State of New Hampshire
Inter-Department Communication

Date: January 12, 2010

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At (Office): Environmental Services
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Subject: Probabilistic Assessments of Water Quality in NH's Estuarine Waters

To: Gregg Comstock, Supervisor, Water Quality Planning Section

The purpose of this memorandum is to summarize the results of probabilistic assessments of water quality for New Hampshire's estuarine waters. Probability based monitoring uses randomly assigned stations to take an unbiased sample of a natural resource. Statistics from the sample can be used to make inferences about conditions throughout the resource. The major advantage of this approach is that 100% of the resource can be assessed at minimal cost. The biggest disadvantage is that the specific locations of water quality violations cannot be inferred from the sample. Therefore, the results of the probabilistic assessment must be used in concert with the deterministic assessments of individual assessment units in the Assessment Database (ADB).

This memorandum describes the methods used to develop probabilistic assessments for NH's estuaries and the results. Tables containing the required data elements for reporting probabilistic data for the Section 305(b) Report are included.

Methods

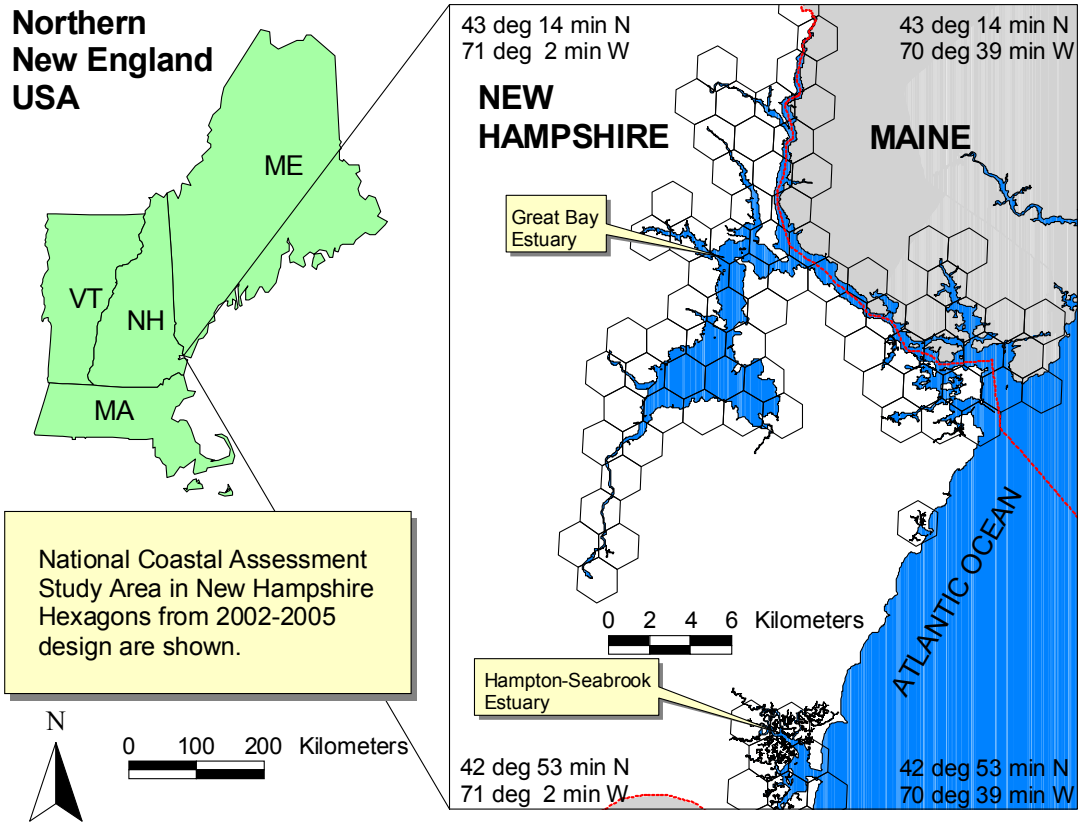
Data Source

The data sources for these assessments are the National Coastal Assessment (2002 to 2006) and the New Hampshire Estuaries Probability Based Monitoring Program (2007). The National Coastal Assessment was a seven-year monitoring effort funded by the U.S. Environmental Protection Agency and implemented within New Hampshire's estuaries by the N.H. Department of Environmental Services (DES) and the University of New Hampshire (UNH). Each coastal state was monitored using a consistent suite of indicators and a probabilistic monitoring design so that an accurate assessment of the nation's coastal resources could be completed. After the National Coastal Assessment ended in 2006, DES and the Piscataqua Region Estuaries Partnership funded water quality sampling in the estuary using a probabilistic design in 2007 (the second year of a two year design), and 2008-2009 (a two year design). This monitoring program is called the New Hampshire Estuaries Probability Based Monitoring Program. Complete data from the 2008-2009 probabilistic design are not available. Therefore, the most recent water quality data for these assessments are from the 2006-2007 design and the most recent sediment quality data are from 2002-2005.

Study Area

DES has delineated 69 assessment units of estuarine waters in New Hampshire covering a total of 17.97 square miles. The National Coastal Assessment study area for New Hampshire is larger (21.71 square miles). It covers all of the New Hampshire estuarine assessment units plus some estuarine area in Maine. The study area was designed for the Great Bay Estuary, the Piscataqua River, and the Hampton/Seabrook Estuary. The centerline of the Piscataqua River forms the border between New Hampshire and Maine. The National Coastal Assessment study area was overlain by a grid of 82 equal area hexagons for the stratified random probability based monitoring design for 2002-2005 (Figure 1). Out of the 82 hexagons in the original study design, 71 hexagons were entirely or partially in NH waters, and 11 were located entirely in Maine. For the 2006-2007 study design, 50 stations were randomly located throughout the estuary using a Generalized Random Tessellation Stratified (GRTS) spatially-balanced survey design. Thirty-nine and eleven of the 50 stations fell in New Hampshire and Maine, respectively.

