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Table 3. The occurrence and composition of benthic algae collected in Barnegat Bay from June 1965 to June 1968. (After Taylor, 1970.)

Month	Number of Species					% Composition			
	Chlorophyta	Xanthophyta	Phaeophyta	Rhodophyta	Total	Chlorophyta	Xanthophyta	Phaeophyta	Rhodophyta
Jan	10	0	14	13	37	27.0	0	37.8	35.1
Feb	9	0	14	12	35	25.7	0	40.0	34.2
Mar	13	0	15	22	50	26.0	0	30.0	44.0
Apr	8	0	9	15	32	25.0	0	28.1	46.8
May	19	0	21	24	64	29.6	0	32.8	37.5
Jun	31	1	22	35	89	34.8	1.1	24.7	39.3
Jul	25	0	8	34	67	37.3	0	11.9	50.7
Aug	15	0	3	23	41	36.5	0	7.3	56.0
Sep	3	0	0	8	11	27.2	0	0	72.0
Oct	12	0	3	23	38	31.5	0	7.8	60.5
Nov	2	0	1	13	16	12.5	0	6.2	81.2
Dec	17	0	21	19	57	29.8	0	36.8	33.3

Ulva lactuca, *Gracilaria tikvahiae*, *Codium fragile*, *Zostera marina*, *Ceramium fastigiatum*, and *Agardhiella subulata*) consistently dominate the flora. For example, from June 1965 to June 1968, 86.5% of the benthic algae occurred less than 50% of the time (Loveland et al., 1969). Thirty-one species appeared only twice during this three-year period, and more than half (58%) of the species were present less than 25% of the time. Only 16 species were sampled more than 50% of the time. Since 1965, the only major change in dominance has been *Codium fragile*, which first appeared in the bay in 1965 and rapidly became a dominant species (Taylor, 1967; Taylor et al., 1969).

Table 4 shows an annual rank of the top 10 macroflora in Barnegat Bay

Table 4. The top ten macrophyte species collected in Barnegat Bay between 1969 and 1973. Species ranked according to the percent dry weight of sample summed over the entire year. (After Vouglitois, 1976).

Rank	Year 1969	1970	1971	1972	1973
1	Ulva lactuca	Ulva lactuca	Ulva lactuca	Ulva lactuca	Ulva lactuca
2	Codium fragile	Gracilaria tikvahiae	*Zostera marina	*Zostera marina	Gracilaria tikvahiae
3	*Zostera marina	*Zostera marina	Codium fragile	Gracilaria tikvahiae	Ceramium sp.
4	Gracilaria tikvahiae	Codium fragile	Gracilaria tikvahiae	Codium fragile	Enteromorpha intestinalis
5	Ceramium fastigiatum	Enteromorpha linza	Enteromorpha intestinalis	unidentified Ulvaceae	*Zostera marina
6	Polysiphonia harveyi	Agardhiella subulata	Enteromorpha sp.	Enteromorpha intestinalis	Codium fragile
7	Cladophora sp.	Polysiphonia harveyi	Agardhiella subulata	Agardhiella subulata	Spyridia filamentosa
8	Agardhiella subulata	Ceramium sp.	*Ruppia maritima	Chaetomorpha aerea	Champia parvula
9	Ceramium sp.	Ceramium fastigiatum	**	**	Polysiphonia sp.

