External Estimates for Maryland Oyster Stock Assessment

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Compiled by Maryland Department of Natural Resources/University of Maryland Center for Environmental Science Team for Fulfillment of Oyster Stock Assessment Term of Reference #1

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1. Natural Mortality

Definition

Natural mortality = usually defined as mortality due to the combined causes of disease, starvation, predation, environmental conditions, old age, etc. (Ricker 1975; Miranda and Bettoli 2007). This includes all causes of mortality other than those effects directly due to fishing, such as harvest or death after catch and release.

Disease and unfavorable environmental conditions are thought to cause mortality in oyster populations in Maryland, but separating components of natural mortality is difficult because causes of mortality for individual oysters is usually not known. Therefore, natural mortality estimates include all sources of mortality known to affect oysters in Maryland.

Estimates

There are at least five different studies that provide estimates of natural mortality for oysters in Maryland (Table 1). These studies fall into two categories for sources used to estimate mortality. The first group involves relatively small groups of oysters placed in trays or attached to strings, kept on the bottom or suspended in the water column, and monitored over time.

The second group of studies all used data on the number of live oysters and boxes from the Maryland DNR fall survey to estimate natural mortality rates. Although these studies all used the same data, mortality was estimated in slightly different ways and for different spatial scales and populations of oysters. Some studies provide annual mortality estimates for the entire state. Some divide up estimates by different salinity zones and disease intensities.

Table 1. Data related to natural mortality estimates for the eastern oyster in Chesapeake Bay. D_{all} = All boxes, D_{rec} = Recent boxes, L = Live oysters.

Source	Method	Estimate(s)	Comments
Beaven 1950	$D_{all}/(D_{all} + L)$?	CBL: 1 year, 6 - 49% CBL: 2 years, 15 - 17% Chincoteague Bay: 1 year 3 - 5%	Trays on bottom; Estimates for MD oysters sources only
Shaw 1966	$D_{all}/(D_{all} + L)$?	Tred Avon: 44% Chincoteague Bay: 74%	Suspended off bottom; Mortality after 1.5 yrs.
Jordan et al. 2002	Model?, formula?	~10 - 60% / year	Annual estimates from 1986 - 2001
Jordan & Coakley 2004	$D_{all}/(D_{all} + L)$	Baywide: 10 - 60% / year Low Salinity: 15% / year Medium Salinity: 35% / year High Salinity: 51% / year	Range of annual estimates from 1986 - 2001 for Baywide; Mean 1986 - 2001 for salinity zones. Data from Fall Survey
Vølstad et al. 2008	$D_{rec}/(D_{rec} + L)$ $D_{all}/(D_{all} + L)$	6 - 90%	From Table 2 and estimated using recent boxes for salinity zones, disease intensity, and time since death; They also estimated using all boxes and compared to using recent boxes; Data from Fall Survey
Wilberg et al. 2011	Estimated in model, formula?	~15 - 60%	Range of Baywide annual estimates from 1980 - 2008; Data from Fall Survey

2. Age and Growth

Definition

Age = 1. Time since settlement; 2. Time since egg hatching

Growth = Change in size over time; may be positive or negative and is usually measured in length or weight.

There is usually a relationship between age and size in length or weight for a particular species. Many traditional fisheries models use the von Bertalanffy model to estimate length at age. The slope of a line fit to length-at-age data using the von Bertalanffy model is an estimate of growth.

Estimates for Oysters

There are a few estimates of length-at-age for oysters in Maryland (Table 2), which could possibly be used to fit a von Bertalanffy growth curve for oysters in Maryland.

Table 2. Data related to age and growth of eastern oysters in Maryland portion of Chesapeake Bay. Shell heights for sources 2, 4, 5, and 6 were all estimated from figures using WebPlotDigitizer.

Source		Observed Mean Shell Height (mm) at Age (yr)								
		1	2	3	4	5	6	7	8	9
1		46	73	84	-	-	-	-	-	-
		48	68	73	-	-	-	-	-	-
		67	86	92	-	-	-	-	-	-
		67	79	83	-	-	-	-	-	-
2										
	Figure 1	63	-	-	-	-	-	-	-	-
		42	70	-	-	-	-	-	-	-
		44	74	-	-	-	-	-	-	-
		36	57	-	-	-	-	-	-	-
	Figure 2	40	-	-	-	-	-	-	-	-
		37	59	74	-	-	-	-	-	-
		34	61	81	-	-	-	-	-	-
		29	-	-	-	-	-	-	-	-
	Figure 3	26	-	-	-	-	-	-	-	-
		30	-	-	-	-	-	-	-	-
		29	61		-	-	-	-	-	-
		28	-	-	-	-	-	-	-	-
		28	-	-	-	-	-	-	-	-
	Figure 4	39	67	81	-	-	-	-	-	-
3	Spaniard Point	-	-	-	-	115	-	-	-	-
	Bolingbroke Sands	-	75		-	-	-	-	-	-
	Weems Upper	-	63	-	-	-	-	-	-	-
	Chest Neck	-	56	-	-	-	-	-	-	-
4	Bolingbroke Sands	-	-	97	-	-	-	-	-	-
	Shippen Creek	44	64[a]	81[b]	106[b]	-	-	-	-	-
5	Kitts Marsh	57	75	-	-	-	-	-	-	-
6	Figure #	70	93	131	116	116	97	92	93	102
		64	80	98	116	-	-	-	119	-
		63	77	95	100	-	-	-	-	-
		58	-	90	97	-	-	-	-	-
		54	-	84	-	-	-	-	-	-
		52	-	80	-	-	-	-	-	-

[1]Beaven (1950), [2]Beaven (1953), [3]Coakely (2004), [4]Liddell (2008), [5]Harris 2003, [6]Paynter et al. (2010); [a]mean size of 11 month and 13 month, no 12 month size; [b]11 month size, no other available

3. Fecundity

Definition

Fecundity = 1. Number of eggs produced by one female; 2. Number of eggs present in ovary before spawning.