Figure 1: Study Area for the National Coastal Assessment in New Hampshire



Data Collection

Between 2002 and 2005, DES and UNH attempted station visits to each of the 82 hexagons in the study design. The estuarine waters were surveyed by monitoring water quality, sediment quality, benthic community indicators, and fish communities at a randomly chosen location in each hexagon during the index period of July 1 through September 30. Within each hexagon, three

random sampling locations in the estuarine resource were generated using ArcInfo software. The first random point was designated the "A" site. The second and third random points were designated the "B" and "C" sites, respectively. Field teams from UNH visited the A sites in each hexagon. If the crew was unable to collect a sample at the A site, the crew went to the B site. If the B site was also unsuitable, the sample was collected from the C site. If the C site could not be sampled, the hexagon was abandoned. Field teams from UNH collected sediment samples from 75 of the 82 hexagons between 2002 and 2005. Water samples were collected at 81 of the 82 hexagons in 2002-2003 and 80 of the 82 hexagons in 2004-2005.

In 2006-2007, DES and UNH attempted station visits to each of the 50 randomly assigned stations in the estuary. If a station could not be sampled, then the UNH field crew replaced the station with the next random station from the list until 50 random stations had been sampled. Water samples were collected from 50 stations during the summer index period. There was not enough funding to collect samples for sediment quality, benthic community indicators, or fish community indicators.

The field crews followed nationally standardized protocols for sample collection and analysis (Strobel, 2004; Heitmuller, 2001). Some of the water parameters were the following: Water temperature, salinity, dissolved oxygen, pH, chlorophyll-*a*, nitrogen as nitrate and nitrite, nitrogen as ammonium, total nitrogen (starting in 2004), phosphorus as orthophosphate, total suspended solids, enterococcus, and fecal coliform bacteria. Analysis of water samples was performed by various laboratories under contract to the EPA between 2000 and 2003. Samples collected in 2004 and later years were analyzed by the Water Quality Analysis Laboratory and the Jackson Estuarine Laboratory at UNH.

Sediment samples from 2002 to 2005 were collected using a 0.04 m^2 Young-modified Van Veen grab and then analyzed for chemistry, toxicity, and benthic macroinvertebrate abundance (Strobel, 2004). The concentrations of polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), chlorinated pesticides, and metals in the sediment were measured using methods outlined in Griffith and Kravitz (2008). Bioassays with an indicator organism, *Ampelisca abida*, were used for sediment toxicity as described in Strobel et al. (1995). Benthic macroinvertebrates were extracted from the sediment using a 0.5 mm mesh sieve. Invertebrates were counted and then identified to the lowest taxonomic level, usually species (Strobel et al., 1995).

