

Fish Production from a Large Scale Marsh Restoration Program

Kenneth A. Strait
PSEG Estuary Enhancement Program

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Area Protected or Restored by PSEG's EEP

TABLE 1. Area Protected or Restored by PSEG's Estuary Enhancement Program (hectares)

Type	Site	Wetland Restoration Area	Upland Buffers	Other Lands	Total Area
Diked Salt Hay Farm Restoration	Commercial Township Restoration Site	1171	137	380	1688
	Dennis Township Restoration Site	149	6	79	234
	Maurice River Township Restoration Site	459	44	62	565
New Jersey <i>Phragmites</i>-Dominated	Alloways Creek Restoration Site	648	547	58	1253
	Cohansey River Restoration Site	368	59	0	427
Delaware <i>Phragmites</i>-Dominated	Cedar Swamp Restoration Site	754	0	3	757
	The Rocks Restoration Site	298	0	0	298
Additional New Jersey Lands	Bayside Tract	0	737	1046	1783
	Heislerville WMA Lands	0	81	0	81
	Millville WMA Lands	0	211	0	211
	New Sweeden WMA Lands	0	125	0	125
	Dennis WMA Lands	0	46	0	46
Additional Delaware Lands	Lang Tract Restoration Site	102	0	4	106
	Silver Run Restoration Site	125	0	1	126
	Woodland Beach Restoration Site	476	0	3	479
	Miscellaneous Uplands	0	0	588	588
GRAND TOTAL		4552	1993	2223	8767

NEXT

Maurice River Township Wetland Restoration Site



Early 1998



Summer 2001



Spring 1998



Summer 2003

Dennis Township Wetland Restoration Site



After restoration construction - Fall 1996



After restoration construction - Fall 1996



Spring 1997



Summer 2000

Commercial Township Wetland Restoration Site



July 1999 post-construction



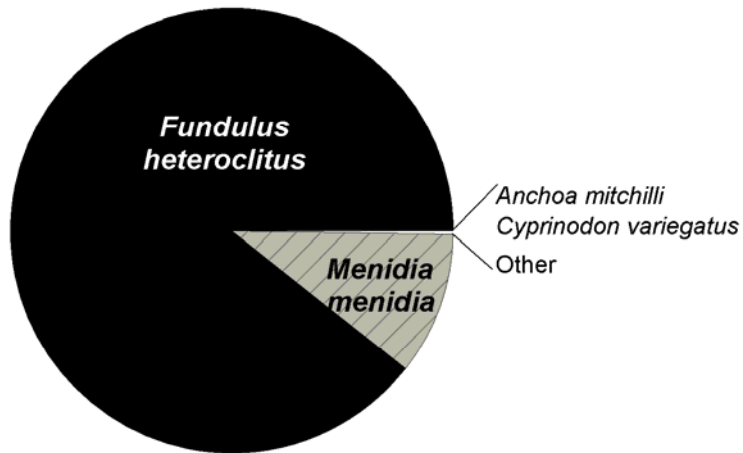
August 2003 photo of the same location

Fish Assemblage & Marsh Function

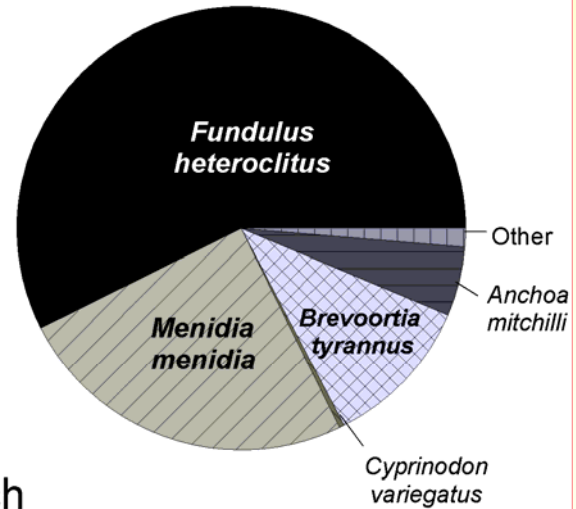
- **Structural Attributes**
 - **Species Composition**
 - **Abundance**
 - **Assemblage structure**
- **Functional Attributes**
 - **Feeding**
 - **Growth**
 - **Survival**
 - **Production**

