Cultch and oyster density standards for reef restoration, sustainable harvest and fishing at maximum sustained yield

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10/12/2021

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NOAA Saltonstall-Kennedy Program

Introduction to the model

- Initially developed for Louisiana oyster fishery
- Annual stock assessment provides: oyster density, oyster numbers by size, cultch density and reef area
- These are inputs to the model which simulates growth, natural and fishing mortality, and cultch loss or gain
- Shells of dead oysters are added to the reef and shells of fished oysters are debited
- Growth and mortality are size and time dependent
- Fishing can occur for seed and/or sack oysters
- Fishing rate is time dependent
- Initial sustainability goal: no-net cultch loss (NNL)

Incorporation of cultch and oyster density standards

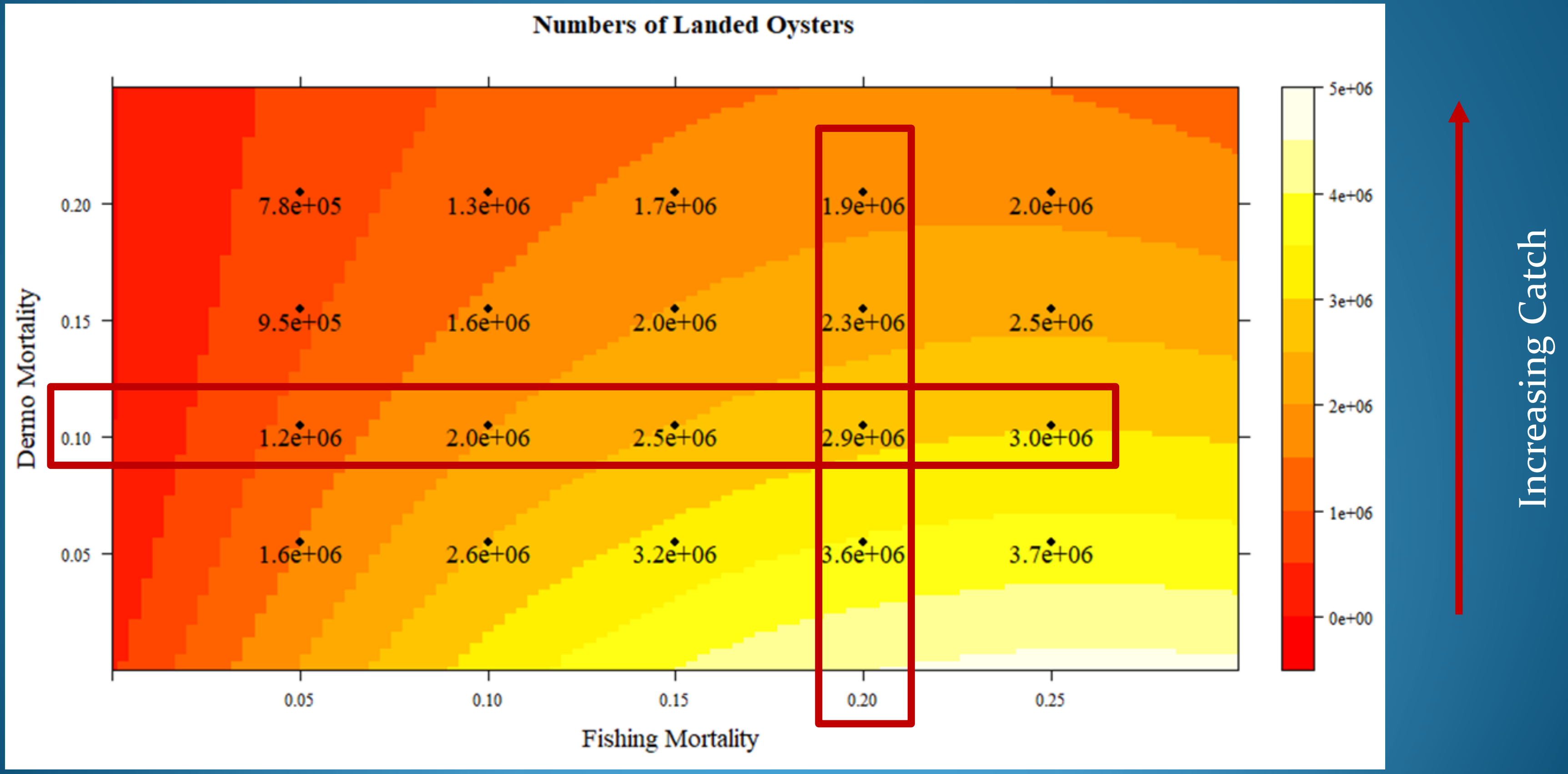
- New sustainability goal: oyster density/cultch density standard (OCS) for fishing at Maximum Sustained Yield (*msy*)