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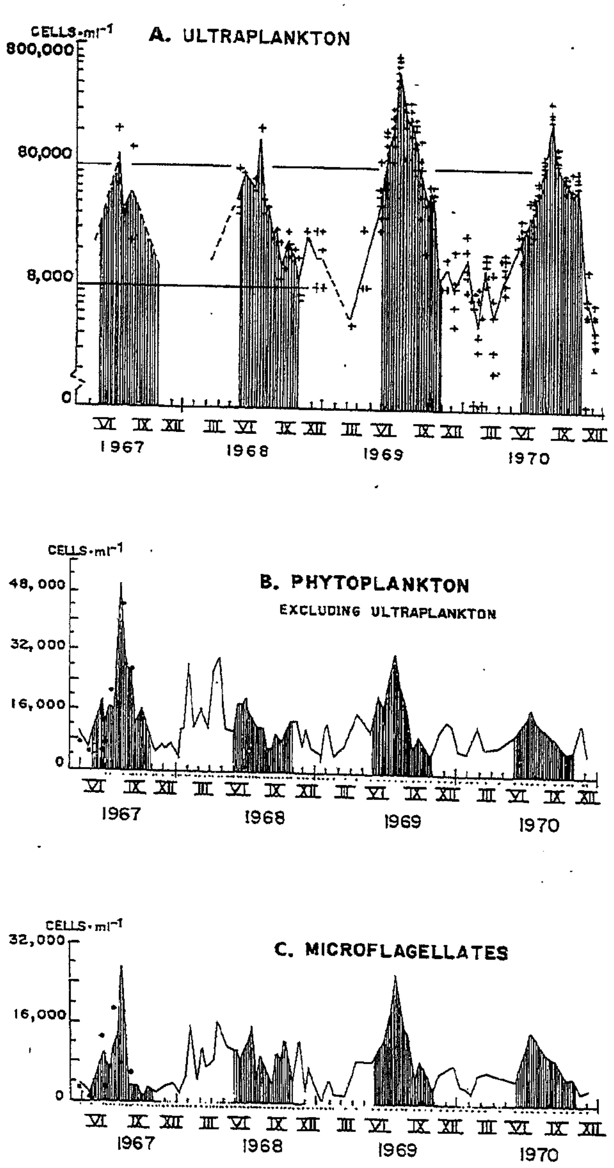

Figure 4. Selected phytoplankton assemblage counts for Barnegat Bay from 1967 to 1970. (A) Ultraplankton (note log scale). (B) Total phytoplankton excluding ultraplankton. (C) Total microflagellates. Shaded portions

1959). Mountford (1971) found a positive correlation betwee
and nanoplankton abundance and high summer gross phot
Valkenburg and Flemer (1974) demonstrated that
photosynthesis in Chesapeake Bay water samples was due to
less than 30 μm in size.

Microflagellates, taken together as a broad taxonomi
extremely abundant in Barnegat Bay (Figure 4C), rea
densities of 16,000-27,000 cells ml^{-1}. Next to ultraplankton,
were the most abundant phytoplankton organisms. Their
surface to volume ratio, and ability to swim toward or away
other stimuli may give them a competitive advanta
phytoplankton. Their potential for utilizing heterotrophic
also cannot be discounted (Cohen, personal communication).

Conrad and Kufferath (1954) reported a number of
variations in the microflagellate, *Calycomonas gracilis.* Sever
organism were common in Barnegat Bay during the period
and October (Figure 5A). Marshall and Wheeler (1965) fo
and *C. ovalis* dominant in the Niantic estuary through muc
from March through November, comprising up to 99% of
Calycomonas is present in Chesapeake Bay during summ
abundant than in Barnegat Bay (Mountford, unpublish
organism has a durable lorica and is, thus, easily distinguis
genera and enumerated. Many other microflagellates are diff
in fixed material and may frequently be confused, even
zoospores and gametes of benthic algae. Quantitative
individual species is, therefore, suspect, but the
microflagellates as a group is indisputable. The genera
Cryptomonas, Pyramimonas, Carteria, Scherefflia, and *Chroom*
recorded through the year under a wide range of environment

During summer, another major group of phyto
dinoflagellates, were consistently abundant. Martin (1
dinoflagellate accumulations which discolored the water,
dinoflagellate accumulations were also noted during the study
here. Intense luminescent, dinoflagellate blooms occurre
night during summer and fall. They were most often observ
weather or in coves sheltered from the wind. The thecate
Gonyaulax spinifera, was often associated with luminescent e
of *Noctiluca miliaris* (a nonphotosynthetic dinoflagellate) w
late in the year as November (1968) off Island Beach State Pa
personal communication).

