



TOWN OF STRATHAM

Incorporated 1716

10 Bunker Hill Avenue · Stratham, NH 03885

Town Clerk/Tax Collector 603-772-4741

Select Board's Office/ Administration/ Assessing 603-772-7391

Code Enforcement/ Building Inspections/ Planning 603-772-7391

PLANNING BOARD MEETING AGENDA

October 18, 2023, 7:00 pm

Stratham Municipal Center

10 Bunker Hill Avenue, Stratham NH

1. Call to Order/Roll Call

2. Review and Approval of Minutes:

- a. October 4, 2023 Planning Board Minutes

3. New Business:

- a. Public hearing to adopt amendments to Stratham Site Plan Regulations including to Sections III Scope & Requirements, Section IV Application Procedures and Requirements, Section V Design & Construction Requirements. The proposed amendments relate to application processes and notification fees, criteria qualifying projects for site plan review, and required materials for site plan applications.
- b. Discussion of proposed zoning amendments for 2024
- c. Miscellaneous Community Planning Issues
 - 1. 2023 PREP State of Our Estuaries Report
 - 2. MS4 Requirements

4. Adjournment

No new agenda items will be heard after 10:00 pm subject to the discretion of the Planning Board Chair. Full text of the agenda and related information can be found on file with the Stratham Planning Department and posted on the Town website at <https://www.strathamnh.gov/planning-board>. All interested persons may be heard. Persons needing special accommodations and /or those interested in viewing the application materials should contact the Stratham Planning Department at (603) 772-7391 ext. 180.



Stratham Planning Board Meeting Minutes
October 4, 2023
Stratham Municipal Center
Time: 7:00 pm

Members Present: Thomas House, Chair
David Canada, Vice Chair
Mike Houghton, Select Board's Representative
Chris Zaremba, Regular Member
John Kunowski, Regular Member
Nate Allison, Alternate Member

Members Absent: None.

Staff Present: Mark Connors, Director of Planning and Community Development

1. Call to Order/Roll Call

Mr. House called the meeting to order at 7:00 pm and took roll call.

2. Approval of Minutes

a. September 20, 2023

Mr. Zaremba made a motion to approve the September 20, 2023 meeting minutes. Mr. Kunowski seconded the motion. All voted in favor and the motion was approved.

3. New Business:

a. Stratham Community Power Presentation by Paul Deschaine, Stratham Energy Commission

Mr. Deschaine began his presentation thanking the Board for their time and directed their attention to a handout describing the Community Power Initiative that the Select Board supports and the Energy Commission has initiated. The Commission has identified a means of communication to the Town and its residents, by way of presentation to each of the Town Boards, Commissions, and committees. Mr. Deschaine explained that on each electric bill there is a distribution cost for wires, crews, billing, etc. along with the power supply charge. The distribution cost includes a margin for profit. Up until now there were only two options for power supply: Unitil's default rate which goes out to bid every 6 months and on which there is no mark-up, or a third-party power supplier with varying terms. Sometimes third-party is less than the default rate and sometimes not. Within the last year the default rate increased dramatically. Just prior to that the Statutes changed and now allow Community Power. Community Power allows communities to aggregate all of their users into one buying block. Through that power of the market, the Town can market its customer base to different utilities. The process is that the Town created and the Select Board approved a plan

45 that was sent to the New Hampshire Public Utilities Commission for approval. The PUC approved
46 Stratham's Plan. The final step is approval at Town Meeting. This step could take place in March
47 at the annual Town Meeting, but the next default rate bid is in February, therefore a Special Town
48 Meeting has been scheduled for October 26, 2023 at 7:00 pm at Stratham Memorial School. About
49 80% of Stratham uses the default rate. If the vote is passed, then Stratham can participate in the
50 next rate bid process. The Commission recommended and the Select Board agreed that Stratham
51 should choose the Community Power Coalition of New Hampshire which is a non-profit
52 organization representing over 43 New Hampshire communities. About 15 communities are
53 currently in the plan including Exeter, Rye, and Portsmouth. Their initial rate in May 2023 was 15
54 cents per kWh where Unitil's default rate was 26 cents per kWh. If Stratham had been able to
55 participate in the May 2023 rate process, the average Stratham customer would have saved \$315
56 in the period of May through August. In August Unitil's rate came down, but CPC's rate was still
57 lower by about 1 or 2 cents. There is no cost to the taxpayer if the Special Town Meeting vote is
58 passed.