Water and sediment data were quality assured by EPA and DES following a quality assurance project plan (Heitmuller, 2001). Quality assurance checks and modifications to the original data files were documented in annual quality assurance memos.

Statistical Methods

The requirement that the field crews collect a sample from each hexagon resulted in an unequal probability survey design in the 2002-2005 survey. NH's estuaries consist of inland bays and tidal rivers, which were often smaller than the hexagon dimensions. Some of the hexagons in the design straddled the boundary between New Hampshire and Maine. Finally, samples from "B" and "C" sites needed to be discounted by 50 percent and 67 percent, respectively. Therefore, each *hexagon* was assigned a weighting factor which was the area of estuarine waters *in New Hampshire* inside the hexagon (i.e., data for hexagons exclusively in Maine were excluded from the NH assessment). The weighting factor for each *station* was the weighting factor for the hexagon multiplied by 1, 0.5, or 0.67 for "A", "B", or "C" sites, respectively.

The proportion of the estuary meeting water quality standards was calculated by adding the weighting factors for stations in compliance with the standards and then dividing by the sum of the weighting factors for all the stations in the design. All the stations in the design were defined as all the sampled stations plus "A" sites in the hexagons that were not visited for stations with at least some portion of the hexagon in NH tidal waters. The proportion of the estuary not meeting water quality standards was calculated in a similar way. The proportion of the estuary that was not assessed was calculated by the difference between the sum of the other proportions and one. Ninety-five percent confidence interval half-widths (CI) on the estimated proportions were generated using the equation for the error in a mean proportion from a binomial distribution (Triola, 1998),

$$CI = t \cdot \sqrt{\frac{p \cdot (1-p)}{n}}$$

where t is the value of the *t* distribution for the sample size for a 0.05 significance level with a two tailed test, *p* is the proportion of the estuary exceeding a threshold, and *n* is the number of samples in the design (i.e., stations with at least some portion of the hexagon in NH tidal waters).

For the 2006-2007 design, each of the stations had equal weight. To isolate the NH waters, only those stations in NH tidal waters were considered. Proportions of the estuary for different conditions were calculated by dividing the number of stations meeting the condition by the total number of stations. Confidence intervals for the proportions were calculated using the equation shown above.

All the water quality data collected for the National Coastal Assessment in New Hampshire were queried for the period between January 1, 2004, and December 31, 2007. Station visits specifically for water quality sampling were selected from the database using a lookup table. If there was more than one value for a parameter from the chosen station visit (e.g., from multiple depths or field duplicates), the result with the maximum (or minimum) value was used (i.e., the value most likely to exceed the water quality criteria). For pH, which has two criteria, if there was more than one value from a station visit, the minimum value was compared to the 6.5 criterion and the maximum value was compared to the 8.5 criterion. For results reported as below detection limits, the method detection limit was substituted as the value prior to making comparisons to water quality standards. For the water quality parameters involved with this assessment, the method detection limits were always less than the water quality standard.

All sediment data collected between January 1, 2002, and December 31, 2005, were queried from the database. Only one sediment sample was collected at each station. There were not multiple values at the same station for sediment parameters. If the water and sediment data for a hexagon were collected at different sites (e.g., a "B" site and a "C" site, respectively), the weighting factor for the water data was used in the calculations.

The statistical methods and data queries are consistent the methods that were used for the probabilistic assessment for the 2006 and 2008 Section 305(b) Report for New Hampshire.

Environmental Indicators

Three designated uses were assessed using the National Coastal Assessment dataset: Aquatic life use support; Primary contact recreation; and Secondary contact recreation. The core indicators for aquatic life use support were dissolved oxygen, pH, sediment quality, and chlorophyll-a. Total nitrogen was also a core indicator for aquatic life use support for stations that fell in eelgrass

habitat areas. The water quality criteria for total nitrogen ranged from 0.25 to 0.30 mg/L depending on the eelgrass restoration depth. Enterococcus and chlorophyll-*a* were used as indicators for primary contact recreation. For secondary contact recreation, the only core indicator was enterococcus.