Red-water patches which appeared during the warmer
associated with *Prorocentrum minimum, P. redfieldi, Gymnodin*
(probably) *G. splendens.* In 1964, an extensive bloom, locall
as a "red-tide," killed crabs, molluscs, and small fishes nea

er as water temperature and isolation increased. An inland thaw and the sequent increase in freshwater runoff may also have generated a nutrient e contributing to the bloom.

'halassiosira nordenskioldii and *Detonula confervacea*, two large n-forming diatoms, sequentially dominated the phytoplankton in terms ell numbers and biomass during the winter-spring diatom bloom each (Figures 5E, F). It is possible that *T. nordenskioldii* may be inoculated more nutrient-rich bay water from the nearshore ocean (Mountford,)a). Although these large diatom species dominated in terms of biomass, :oflagellates, as a group, still comprised more than 50% of the total iber of cells recorded.

.tense grazing by zooplankton, particularly the copepod *Acartia sonica*, accompanied termination of the winter-spring diatom bloom (see pter 5). This shift could be seen in net plankton samples. During the . bloom, they were rich green, but two weeks later, they were ish-white with zooplankton. Temperature seemed to mediate the ation of growth by *Thalassiosira*. *Skeletonema* usually replaced the *lassiosira-Detonula* complex in spring as water temperature rose toward : and light increased (Curl and McLeod, 1961; Riley, 1966). When water)erature exceeded 20°C, the diatom component decreased, and oflagellates and dinoflagellates dominated.

hen water temperature reached approximately 23°C in each of the years ied, massive reproduction by the ctenophore *Mnemiopsis leidyi* provided iden pulsed, predatory effect that rapidly reduced zooplankton biomass untford, 1980b). This reduction of zooplankton may have limited ng pressure on phytoplankton, contributing to higher phytoplankton idance during the summer.

ie resuspension of benthic material may resolubilize the key nutrients h sustain phytoplankton growth (see Chapter 2). Such resuspension rs on many days during the warm months as a function of a strong breeze" effect. Mountford (1971) showed that a distinct negative ionship existed between wind velocity and the maximum observed hi disk depth, a reflection of wind-induced resuspension. Nutrients ıerated in the water column through microbial activities and excretion organisms during the warm months also result in increased ɔplankton production, as do nutrients entering the estuary via streams ıing the New Jersey Pine Barrens (see Chapter 2).

ırophyll Standing Crop

seasonal patterns observed in phytoplankton counts are to some extent cted in data generated by extracting chlorophyll *a* as a biomass estimate.)69 and 1970, chlorophyll *a* concentrations during the warmer months elevated during the period of maximum cell counts. In 1970, however, est individual chlorophyll *a* determinations accompanied the er-spring diatom bloom, reflecting the abundance of large

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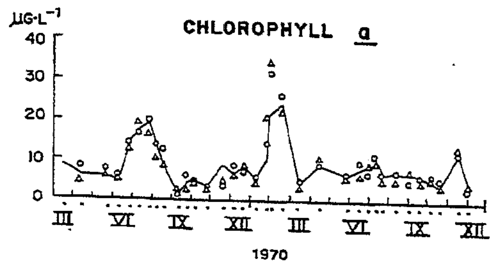

Figure 6. Chlorophyll *a* concentrations in $\mu g\ l^{-1}$ over a 22-month period for middle and lower Barnegat Bay. Solid line is the mean of five stations (I-V). Open circle shows generally higher values within the bay at station III. Open triangle shows generally lower values because of the seawater contribution at station V.

6, chlorophyll concentrations ranged from about 1 to greater than 35 $\mu g\ l^{-1}$. These surface sample values probably underestimate peak concentrations that occur in blooms because dense plankton patches did not occur at the precise points sampled. The range of values is comparable to that observed in Chesapeake Bay by Flemer (1970), but is lower than that of the Indian River, Delaware, which ranged from 10 to 400 $\mu g\ l^{-1}$. It is also lower than some tidal rivers of Chesapeake Bay, such as the Potomac, where severe eutrophication is reflected in dinoflagellate-bloom, chlorophyll *a* levels (phaeopigment corrected) substantially greater than 1,000 $\mu g\ l^{-1}$ (Academy of Natural Sciences of Philadelphia, 1977).

