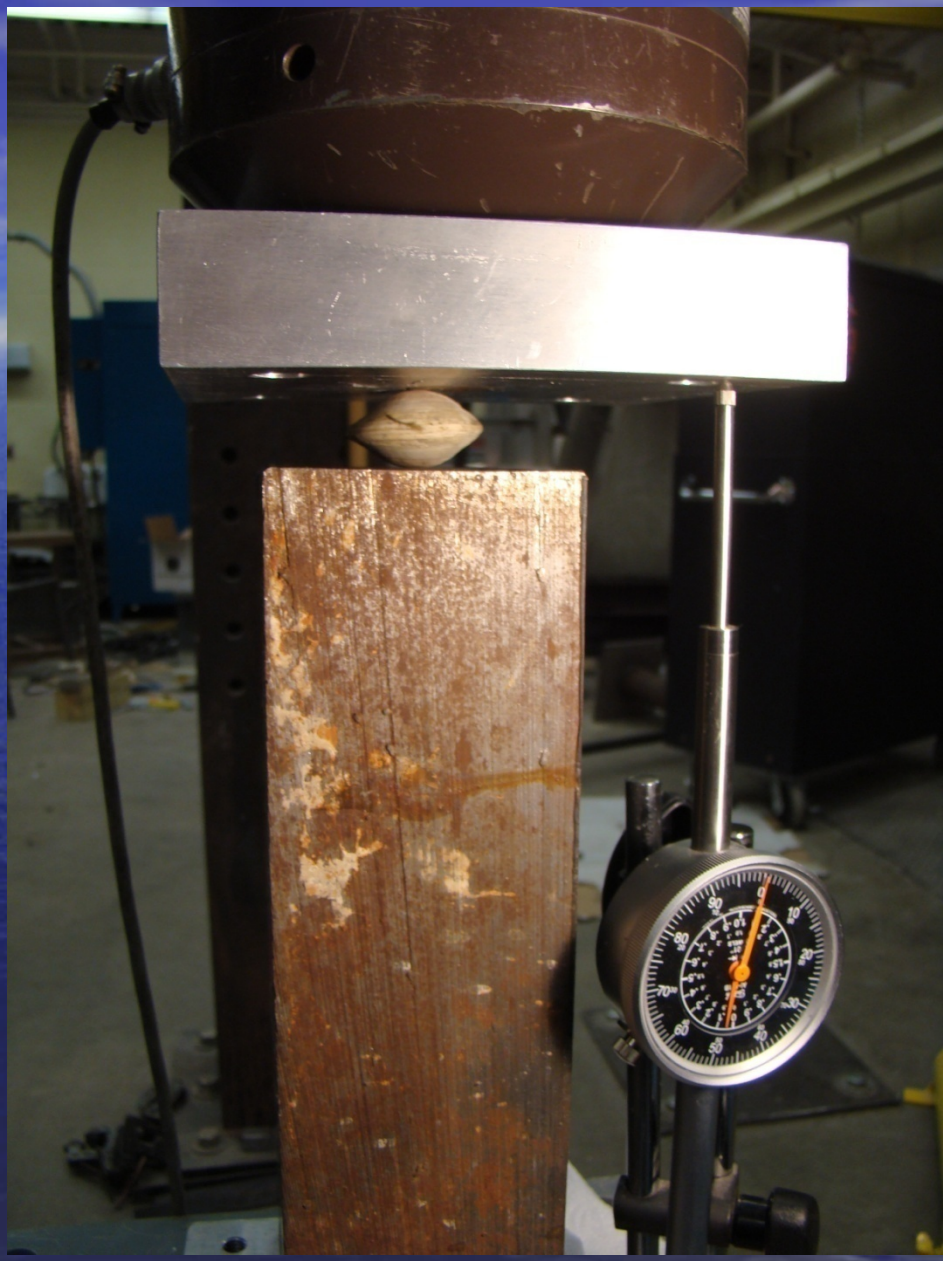


Young of Year Ray predation on oyster seed