- How was the OCS derived?

  (Solinger et al., submitted to *Canadian Journal of Fisheries and Aquatic Sciences*)

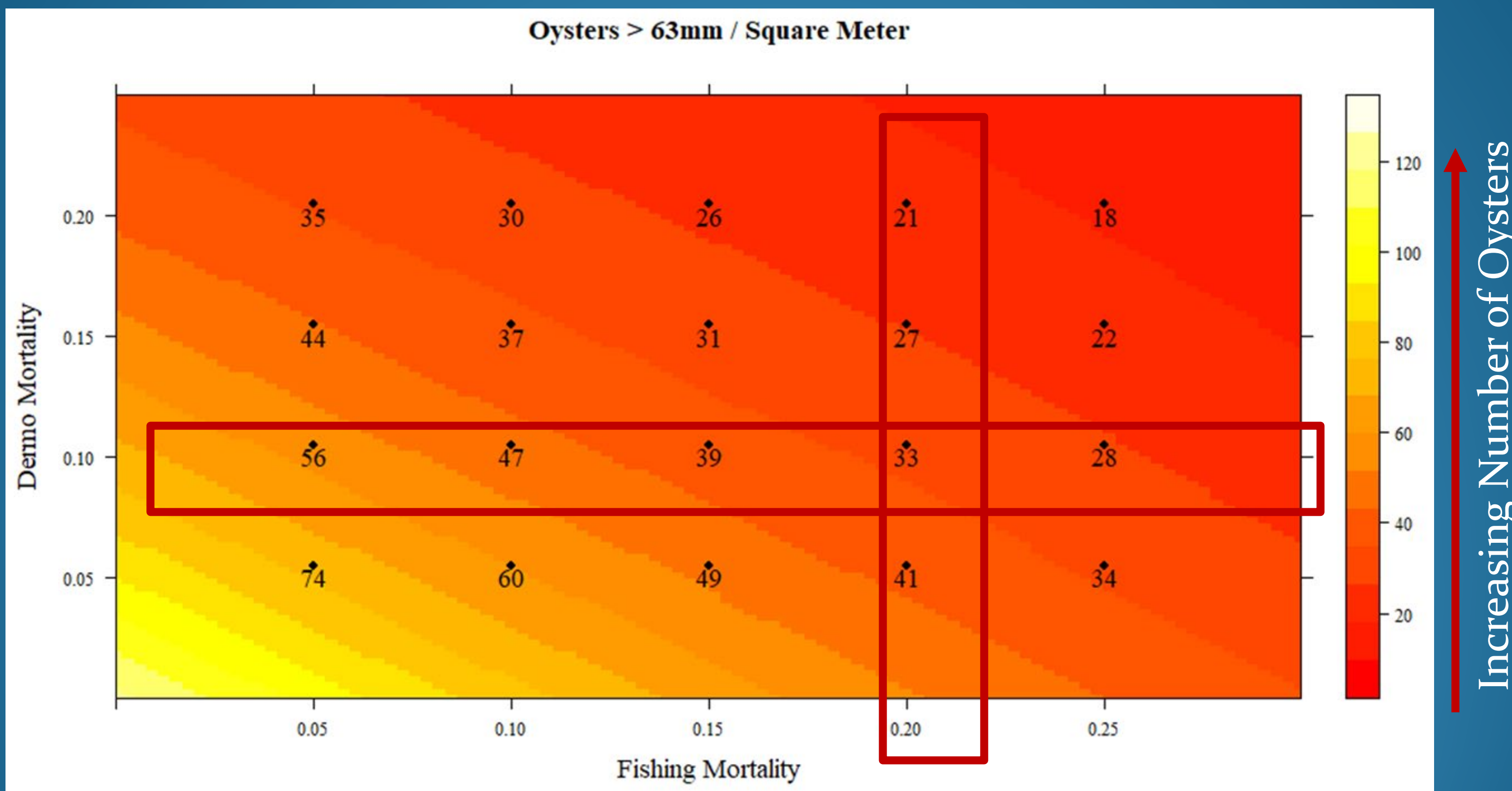
How many oysters can be harvested?