On a given date, chlorophyll *a* concentrations often varied substantially from one station to another. Much of this variation reflects the patchiness characteristic of phytoplankton distribution in coastal embayments (Harris and Smith, 1977). Long-term data taken over 22 months, however, began to reflect differences which appeared to be characteristic of position within the estuary. An example of this pattern is reflected in Figure 6, where station V, located closer to the influence of less phytoplankton-rich seawater, had consistently lower standing crop than stations either upestuary or closer to the mouths of tidal creeks discharging to the bay (Mountford, 1969b). Nutrient studies in Chapter 2 help to explain this observation.

Primary Productivity

Primary production in Barnegat Bay (Figure 7) showed a seasonal periodicity which followed phytoplankton abundance and the annual temperature cycle. This periodicity is not always seen in temperate estuaries because, while productivity may be high, grazers may limit phytoplankton standing crop. In Barnegat Bay, zooplankton depression resulting from ctenophore predation may permit the maintenance of higher phytoplankton standing crop.

Maximum observed photosynthesis occurred during the summer months when gross productivity highs ranged from 500 to greater than 750 mg

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death assemblages. Kennish (1978) attributed the lack of individuals among the smaller size classes to poor recruitment in the bay during the mid-1970s. The negative skewness and the predominance of larger and older specimens in the death assemblages were ascribed to growth rates that decrease with age and mortality rates that increase with age subsequent to spat settlement. Most clams among the life assemblages comprised larger size classes (40-70 mm) and older age classes (4-9 years).

In Barnegat Bay, most hard clams live less than nine years and grow less than 80 mm in shell height and length. Under ideal ecological conditions, however, physiological longevity may exceed 25 years (Hopkins, 1930; Belding, 1931). Life tables formulated by determining the age at death of specimens in death assemblages demonstrate that hard clams older than one year experience low mortality between the ages of one and five years (Table 5) (Kennish, 1978, 1980). Mortality of adults is greatest between the ages of five and nine years. Mortality in early life is greatest during the planktonic and pediveliger stages (Thorson, 1950; Carriker, 1961). Therefore, mortality during ontogeny is high in the planktonic larval and pediveliger stages, lower subsequent to the plantigrade stage, and high again in the gerontic stage.

Seasonal mortality of hard clams in the estuary is highest in the summer and winter and lowest in the spring and fall (Kennish, 1978). High summer mortality may be due to the physiological stress of spawning and to increased predator and parasite activity during the warmer months of the year. High winter mortality may be caused by harsh environmental conditions, including low food supply and excessively low water temperatures (Kennish, 1978).

Distribution and Density

Campbell (1965, 1966, 1969) conducted extensive field surveys of the hard clam resource in central Barnegat Bay during the summers of 1965, 1966, and 1968, and Vouglitois and Kennish (1980) performed similar surveys during the summers of 1978 and 1979. These studies were undertaken to assess the distribution and density of hard clam populations in the estuary and to determine their recreational and commercial value. Approximately 2,430 ha of potential shellfish beds were sampled.

Campbell found hard clams to be uniformly distributed in very low densities throughout the sampling area (Figure 2). In general, densities increased toward the southern perimeter of the bay. Tiller et al. (1952) also reported the most productive clam grounds in the bay's southern range.

The estimated standing crop of hard clams in the central bay amounted to 209,000 bu (bushels) (approximately 948 MT of meats), with clams larger than 66 mm in length being the most abundant. Individuals less than 66 mm in length occurred in extremely low densities, reflecting a very low level of recruitment into the population. Campbell concluded that the bay contained a limited hard clam resource suitable for sport and moderate commercial harvest.

Table 5. Life Table for *Mercenaria mercenaria* at site 4 (see Figure 1). (After Kennish, 1980.)