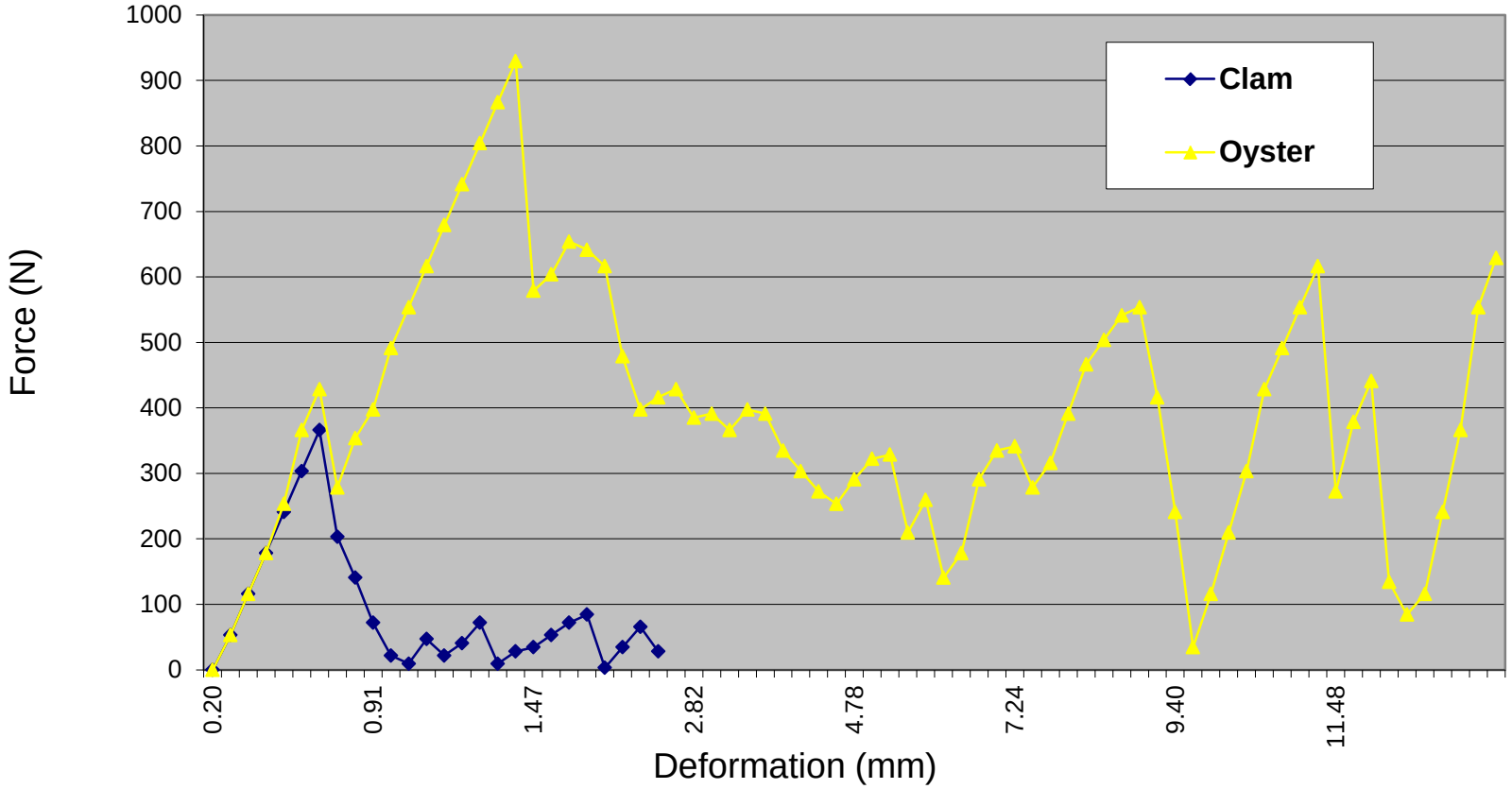


Young of Year Rays



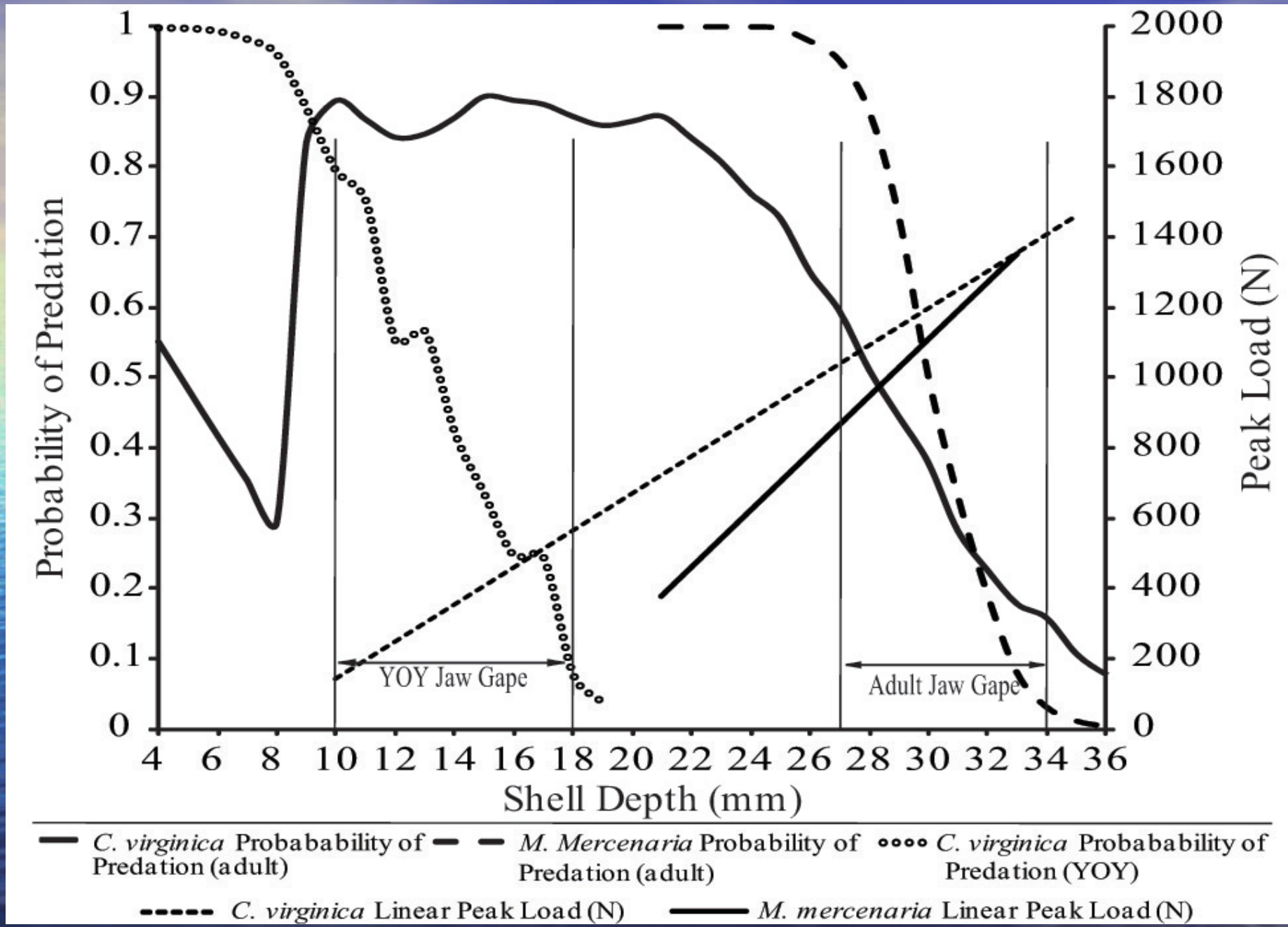
Testing force and deformation required to fracture valves of various bivalve prey of cownose ray