59
60 Mr. House stated that he believes Unitil is offering free solar panels currently and asked how that
61 works into the program. Mr. Deschaine is not familiar with that proposal from Unitil, but he is
62 aware that part of the plan envisions other renewable energy projects that the Town could get
63 involved with. It is not currently offered by CPC, but it is a future option.

64
65 Mr. Canada asked if there has been any opposition. Mr. Deschaine responded that one element of
66 the process is that it is an opt out process. That if it is adopted, the community power program
67 becomes the default service instead of Unitil. Some have questioned why they have to opt out and
68 that is how the Statute is written. The plan also states that Stratham will not implement a
69 community power plan unless the initial rate is less than Unitil's.

70
71 Mr. Kunowski asked if the community power rate will always be less than the Unitil rate. Mr.
72 Deschaine cannot confirm that is the case forever. Mr. Allison noted that Unitil could become
73 more competitive. Mr. Deschaine responded that Unitil has no interest in that since they make no
74 profit from the default rate.

75
76 Mr. House asked if the vote passes, what does the consumer have to do. Mr. Deschaine replied
77 nothing. A notice will be delivered to customers 30 days in advance of implementation which will
78 include a phone number if a customer wants to opt out.

79
80 The second matter relating to possible opposition is there is a problem relative to the utility's
81 compliance with net metering requirements. All community power organizations are having
82 difficulty working with utilities on the credit given to customers with solar energy systems that are
83 getting a benefit from net metering. Most net metering customers will not be included in the initial
84 offering unless a decision is made by PUC before February 2024. The plan does allow participation
85 by net metering customers, but it can't be implemented immediately. Mr. Canada stated that he
86 has net metering and asked if that means he can't join or is it that he just doesn't get the advantage
87 of the buy back. Mr. Deschaine replied there are three scenarios for net metering. The first is if the
88 power generated onsite never exceeds the total load, then that customer should join. If a customer's
89 power production occasionally exceeds the use then the program still might be advantageous. If a
90 customer's power production always exceeds the power used, then that customer should review
91 their individual situation carefully.

92
93 Mr. Canada asked if the supplier changes periodically. Mr. Deschaine replied yes and they are

94 matching the same time periods for bidding as the power companies. Once there is more experience
95 and a stable customer base then the CPC will analyze the market more frequently.
96

97 Mr. Kunowski asked if Unitil will still bill customers. Mr. Deschaine replied there will still be one
98 bill. That might be one solution for net metering is to have independent billing from CPC, but
99 that's not desirable. Mr. Deschaine noted that only about 5 to 6 % of Stratham customers have net
100 metering.
101

102 Mr. Connors asked for confirmation of the meeting format in that the Supervisors of the Checklist
103 will be present to confirm voter registration, then a presentation, and a formal vote. Mr. Deschaine
104 agreed and noted that overwhelmingly there has been positive response.
105

106 Mr. Kunowski asked if there is concern with low attendance at the meeting making a decision for
107 the majority of the town, and realizes that is the case for any town meeting. Mr. Deschaine agreed
108 and added that is why they are trying to get the word out that this is a positive program and to
109 encourage attendance.
110

111 Mr. House asked Mr. Connors if the Board needed to open the discussion for public comment. Mr.
112 Connors replied it is not required, but recommended that they do so. **Mr. Zaremba made a motion
113 to open the meeting to the public. Mr. Kunowski seconded the motion. All voted in favor and
114 the motion was approved.**
115

116 Bruce Scamman of 3 Blossom Lane asked if the customers currently using a third party will
117 automatically be switched. Mr. Deschaine replied those customers have contractual obligations
118 they are obligated to. The provider might not have a cancellation fee or the fee might be monetarily
119 in the customer's favor. Mr. Deschaine added that relative to the Town's plan, a customer can opt
120 in and opt out at any time, but Unitil might have some restrictions on that frequency. Mr. Scamman
121 asked if the plan is online. Mr. Deschaine replied yes, that it is on the Stratham Energy
122 Commission's webpage. Mr. Scamman commented that he looked at the Town's web page
123 regarding Town Meeting last week and did not see any mention of the Special Town Meeting and
124 suggested it be updated.
125