- Oyster population at equilibrium assumed (unchanging live population and reef structure)
- Dermo mortality = 10% chosen as common
- Maximum catch occurs between 20 and 25% F, yielding 2.9 million oysters
- Thus, at a level of 10% Dermo mortality, an F of about 20% is recommended
- Total mortality (Natural + Dermo + Fishing) is then 40% per year



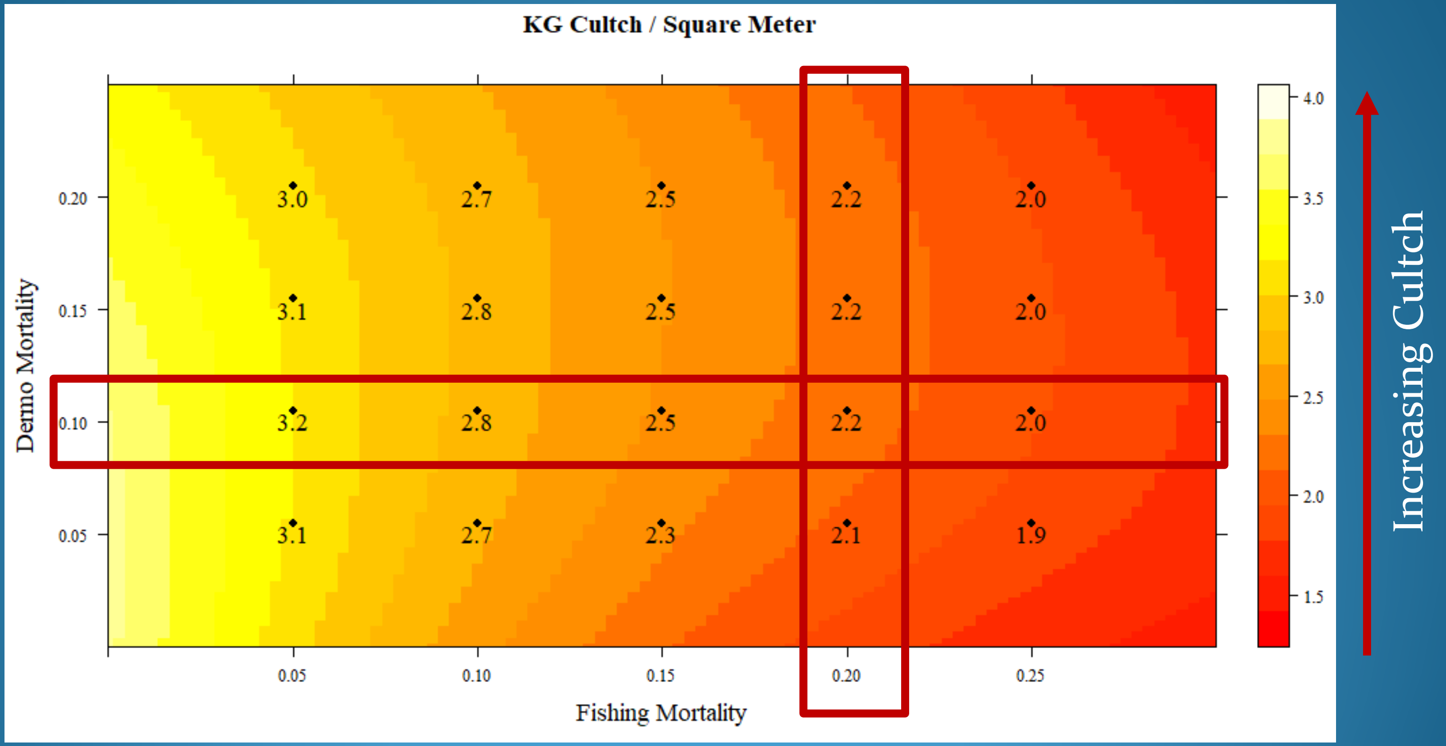
What is the required oyster density?