These indicators were evaluated at each of the stations to determine whether the station should be classified as Fully Supporting, Insufficient Information, or Not Supporting per the DES Consolidated Assessment and Listing Methodology (CALM) (NHDES, 2010). For aquatic life use support, Table 1 illustrates how the results from the three indicators were combined to classify individual stations. In order to have complete data for all of the indicators for aquatic life, sediment results from 2002-2005 and water quality results from 2004-2005 were used for these assessments.

Table 1: Decision Rule for Aquatic Life Use Support Classifications

Criteria	Classification
If all of the indicators met state standards, i.e., DO >= 5 mg/L pH >= 6.5 and <= 8.5 Sediment Quality = GOOD or FAIR Chl-a <= 10 ug/L TN <= 0.25 to 0.30 or Not Applicable	Fully Supporting
If any of the indicators violated state standards DO < 5 mg/L pH < 6.5 or > 8.5 Sediments = POOR Chl-a >10 ug/L TN > 0.25 to 0.30 if applicable	Not Supporting
If data were missing for any of the indicators but none of the available data violated state standards	Insufficient Information
If no data were available for any of the indicators	Not Assessed

The probabilistic assessments for aquatic life use support deviated from the requirements in the CALM in three ways. First, sample size requirements were waived since the results at all the stations would be aggregated. Second, daily average dissolved oxygen data were not required. Per the CALM, assessments of dissolved oxygen should use data on both instantaneous DO concentrations (in mg/L) and daily average measurements of DO (in %sat). Since the NCA dataset consisted of grab samples for water quality, daily average DO data were not available. And, third, the conditional relationships between nitrogen, chlorophyll-a, water clarity, and eelgrass populations from Table XX of the CALM (DES, 2010) were not considered. Instead, the total nitrogen and chlorophyll-a concentrations were evaluated independently relative to their individual standards.

Sediment impairments were determined using a combination of sediment chemistry, sediment toxicity and benthic community data according to the following protocol.

- For each station, the total PAHs, total DDT, and total PCB concentrations were calculated by summing the detected concentrations of the individual congeners. The number of individual PCB and PAH congeners varied slightly for different years because of changing laboratories. The totals for these classes of compounds were added to the database of results for individual heavy metals and pesticides. Then, the concentrations of toxic contaminants in the sediment sample from each station were compared to DES

sediment screening values, Threshold Effect Concentrations and Probable Effect Concentrations (NHDES, 2005). Sediment concentrations reported as below method detection limits were not compared to screening values.

- Sediment toxicity was assessed using the test organism *Ampelisca abdita,* a small shrimp-like amphipod. A sediment sample was considered to have significant toxicity if the percent survival of organisms exposed to the sediment was less than 80% compared to an unexposed control group and the difference was statistically significant.
- Benthic community data was evaluated using a benthic index for Gulf of Maine sediments developed by the Atlantic Ecology Division of EPA. The index was calculated as follows:

  Benthic Index = 0.494 * Shannon + 0.670 * MN_ES50.05 – 0.034 * PctCapitellidae

  where:

  Shannon = Shannon-Wiener H' diversity index

  MN_ES50.05 = Station mean of 5th percentile of total abundance frequency distribution of each species in relation to its ES50 value, where ES50 is the expected number of species in a sample of 50 individuals

  PctCapitellidae = percent abundance of capitellid polychaetes

  The benthic index was considered poor for values less than 4, fair for values >=4 and <5, and good for values >=5.
- A sediment sample was considered impaired if the concentration of a chemical was higher than a Probable Effect Concentration or five times a Threshold Effect Concentration screening value and either the sediment toxicity test indicated significant toxicity or the benthic index was poor. A sample was considered to be in fair condition if the sediment contamination was higher than the screening values (as defined in the previous sentence) and the benthic index was fair. The remaining samples were considered to be in good condition relative to benthic community impacts. A station was categorized as "not assessed" if no sediment data were available. If either the sediment chemistry or the biological data were missing for a station, the station was categorized as having "partial data".

For primary and secondary contact recreation, the decision rules used to make use support classifications are shown in Tables 2 and 3. For these assessments, only water quality data were needed so the latest data from 2006-2007 were used.