Age interval x to x + 1 years	Proportion dying in interval (x, x + 1) 1000 q_x	Number living at age x I_x	Number dying in interval (x, x + 1) d_x	Number of time-spans lived in interval (x, x + 1) L_x	Total number of time-spans lived past age x T_x	Average life expectancy (in years) at age x e_x	Proportion surviving in interval (x, x + 1) P_x
1-2	0.00	1000	0	1000.0	5074.0	5.0740	1.0000
2-3	0.00	1000	0	1000.0	4074.0	4.0740	1.0000
3-4	30.00	1000	30	985.0	3074.0	3.0740	0.9700
4-5	122.68	970	119	910.5	2089.0	2.1536	0.8773
5-6	324.32	851	276	713.0	1178.5	1.3848	0.6757
6-7	775.65	575	446	352.0	465.5	0.8096	0.2244
7-8	620.16	129	80	89.0	113.5	0.8798	0.3798
8-9	1000.00	49	49	24.5	24.5	0.5000	0.0000

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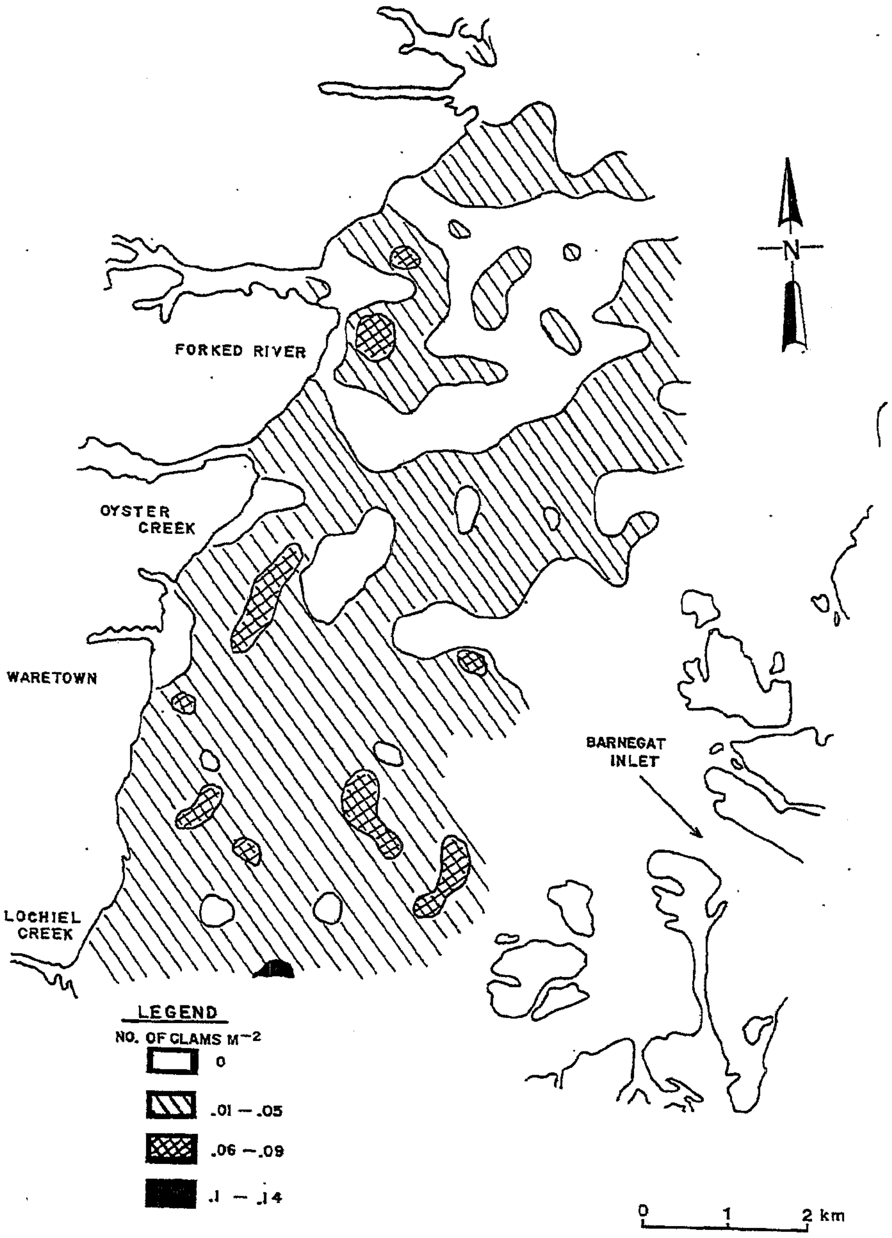


Figure 2. Distribution and density of the hard clam, *Mercenaria mercenaria*, in central Barnegat Bay during the summers of 1965, 1966, and 1968. (After Campbell, 1969.)