About 33 market-sized oysters are required to support an oyster population with a Dermo mortality of 10% and fishing mortality of 20%



What is the required cultch density?

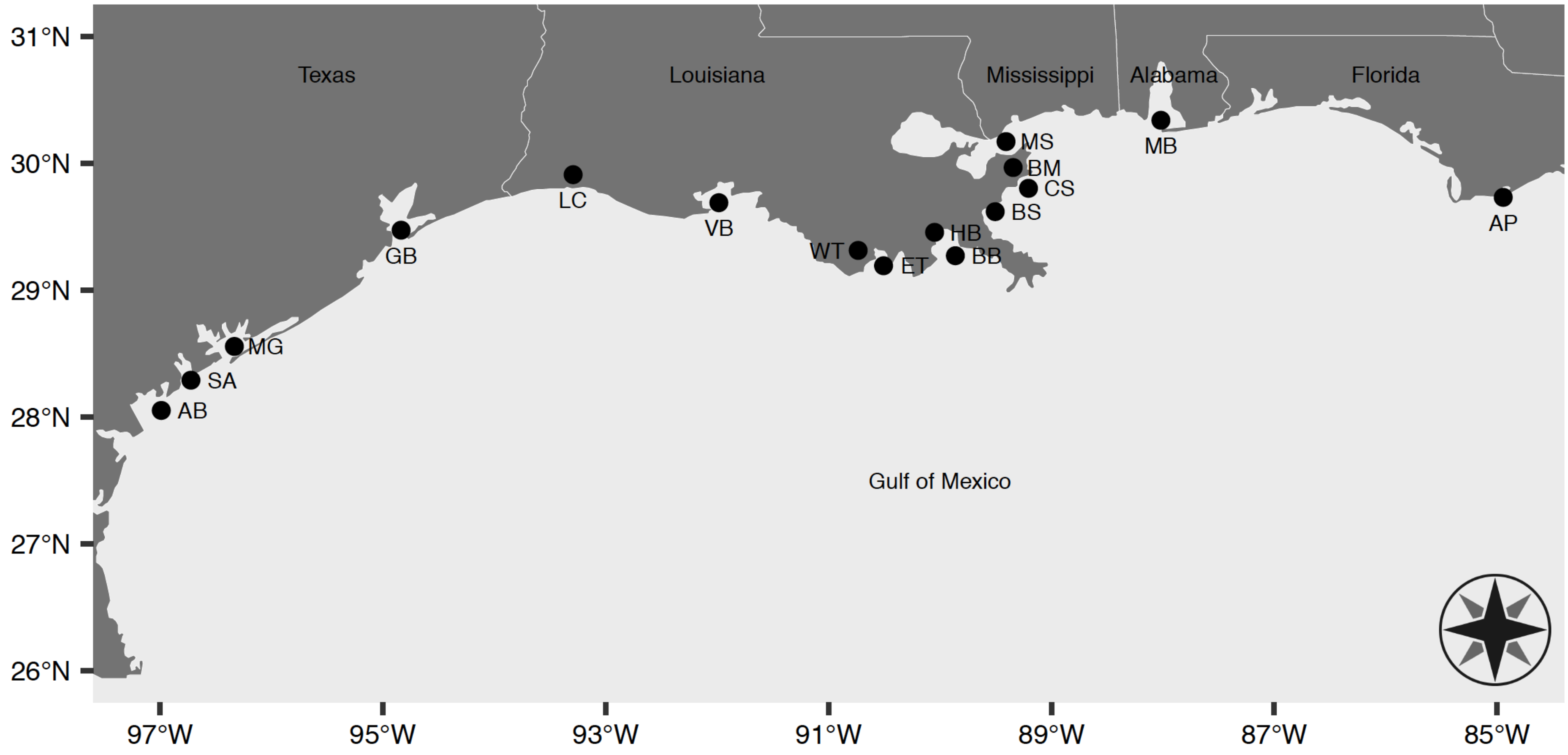
- As is expected, increasing fishing mortality (F) reduces volume of cultch per square meter
- Note that cultch is relatively consistent with Dermo, because Dermo continues to contribute cultch to the shell bed
- At D = 0.10 and F = 0.20, 2.2 kg of cultch is needed to sustain the population