For species, such as oysters, where individuals reproduce more than once during their life time, fecundity can be measured at different time scales. For example, Galstoff (1930) induced individual female oysters to spawn and determined fecundity by estimating the number of eggs released during the spawning reaction (measured by contraction of the adductor muscle) that varied among individuals from 36 to 70 minutes. Fecundity has also been examined by determining the number of eggs present within individuals collected during the spawning season (Cox and Mann 1992).

Estimates

There are relatively few estimates of fecundity for oysters in the Chesapeake Bay. Cox and Mann (1992) examined variation in mean fecundity over time (June to October) among four stations in the James River, Virginia and found a range of 0.91 - 26.93 million eggs per female.

Galtsoff (1930) estimated that individual oysters produced between 15 and 115 million eggs in one spawning period based on observations of 4 female oysters held in tanks and induced to spawn at Woods Hole, Massachusetts. He does not explicitly state where he obtained oysters for these experiments, but it was probably somewhere nearby.

There are a few biotic and abiotic factors thought to affect fecundity, such as individual oyster size, water salinity, and disease prevalence and intensity.

Individual oyster weight was related to fecundity by Thompson et al. 1996 using the following equation:

$$\text{Fecundity} = 39.07 \times w^{2.36}$$

where w is dry tissue weight in mg and units of fecundity are millions of eggs per female.

4. Age at Maturity

Definition
Age at Maturity = age at which individuals are capable of reproducing.

Size at maturity = size at which individuals are capable of reproducing.

Estimates
There are no known estimates for age- or size at maturity for oysters in the Chesapeake Bay. Below are the sources from other areas that are related to age and size at maturity.

Galtsoff (1964; page 324) states "Toward the end of the second breeding season the primary gonad is transformed into a definite ovary or spermary."

Coe (1930) found that nearly all individuals in oyster populations from West Sayville, New York and New Haven, Connecticut were sexually mature and engage in reproduction by the end of their first year. Mean size was 31.28 and 38.54 mm for males and females, respectively, from New Haven while mean size from West Sayville was 46.33 and 59.33 mm for males and females, respectively.

5. Shell Budgets, Habitat Extent, and Rate of Habitat Change

Definition

Shell Budget = Difference between amount of shell added and removed from a specific area over time. Natural addition of shell is primarily due to the settlement and growth of new oysters to a population, while natural removal is due to the breakdown of shells after oysters die and consumption of oysters by predators, excluding humans. Large amounts of shell are removed and added every by humans. Harvest of wild oysters removes shell from oyster populations while the planting of oyster shell by humans adds shell. In Maryland the amount of shell directly removed by humans through harvest is likely greater than the amount added back through shell plantings in most years.

Habitat Extent = Area of bottom occupied by oysters; Volume of oysters present in a given area

Habitat Change = Difference in Habitat extent over time; can be negative (net loss) or positive (net gain).

Estimates

There are data for the amount of shell planted over time in Maryland from 1960 until the present time (see Data Sources document) that could be used as an estimate of the addition of shell by humans. Removal of shell by humans is primarily from harvest and so harvest records could be used to estimate the amount of shell removed each year.

6. Stock-Recruitment Relationship

Definition

Stock = Usually defined as a population or portion of population capable of reproducing; can be measured in different ways, such as spawning stock biomass, which estimates spawning stock based on the biomass of individuals that are capable of reproducing.

Recruitment = usually defined as size or life history stage or age when individuals of a species begin to be present. In a fisheries context, this is usually defined in terms of when individuals start to get caught by the fishery.

Stock-Recruitment relationship = An empirical or theoretical relationship between the stock (e.g., spawning stock biomass) and recruitment (e.g., number of age 1 fish caught in fishery) of a particular species, usually in a specific geographic location (e.g., Gulf of Mexico) during a certain time period (e.g., 1990 – 2005).

When a clear stock-recruitment relationship is found to exist, it is useful because the number of recruits at a future point in time can be predicted based on the present stock. However, many times there is not a clear stock-recruitment relationship (see below).

Estimates

There are very few studies examining stock-recruitment relationships for oysters.

Wilberg et al. (2011) examined the stock recruitment relationship of oysters in Maryland and found that recruitment generally increased linearly with stock size, but there was a lot of unexplained variability and the largest recruitment event occurred at a low stock size.

Powell et al. (2009) examined stock-recruitment relationships for oysters in Delaware Bay, and found that recruitment did not increase linearly with size but had a maximum at medium levels of stock abundance and decreased with smaller or larger stock abundances.

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