Comparison of Compression Force (N) and Deformation (mm) on an Clam and Oyster

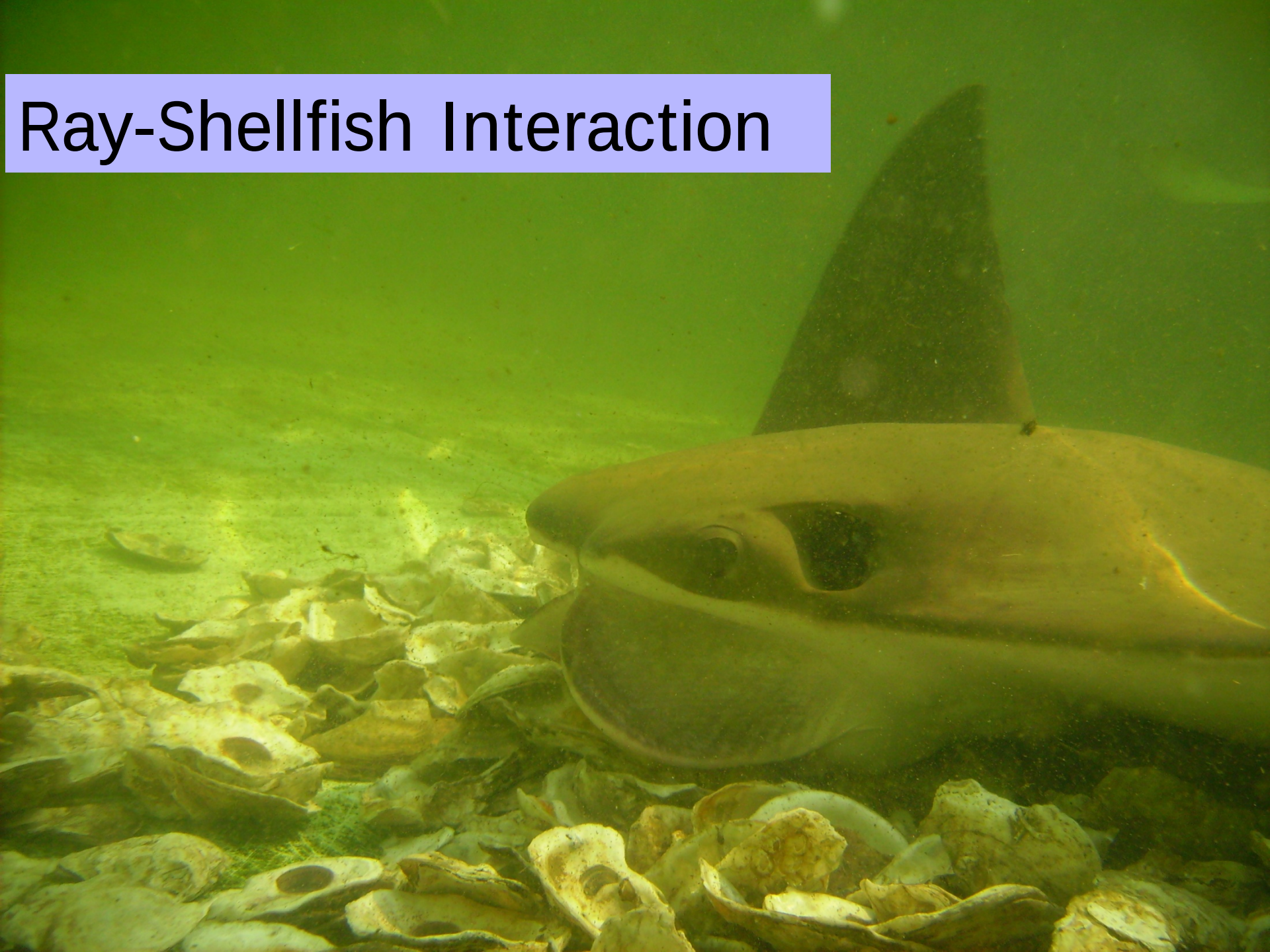


pound-force (lbf) with 1 lbf = 4.4482 Newton.

Note the more elastic component of oysters verse hard clam…requiring considerably more force process oysters v hard clams


Probability of Predation
Peak Load (N)
Shell Depth (mm)
YOY Jaw Gape
Adult Jaw Gape
C. virginica Probability of Predation (adult)
M. Mercenaria Probability of Predation (adult)
C. virginica Probability of Predation (YOY)
C. virginica Linear Peak Load (N)
M. mercenaria Linear Peak Load (N)