Application of oyster and cultch density standard (OCS) to the Gulf of Mexico

OCS: 30 oysters/m^2 (> 75 mm)
2000 g/m^2 cultch (surficial)

Sample Locations



Mean monthly water temperatures

Month	Temp. (°C)
January	11
February	12
March	16
April	20
May	24
June	28
July	29
August	29
September	28
October	23
November	17
December	13

Data from Eugene Island, central coastal Louisiana:
https://www.currentresults.com/Oceans/Temperature/louisiana-alabama-average-water-temperature.php#c.

Monthly Fishing Scenarios

STATE	SITE	SACK/SEED	EFFORT	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
TX	Galveston Bay	Sack	100%	4.8	0.0	0.6	0.6	0.0	0.0	0.0	0.0	0.0	0.0	60.8	33.2
TX	Matagorda Bay	Sack	100%	6.9	51.5	22.6	10.2	0.0	0.0	0.0	0.0	0.0	0.0	4.6	4.2
TX	San Antonio Bay	Sack	100%	28.7	9.3	9.8	6.0	0.0	0.0	0.0	0.0	0.0	0.0	21.2	24.9
TX	Aransas Bay	Sack	100%	13.1	16.6	34.6	29.6	0.0	0.0	0.0	0.0	0.0	0.0	0.8	5.4
LA	West Terrebonne	Sack	10%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50.0	50.0
LA	West Terrebonne	Seed	90%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0
LA	Lake Calcasieu	Sack	100%	25.0	25.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.0	25.0
AL	Mobile Bay	Sack	100%	25.0	25.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.0	25.0
FL	Halfmoon	Sack	100%	0.0	0.0	0.0	0.0	0.0	50.0	50.0	0.0	0.0	0.0	0.0	0.0
FL	Lighthouse	Sack	100%	0.0	0.0	0.0	0.0	0.0	50.0	50.0	0.0	0.0	0.0	0.0	0.0
FL	Normans	Sack	100%	0.0	0.0	0.0	0.0	0.0	50.0	50.0	0.0	0.0	0.0	0.0	0.0
FL	Hotel	Sack	100%	0.0	0.0	0.0	0.0	0.0	50.0	50.0	0.0	0.0	0.0	0.0	0.0
FL	East Lumps	Sack	100%	0.0	0.0	0.0	0.0	0.0	50.0	50.0	0.0	0.0	0.0	0.0	0.0
FL	Cat Point	Sack	100%	20	20	20	20	20	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FL	Bulkhead	Sack	100%	20	20	20	20	20	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Low, moderate and high salinity year assumptions

Month	Low Salinity	Moderate Salinity	High Salinity
J	9.8	18.3	18.8
F	9.0	15.0	21.8
M	7.3	15.3	20.5
A	6.5	13.8	22.3
M	7.3	12.8	21.8
J	9.0	12.8	17.8
J	5.5	11.3	16.3
A	7.3	11.0	18.5
S	9.0	14.0	19.3
O	11.8	16.0	23.0
N	12.3	16.3	23.8
D	11.5	16.0	25.0
Annual Mean	**8.8**	**14.4**	**20.7**