Table 2: Decision Rule for Primary Contact Recreation Classifications

Criteria	Classification
If the predicted enterococcus concentration was less than 75% of the geometric mean criterion (<=26 cts/100ml) AND If the chlorophyll-*a* concentration was either <=20 ug/L or not measured.	Fully Supporting
If the predicted enterococcus concentration was greater than the single sample maximum criterion (>104 cts/100ml) OR If the chlorophyll-*a* concentration was >20 ug/L.	Not Supporting
If the predicted enterococcus concentration was between 75% of the GMC and SSMC (>26 and <=104 cts/100ml) OR If there were no data for enterococcus and the chlorophyll-*a* concentration was <=20 ug/L.	Insufficient Information
If no data were available for enterococcus or chlorophyll-*a*.	Not Assessed

Table 3: Decision Rule for Secondary Contact Recreation Classifications

Criteria	Classification
If the predicted enterococcus concentration was less than 75% of the geometric mean criterion (<=131 cts/100ml)	Fully Supporting
If the predicted enterococcus concentration was greater than the single sample maximum criterion (>520 cts/100ml)	Not Supporting
If the predicted enterococcus concentration was between 75% of the GMC and SSMC (>131 and <=520 cts/100ml)	Insufficient Information
If no data were available for enterococcus	Not Assessed

As with aquatic life use support, the sample size requirements at each individual station from the CALM were waived because the results from all the stations were aggregated. In addition, geometric mean concentrations of enterococcus were not calculated because stations were not visited more than once during the field season. The CALM states that a Fully Supporting assessment can be made in the absence of a geometric mean concentration if ~~at~~ there are least two single samples and all samples have concentrations that are less than 75% of the geometric mean criterion. Therefore, 75% of the geometric mean criterion was used as the threshold below which the waters would be considered fully supporting.

Results and Discussion

Aquatic Life Use Support

The percent of the NH's estuaries that were fully supporting and not supporting of the designated use was 21.4% and 71.3%, respectively (Table 4). The remaining 7.3% of the resource was not classified due to incomplete or no data. In 2008, only 3.80% of the resource was classified as not supporting. This percentage of not supporting area increased in this report because chlorophyll-a and nitrogen were added as indicators of aquatic life use support. DES did not have criteria for these indicators in 2008 so were not part of the assessment. Therefore, the majority of non-supporting area is due to exceedences of the new criteria for chlorophyll-a or nitrogen.

Primary Contact Recreation

The percent of the NH's estuaries that were fully supporting and not supporting of the designated use was 82.1% and 7.7%, respectively (Table 5). The remaining 10.3% of the resource was not classified due to incomplete or no data. The 7.7% of the resource that was not supporting was due to impairments at three stations. The impairments at two stations were due to enterococcus. Chlorophyll-*a* caused the impairment at one station.

Secondary Contact Recreation

The percent of the NH's estuaries that were fully supporting and not supporting of the designated use was 92.3% and 0%, respectively (Table 6). The remaining 7.7% of the resource was not classified due to incomplete or no data.

Table 4A: Summary of Aquatic Life Use Support in NH's Estuaries

Category	Percent	Lower CI*	Upper CI*	Square miles
Fully Supporting	21.42%	11.87%	30.96%	3.85
Insufficient Information	7.27%	1.23%	13.31%	1.31
Not Supporting	71.28%	60.75%	81.80%	12.81
Not Assessed	0.03%	-0.38%	0.45%	0.01
Total	100.00%			17.97

* Lower and Upper CI: Lower and upper bounds of the 95th percentile confidence limits of the percentage.