Figu... 9 populatic performed by ... 1978, the standing crop of hard clams ... proximately meats), one-fifth of that recorded ... (1969). You Kennish (1980) also observed an increase in ... densities t southern margin of the estuary. Specimens greater than 66 mr comprised 70.5% of the population in the survey area du Individuals less than 20 mm in length were scarce (less than population); thus, the low level of recruitment noted by Campbel the 1960s continued in the 1970s.

Ponar dredge samples taken at sites in the central bay by You Kennish (1980) during 1978 and 1979 yielded dense concen recently-set clams between 1 and 5 mm in length (Figure 3). ranged from 20 to 1,580 m^{-2} in 1978 and from 4 to 80 m^{-2} in occurrence of young-of-the-year clams coincided, to a large extent of adults. There were areas, however, where significant concen adults existed in the absence of recently-set juveniles. Young c found exclusively in sandy sediments along the eastern and weste of the bay, and they were conspicuously absent from the deep portion of the estuary where fine muddy sediments predominate. densities suggest that the chronic problem of year-class failure r recent years (Kennish, 1978, 1980) may not be caused by a lack of larval settlement but by heavy losses to predators following settlem

Carriker (1961) investigated the distribution and density of r hard clams in Little Egg Harbor, an estuary contiguous with Barne the south, and found a maximum of 125 m^{-2}. This density is su less than that observed in Barnegat Bay during 1978. Historically hard clam landings in Little Egg Harbor have been two to four tir than those in Barnegat Bay.

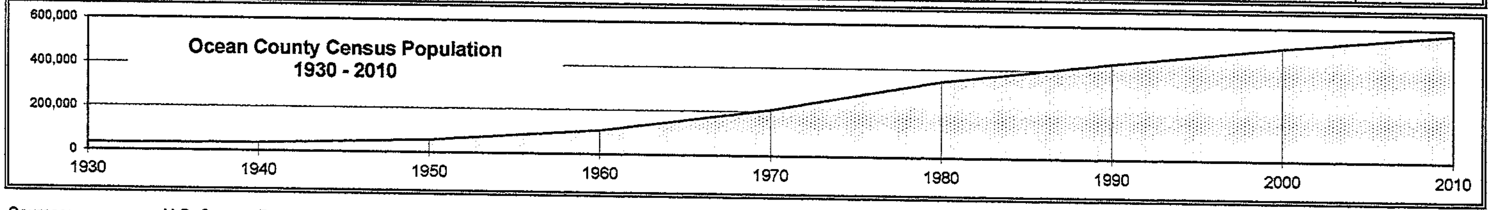
Status of the Resource

The hard clam is the most valuable species landed commercially i Bay (see Chapter 11). It is also harvested in the recreation although no catch statistics exist. Commercial landings of the hard significantly greater during the 1950s (approximately 300 MT of year) than during the 1960s and 1970s (approximately 100 MT of year), reflecting, in part, the recent closure of many hectares o beds due to a deterioration in water quality. Figure 4 shows hect bay which are presently closed to shellfishing on a seasonal and ar because of adverse water quality conditions.