Data from Melancon et al., 1998

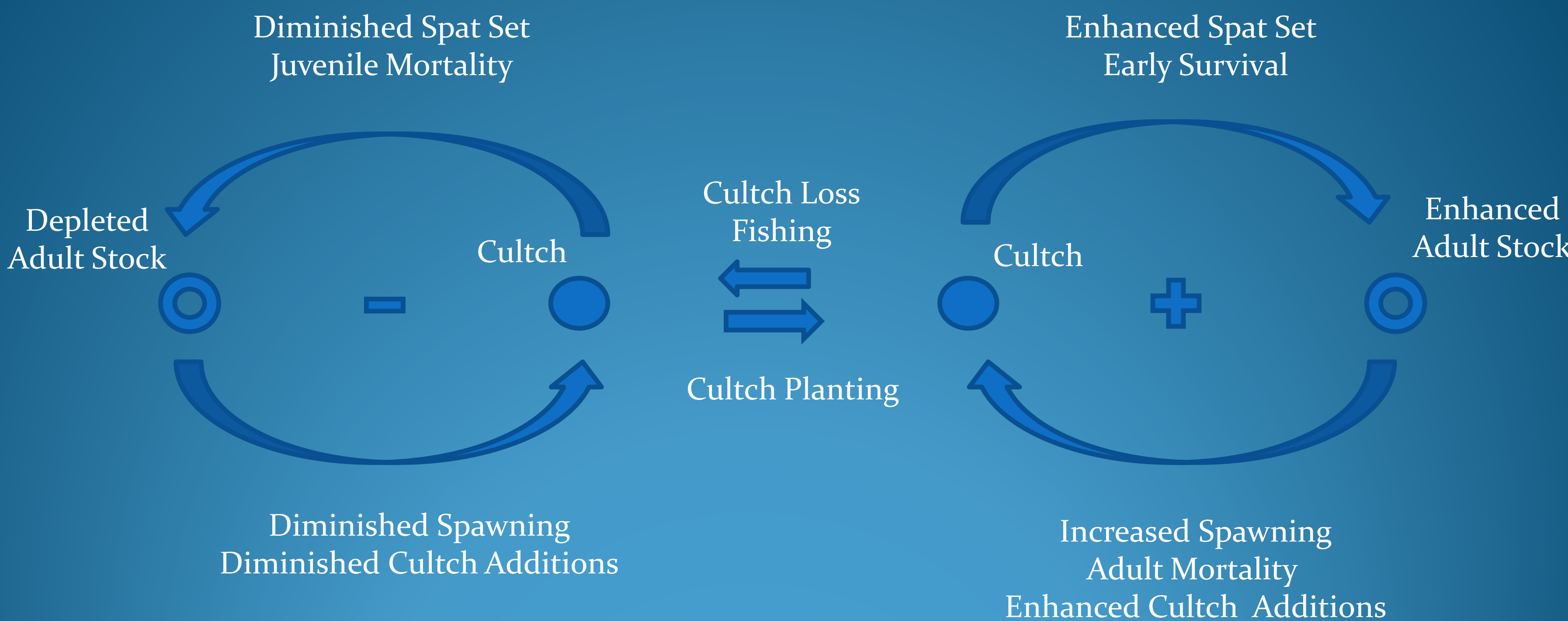
Gulf of Mexico simulated harvests

	Salinity	TX		LA		AL		FL	
OCS		Sack	Seed	Sack	Seed	Sack	Seed	Sack	Seed
	Low	0	N/A	0	0	0	N/A	26,732	N/A
	Moderate	0	N/A	0	0	0	N/A	5,228	N/A
	High	0	N/A	0	0	0	N/A	0	N/A
NNL									
	Low	1,130,391	N/A	478,229	25,203	31,343	N/A	62,070	N/A
	Moderate	941,158	N/A	458,929	6,741	230	N/A	14,690	N/A
	High	439,469	N/A	267,104	8,043	9,706	N/A	246	N/A

Soniat et al., submitted to JSR

- Sack and seed harvest is in Louisiana sacks (52.85 Liters)
- Salinity is the monthly salinity scenario
- Low salinity scenario yields largest harvests
- Seed fishing harvest in LA only
- Sustainable fishing by OCS standard only in FL
- Sack harvest allowable under NNL in all States
- Seed harvest allowable under NNL standard in LA
- Texas has the highest allowable harvest under NNL standard