Table 4B: Section 305(b) Reporting Data Elements for Aquatic Life Use Support

Data Element	Result
Probabilistic Network Name	National Coastal Assessment
Project ID (Assessment Unit ID)	69 assessment units starting in "NHEST"
Target Population	NH's estuarine resources
Resource Type	Estuary
Designated Use	Aquatic Life Use Support
Indicator	Dissolved Oxygen, pH, Sediment Quality, Chlorophyll-a, Total Nitrogen
Size	17.97
Units	Square miles
Number of sites	71 stations in hexagons covering at least part of the resource.
Percent attaining	21.42%
Percent insufficient information	7.30%
Percent not attaining	71.28%
Data	2004 and 2005 data for water quality, 2002-2005 data for sediment quality
Confidence	+/-11%

Figure 2: Summary of Aquatic Life Use Support in NH's Estuaries

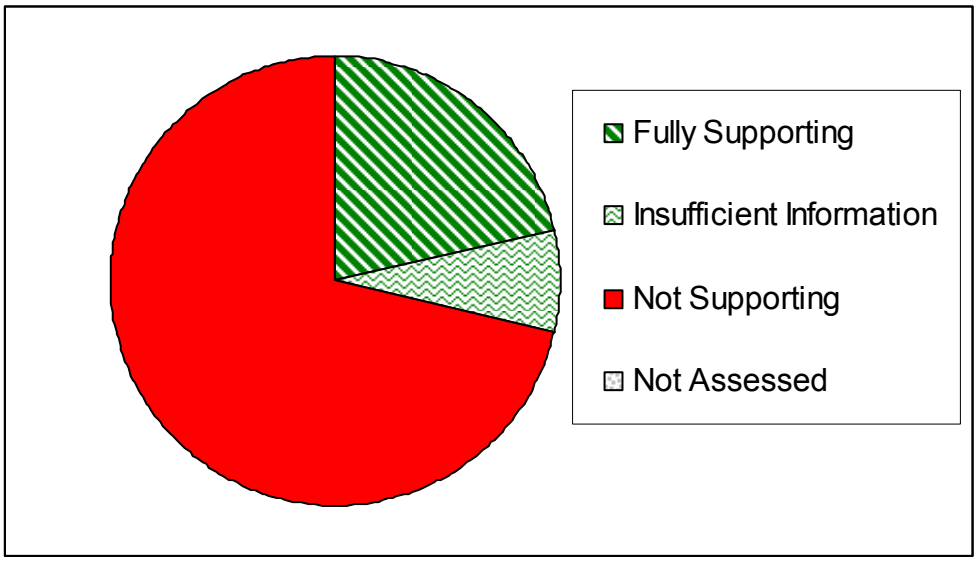


Table 5A: Summary of Primary Contact Recreation Use Support in NH's Estuaries

Category	Percent	Lower CI*	Upper CI*	Square miles
Fully Supporting	82.05%	71.31%	92.80%	14.75
Insufficient Information	7.69%	0.23%	15.15%	1.38
Not Supporting	7.69%	0.23%	15.15%	1.38
Not Assessed	2.56%	-1.86%	6.99%	0.46
Total	100.00%			17.97

* Lower and Upper CI: Lower and upper bounds of the 95th percentile confidence limits of the percentage.

Table 5B: Section 305(b) Reporting Data Elements for Primary Contact Recreation Use Support

Data Element	Result
Probabilistic Network Name	National Coastal Assessment
Project ID (Assessment Unit ID)	69 assessment units starting in "NHEST"
Target Population	NH's estuarine resources
Resource Type	Estuary
Designated Use	Primary Contact Recreation Use Support
Indicator	Enterococcus
Size	17.97
Units	Square miles
Number of sites	39 stations in hexagons covering at least part of the resource.
Percent attaining	82.05%
Percent insufficient information	10.26%
Percent not attaining	7.69%
Data	2006 and 2007 data for water quality
Confidence	+/-11%