Ray-Shellfish Interaction



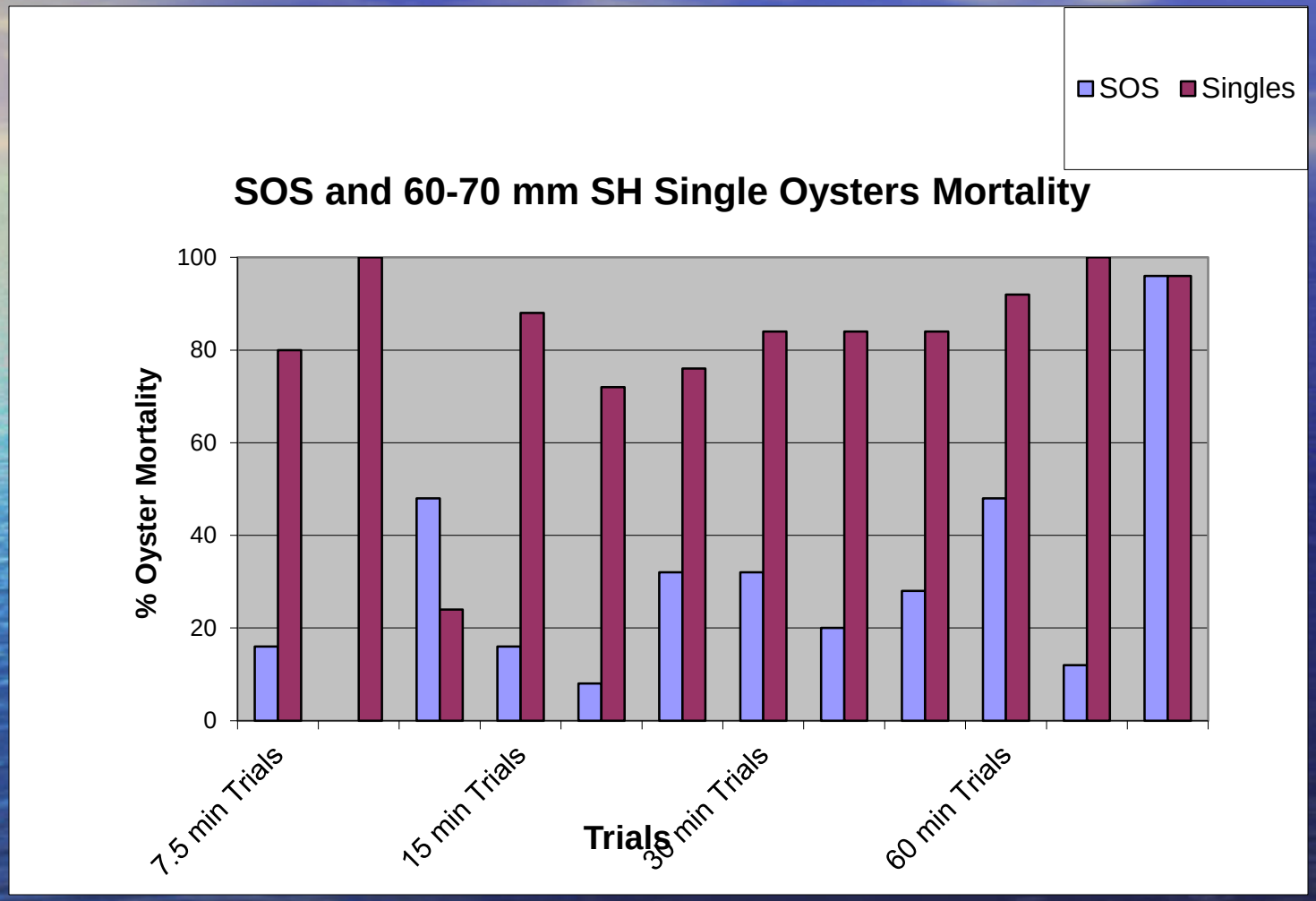
Comparison of ray predation on two different size oysters of *C. ariakensis* and *C. virginica* by cownose rays. *N* = number of trials, 25 bivalves of each species were introduced to rays in each 15 min trial. Fisher's combined probability values are shown.

Shell Height (mm)	*N*	*C. ariakensis* Success/Failure	*C. virginica* Success/Failure	χ^2	P-value
45-55	2	48/2	45/5	5.697	0.222
75-85	3	38/47	42/33	8.785	0.186

Comparison of ray predation on *M. mercenaria* and *C. virginica*.

N	*M. mercenaria* (SH 35-40) Success/Failure/SD	*C. virginica (SH 45-55)* Success/Failure/SD	χ^2	P-value
3	73/2/24	51/24/23	35.65	0.0001

Industry Need for Extensive Oyster Culture
SOS = Spat on Shell



Given time, rays have success preying on SOS oysters

Spat-on-Shell Trial

Cownose rays methodically break down oyster clusters, removing one at a time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