Oyster reef management: a general theory of oyster reef functionality



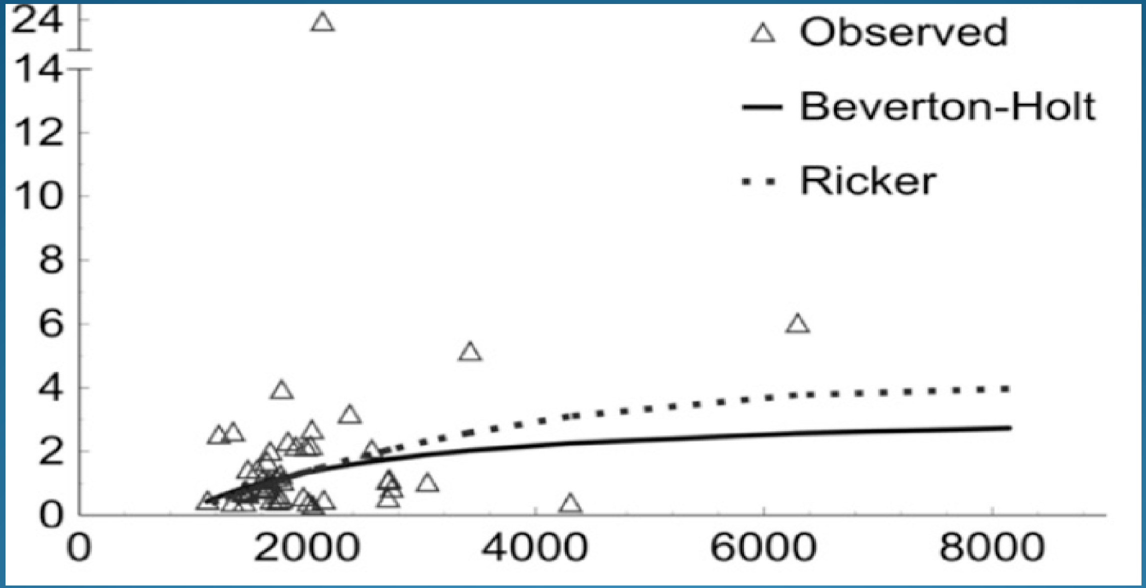
Oyster reef management: cultch

- Shell is a temporary resource
  - Shell half-lives measured *in situ* confirm that shell half lives are about 5 years in the Gulf of Mexico (Pace et al. 2020. JSR 39:245–256)

- Clean shell (ESA) diminishes very quickly
  - The decay rate of the "clean factor" associated with newly planted shell has been measured: Half life = 0.81 years (Ashton-Alcox 2021. JSR 40:191-211). Implies annual planting under NNL.

Oyster reef management: cultch vs. recruitment

Recruits (billions)



Effective Surface Area (hectares)