Fish Species Composition and Relative Abundance in Small Marsh Creeks

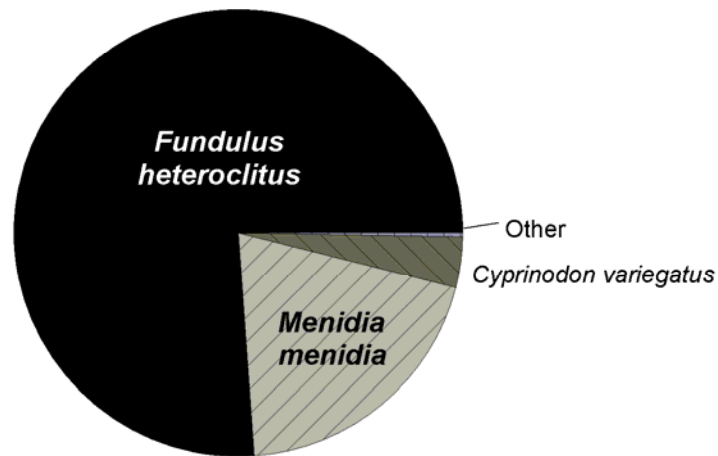
Commercial Township



Dennis Township



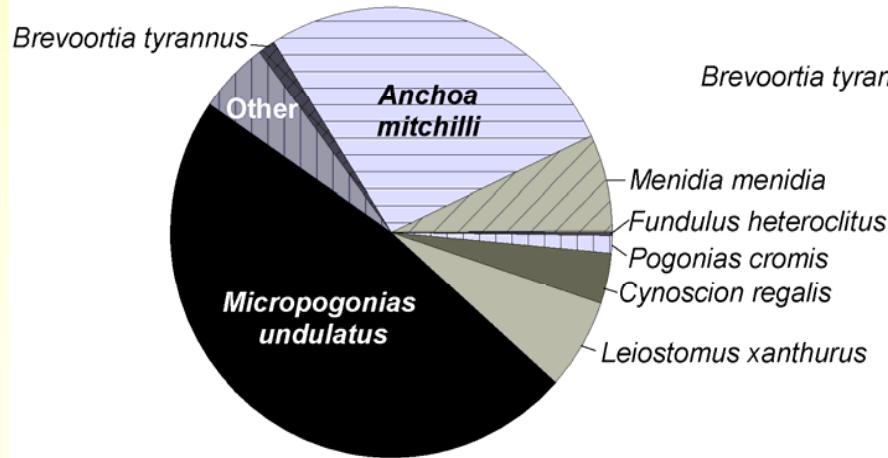
Moores Beach



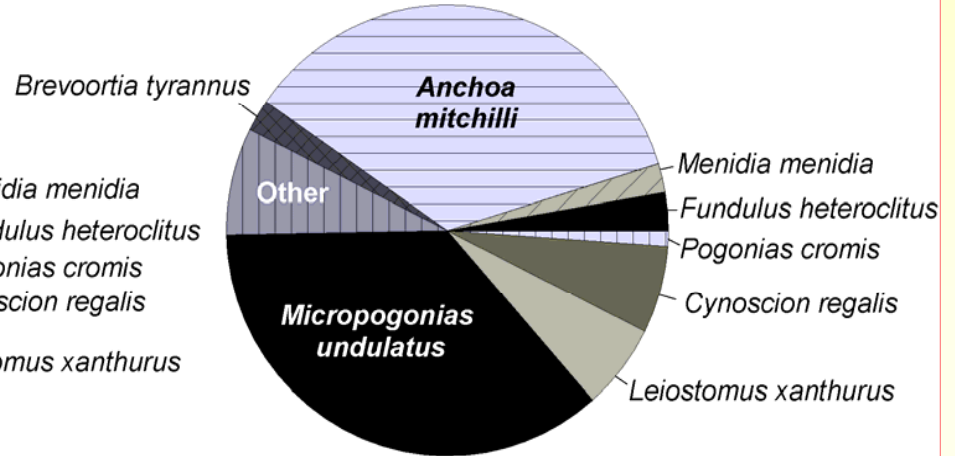
NEXT

Fish Species Composition and Relative Abundance in Large Marsh Creeks

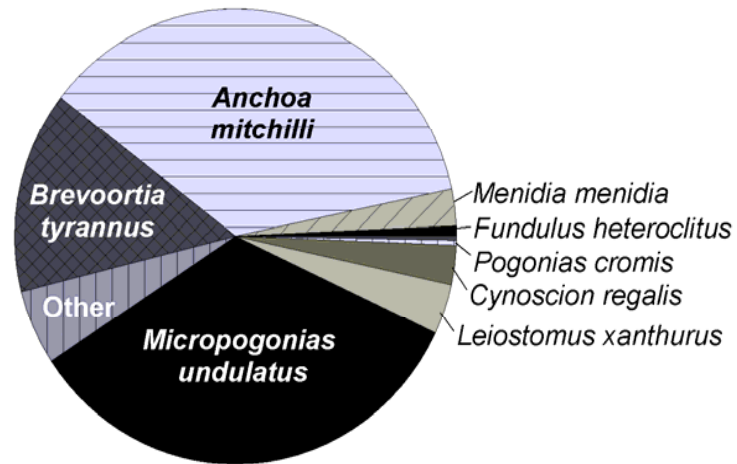
Commercial Township



Dennis Township



Moores Beach

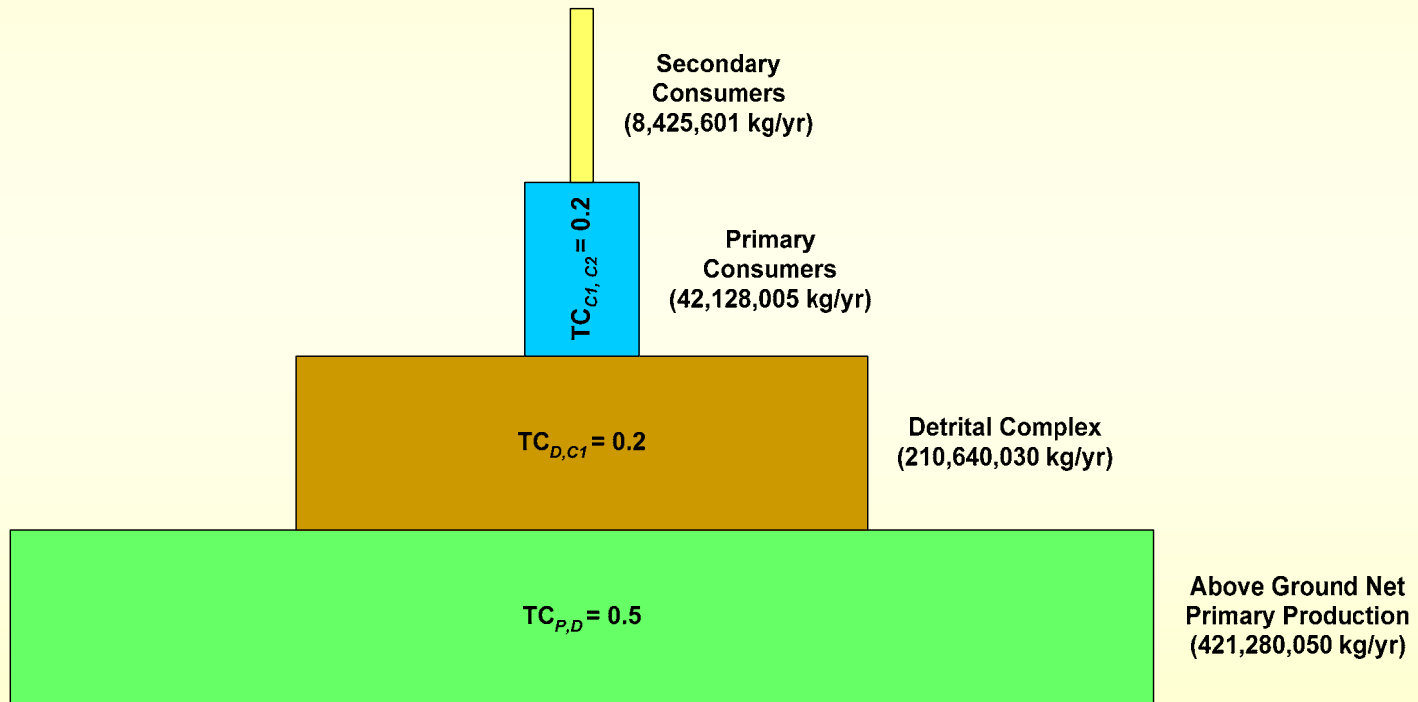


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Production of Biomass of Secondary Consumers

- Aggregated food chain model (“AFCM”) used to facilitate calculation of wetland-based production
 - **Increased PP from restored marshes results in increased production at higher trophic levels plus direct use of restored habitat**
 - **Simplifies complex food web interactions by aggregating species and lifestages across similar trophic levels to reflect basic ecosystem function**
 - **Calculate production for a species per hectare of salt marsh based on relative abundance within each trophic level**
 - **Production of biomass of secondary consumers based on empirical data on biomass of aboveground vegetation within the restored salt hay farm marshes**
 - **Lower trophic levels (*i.e.*, primary consumers) included in assessment by assuming all production by primary consumers consumed by secondary consumers**
 - **Three trophic transfers applied:**
 - 1) vegetation to the detrital complex
 - 2) detrital complex to primary consumers
 - 3) primary consumers to secondary consumers