Tiller et al. (1952), in a review of the hard clam fishery of t coast, indicated that the most productive clam grounds in N extended from the southern part of Barnegat Bay to Cape May. Harbor and Great Bay had the greatest harvests, and these tw

Historical Population Trends in Ocean County, by Municipality, 1930 - 2010

Municipality	Incorporation Date	1930	1940	1950	1960	1970	1980	1990	2000	2010	Total Change
Barnegat Township	1846	1,037	1,045	1,173	1,270	1,539	8,702	12,235	15,270	20,936	19,891
Barnegat Light Borough	1904	144	225	227	287	554	619	675	764	574	349
Bay Head Borough	1886	429	499	808	824	1,083	1,340	1,226	1,238	968	469
Beach Haven Borough	1890	715	746	1,050	1,041	1,488	1,714	1,475	1,278	1,170	424
Beachwood Borough	1917	394	650	1,251	2,765	4,390	7,687	9,324	10,375	11,045	10,395
Berkeley Township	1875	811	1,127	1,550	4,272	7,918	23,151	37,319	39,991	41,255	40,128
Brick Township	1850	1,172	1,376	4,319	16,299	35,057	53,629	66,473	76,119	75,072	73,696
Eagleswood Township	1874	483	551	623	766	823	1,009	1,476	1,441	1,603	1,052
Harvey Cedars Borough	1894	53	74	106	134	314	363	362	359	337	263
Island Heights Borough	1887	453	392	795	1,150	1,397	1,575	1,470	1,751	1,673	1,281
Jackson Township	1844	1,719	2,153	3,513	5,939	18,276	25,644	33,233	42,816	54,856	52,703
Lacey Township	1871	692	752	966	1,940	4,616	14,161	22,141	25,346	27,644	26,892
Lakehurst Borough	1921	947	827	1,518	2,780	2,641	2,908	3,078	2,522	2,654	1,827
Lakewood Township	1892	7,869	8,502	10,809	16,020	25,223	38,464	45,048	60,352	92,843	84,341
Lavallette Borough	1887	287	315	567	832	1,509	2,072	2,299	2,665	1,875	1,560
Little Egg Harbor Township	1798	547	577	644	847	2,972	8,483	13,333	15,945	20,065	19,488
Long Beach Township	1899	355	425	840	1,561	2,910	3,488	3,407	3,329	3,051	2,626
Manchester Township	1865	1,009	918	1,758	3,779	7,550	27,987	35,976	38,928	43,070	42,152
Mantoloking Borough	1911	37	58	72	160	319	433	334	423	296	238
Ocean Township	1876	387	427	520	921	2,222	3,731	5,416	6,450	8,332	7,905
Ocean Gate Borough	1918	174	242	452	705	1,081	1,385	2,078	2,076	2,011	1,769
Pine Beach Borough	1925	72	163	495	985	1,395	1,796	1,954	1,950	2,127	1,964
Plumsted Township	1845	1,215	1,580	2,093	3,281	4,113	4,674	6,005	7,275	8,421	6,841
Point Pleasant Borough	1920	2,058	2,082	4,009	10,182	15,968	17,747	18,177	19,306	18,392	16,310
Point Pleasant Beach Borough	1886	1,844	2,059	2,900	3,873	4,882	5,415	5,112	5,314	4,665	2,606
Seaside Heights Borough	1913	399	549	862	954	1,248	1,802	2,366	3,155	2,887	2,338
Seaside Park Borough	1898	571	653	987	1,054	1,432	1,795	1,871	2,263	1,579	926
Ship Bottom Borough	1925	277	396	533	717	1,079	1,427	1,352	1,384	1,156	760
South Toms River Borough	1927	405	445	492	1,603	3,981	3,954	3,869	3,634	3,684	3,239
Stafford Township	1749	1,039	1,253	1,347	1,930	3,684	10,385	13,325	22,532	26,535	25,282
Surf City Borough	1884	76	129	291	419	1,129	1,571	1,375	1,442	1,205	1,076
Toms River Township	1767	3,970	5,165	7,707	17,414	43,751	64,455	76,371	89,706	91,239	86,074
Tuckerton Borough	1901	1,429	1,320	1,332	1,536	1,926	2,472	3,048	3,517	3,347	2,027
Ocean County	**1850**	**33,069**	**37,675**	**56,609**	**108,240**	**208,470**	**346,038**	**433,203**	**510,916**	**576,567**	**538,892**



Sources: U.S. Census Bureau, 2010 Census Redistricting Data (Public Law 94-171) Summary File, Table H1; NJ Department of Labor and Workforce Development, February, 2011.
Prepared by: Ocean County Department of Planning, March 2011.