65 year time series

Delaware Bay

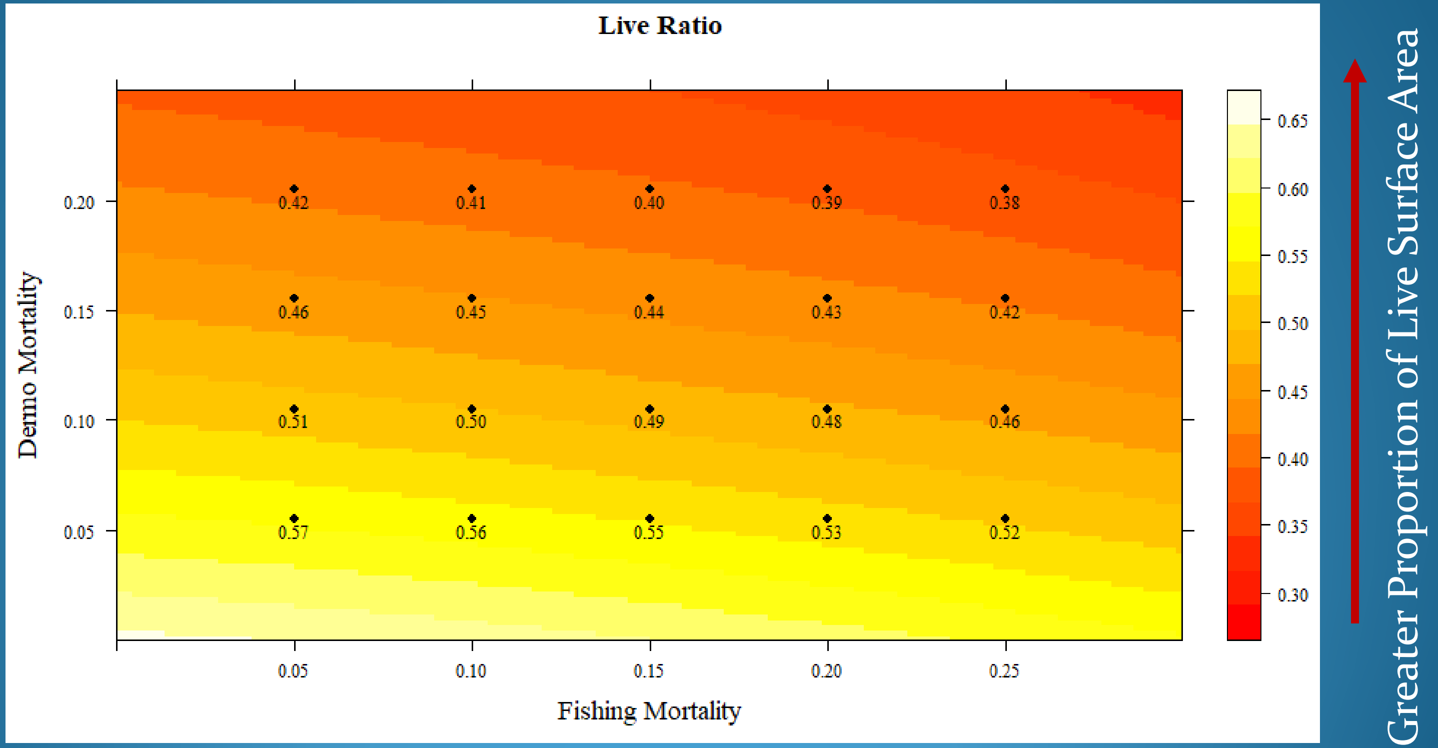
Moderate mortality reefs

Hemeon et al. 2020. JSR 39:633-645,

- Differential recruitment among substrate types and regions in Delaware Bay were used to estimate ESA (clean cultch)
- Larvae preferentially set on live oysters and boxes vs. other cultch
- Habitat quality is a surrogate for broodstock.
  Total ESA defines recruitment potential!
- The relationship follows a Beverton-Holt process (asymptomatic)
  Excessive ESA/cultch does not always lead to increased recruitment!
- There is a non-zero level of ESA/cultch at which recruitment ceases
  Reefs can be *effectively* extinct with ESA/cultch still present!

Oyster reef management: cultch vs. live surface area

- Haskin Rule: minimum ratio 40% live animals to cultch, used in Delaware Bay. Fishing ends with < 40% ratio
- Live surface area to other cultch assessed here
- Model results converge on Haskin "rule of thumb"
- Live ratio/Haskin Rule could serve as a "quick and dirty" check of overfishing



Oyster reef management: NNL vs OCS

- NNL
  - Doesn't include oyster density/cultch density standard
  - Greater harvests vs OCS (presently)
  - Not self-sustaining (requires cultch planting)
  - Provides no benchmarks for reef restoration
- OCS
  - Includes oyster density/cultch density standard
  - Restricted harvests vs NNL (presently)
  - Self sustaining (no cultch planting required)
  - Provides benchmarks for reef restoration
  - Identifies harvest at maximum sustained yield
- OCS/NNL Hybrid
  - Work toward the cultch standard but fish as NNL
  - Be cognizant of the oyster density standard
  - Don't allow cultch density of < 1000 g/m^2

Oyster reef management: summary

Requirements for successful management of oyster reefs and sustainable fishing are available

- Oyster density and cultch standards serve as restoration targets
- Simulations using OCS provide harvest estimates at maximum sustained yield

Future Activities

- Transfer code (Ruby) to Agencies

(make request to Nathan Cooper, ncooper@my.uno.edu)

- Hold R modeling session for Agency personnel

Jan./Feb. ? 2022

(Laura.Solinger @usm.edu)

Thanks to all!