Aggregated food chain model (“AFCM”)



Annual average production from three restored salt hay farms (2002-2004)

Aggregated food chain model (“AFCM”)

- Average annual (2002 to 2004) production of all secondary consumers attributable to the salt hay farm marshes, estimated to be 8,425,601 kg (wet weight) per year
 - **Assumes all sites have met vegetative Success Criteria**
 - **Includes organisms other than age-0 fish**
 - **Estimate likely under-represents the total secondary production attributable to the salt hay farm marshes**
 - Omits contributions from benthic algae and below ground plant production
 - Omits recycling of production back to lower trophic levels during the trophic transfer process

Uncertainty in Estimates

- Sampling error and inter-annual variability addressed by using multiple years of data
- Uncertainty associated with possible model misspecification errors addressed by using multiple, independent methods to estimate production
 - Vegetation-Based Estimates (Aggregated Food Chain Model)
 - Ecosystem - Based Estimates (Ecopath with Ecosim)
 - Fish Abundance - Based Estimates

Ecosystem-Based Estimates (Ecopath with Ecosim)

- Implemented by Michael G. Frisk and Thomas J. Miller of the Chesapeake Biological Laboratory of the University of Maryland, Robert J. Latour of the Virginia Institute of Marine Science, and Steven J.D. Martell of the University of British Columbia
- Details in PSEG NJPDES Permit Renewal Application
- EwE model was developed with participation from representatives of regulatory agencies and academic institutions
- EwE describes and quantifies production and mortality of individual species and trophic groups in the Delaware Estuary ecosystem

Ecosystem-Based Estimates (Ecopath with Ecosim)

- Two main components:
 - **Mass-balance snapshot of the ecosystem (Ecopath)**
 - Annual production was estimated from reconstructions of historical biomass and recruitment (stock assessments) and estimated losses from anthropogenic sources (e.g. harvest)
 - Twenty-four species, including alewife, American shad, Atlantic croaker, Atlantic menhaden, bay anchovy, blue crab, bluefish, spot, striped bass, weakfish, and white perch were identified along with 16 groups of species (e.g., benthic meiofauna and littoral forage fish)
 - **Dynamic simulation model for predicting changes in biomass over time in response to changes in fishing policies, productivity and trophic interactions (Ecosim)**
 - Re-expresses the static mass-balanced equations inherent to Ecopath as a system of coupled differential equations

Ecosystem-Based Estimates (Ecopath with Ecosim)

- Model estimates for the “base run” scenario and scenario with a 3% reduction in marsh habitat without restoration
 - **Wetland restoration adds annual average total system biomass of 82,903,614 kg**
- Comparison of changes in total system biomass to production of secondary consumers (the metric of production from the AFCM)
 - **Total system biomass used as surrogate for total system production (conservative)**
 - **Production of secondary consumers is subset of total system production**
 - Remove primary production by phytoplankton (14,919,423 kg/yr)
 - Remaining 68,070,257 kg/yr includes production by primary consumers, secondary consumers and tertiary consumers
 - Using trophic conversion factors, portion of total heterotroph production that is production of secondary consumers is 10,979,074 kg/yr
 - 1,920,086 kg/yr for dominant fish species (alewife, American shad, Atlantic croaker, Atlantic menhaden, bay anchovy, blue crab, bluefish, spot, striped bass, weakfish, and white perch) and littoral forage fish