Figure 3: Summary of Primary Contact Recreation Use Support in NH's Estuaries

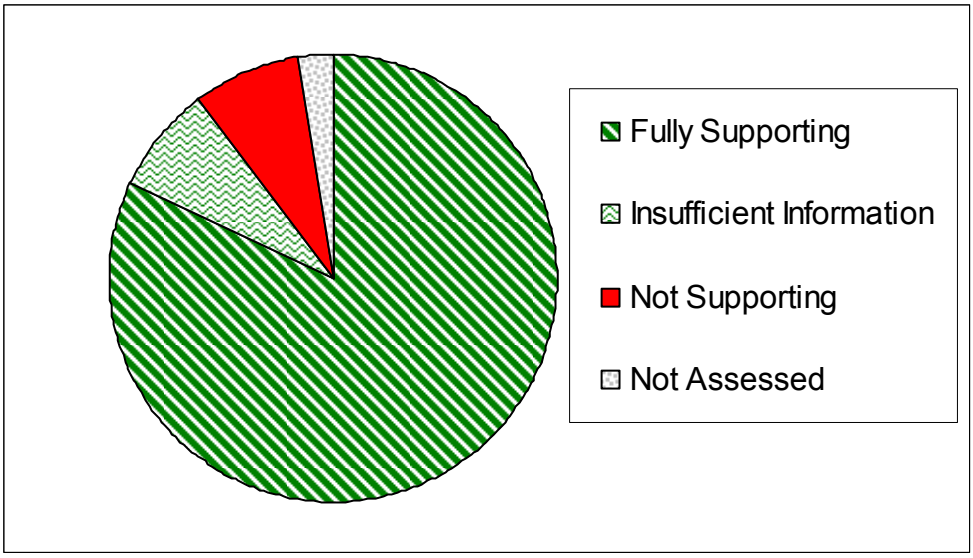


Table 6A: Summary of Secondary Contact Recreation Use Support in NH's Estuaries

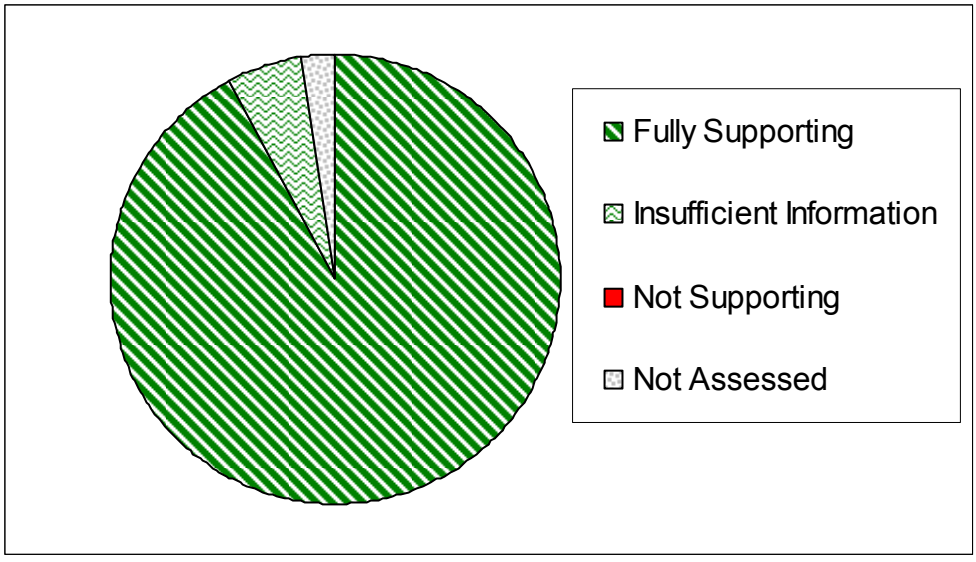
Category	Percent	Lower CI*	Upper CI*	Square miles
Fully Supporting	92.31%	84.85%	99.77%	16.59
Insufficient Information	5.13%	-1.05%	11.30%	0.92
Not Supporting	0.00%	0.00%	0.00%	0.00
Not Assessed	2.56%	-1.86%	6.99%	0.46
Total	100.00%			17.97

* Lower and Upper CI: Lower and upper bounds of the 95th percentile confidence limits of the percentage.

Table 6B: Section 305(b) Reporting Data Elements for Secondary Contact Recreation Use Support

Data Element	Result
Probabilistic Network Name	National Coastal Assessment
Project ID (Assessment Unit ID)	69 assessment units starting in "NHEST"
Target Population	NH's estuarine resources
Resource Type	Estuary
Designated Use	Secondary Contact Recreation Use Support
Indicator	Enterococcus
Size	17.97
Units	Square miles
Number of sites	39 stations in hexagons covering at least part of the resource.
Percent attaining	92.31%
Percent insufficient information	7.69%
Percent not attaining	0%
Data	2006 and 2007 data for water quality
Confidence	+/-7%

Figure 4: Summary of Secondary Contact Recreation Use Support in NH's Estuaries



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