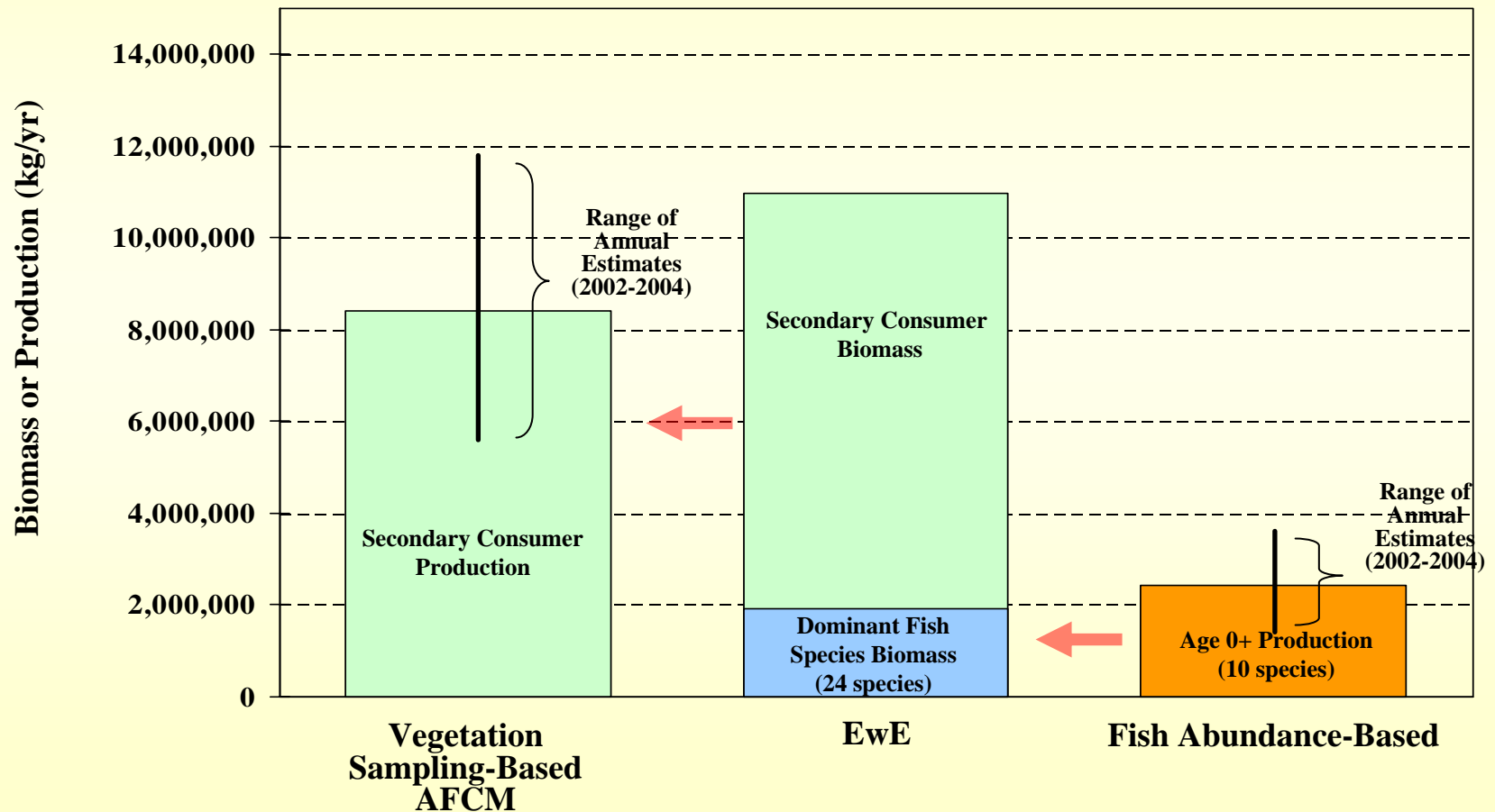
Fish Abundance - Based Estimates

- Production of age-0 fish biomass within the restoration sites plus annual production of age-0 fish biomass in the open waters of Delaware Estuary attributable to the restoration sites
- Estimates based on empirical catch data (2002 to 2004) from baywide and marsh bottom trawl, pelagic trawl, beach seine, and marsh weir sampling
 - **Onsite marsh production attributable to restoration estimated directly from average number of fish present in restored salt marshes and expected daily growth rates (from bioenergetics models) of those fish**
 - **Estimates of open-water production attributable to restoration based on the total open water production of age-0 fish biomass (kg per year), and on fraction of all available food for juvenile fish that was attributable to restoration**
 - Majority of food available to age-0 fish in Delaware Estuary derived from tidal marsh production
 - Ratio of restoration acreage to acreage of all tidal marshes within Delaware Estuary
- Average annual age-0 fish production attributable to restoration for the 10 species of fish estimated to be 2,419,861 kg (wet weight) per year

Uncertainty in Estimates

- Estimates of production from independent methods not directly comparable to estimate from the AFCM, but provide corroboration
 - **EwE estimate of 10,979,074 kg/yr likely an underestimate because it is based on biomass as a surrogate for production**
 - P:B ratios for dominant taxa > 1
 - 1,920,086 kg/yr for dominant fish species
 - **Fish abundance-based estimate of production for 10 species of age-0 fish of 2,419,861 kg provides corroboration for the EwE method for dominant fish species, and therefore, for the AFCM estimate**

AFCM Corroboration



Conclusions

- Vegetation & geomorphology of restored marshes comparable to reference marshes
- Fish utilization data indicate that restored marshes function like reference marshes
- Secondary production from restoration of three formerly diked salt hay farms (1779 ha) estimated to be 8,425,601 kg (wet weight) per year (4736 kg/ha)
- Multiple, independent methods corroborate estimate of secondary production resulting from AFCM