126 **Mr. Zaremba made a motion to close the meeting to the public. Mr. Kunowski seconded the
127 motion. All voted in favor and the motion was approved.**
128

- 129 **b.** Copley Properties, LLC (Applicant), C.A.N. Realty Trust and GGF, LLC (Owners) - Request for
130 review of a Preliminary Consultation application of a proposed redevelopment plan to demolish
131 two existing office buildings and to construct an office building and three additional structures
132 containing a total of 9 (nine) multi-family residential units at 89 and 91 Portsmouth Avenue, Tax
133 Map 13, Lot 21 and 22. Applicant's representative is Emanuel Engineering Inc., 118 Portsmouth
134 Ave., Stratham, NH 03885.
135

136 Mr. Connors introduced the project as two properties containing two existing office buildings on
137 Portsmouth Avenue. The preliminary plan is to demolish the existing buildings, merge the two
138 lots, and construct three new buildings. There would be three two-bedroom apartments in each
139 building and an office building near the front of the site. The access would be moved slightly to
140 the south.
141

142 Bruce Scamman with Emanuel Engineering spoke on behalf of the Applicant. The Applicant is

143 working with the current owners on a possible redevelopment. The proposal is to demolish the
144 existing structures which have been enlarged over the years. Due to all of the past renovations, the
145 Applicant prefers to demolish the existing structures and rebuild. Currently there is a central
146 driveway and parking along the wet area and the powerlines. The property lines are split along the
147 driveway. There is also a foundation in the rear of one building that was constructed for a garage,
148 but the garage was never built. The proposal includes a new driveway, depending on wetlands
149 delineation. Originally the Applicant proposed a central driveway, but old wetlands plans indicated
150 that setbacks would not allow for that. A wetlands scientist reviewed the property this week and
151 determined some areas are not wetlands so there might be some changes to the property layout.
152 The basic plan is to have three triplexes and a commercial office building with a driveway
153 separating them, but the first plan depicts the driveway along the power line easement. The number
154 of units allowed per acre under the Zoning Ordinance was reviewed and determined that nine units
155 would be allowed. The commercial building is proposed in the front to align with the Gateway and
156 Professional/Residential districts.

157
158 Andrew Goddard, the Applicant, added that wetlands flagging has been taking place all week and
159 more concrete information will be available upon completion. The plan before the Board is concept
160 only for mixed-use. Mr. Scamman added that other than the recent project at 94 Portsmouth
161 Avenue, this is the first real mixed-use project proposed recently.

162
163 Mr. Kunowski asked how many office suites would be proposed and how many people would be
164 working. Mr. Scamman responded it's a 3,200 square-foot footprint. Mr. Goddard added that there
165 will be three stories for a total of 10,000 square feet. He included parking that would accommodate
166 a medical office. Conceptually it looks like the property can handle the proposed septic load and
167 the septic load will ultimately dictate the office building use. Mr. Kunowski commented the basis
168 for his question was does the project need that much parking and Mr. Goddard confirmed that with
169 his response. Mr. Scamman added that there is nothing worse than an office building without
170 enough parking.

171
172 Mr. Scamman presented a rendering of the vision of the triplexes showing garage doors and
173 multiple dormers. Mr. Goddard added that similar structures were built recently in Greenland.
174 They have good layouts with two bedrooms and just over 2,000 square feet. Mr. Goddard added
175 that he hoped to obtain four parcels to connect to each other and that is the reason for requesting a
176 curb cut from NHDOT, for future development of the neighboring parcels as well. Mr. House
177 noted that in 2027 NHDOT will begin to redesign the Bunker Hill and Portsmouth Ave
178 intersection. Mr. House asked Mr. Connors if the intersection has been designed yet. Mr. Connors
179 replied that supposedly it is in preliminary engineering, but he has not yet seen a plan. Mr. House
180 asked if a copy of the design can be provided to the Applicant to see if it impacts their plan. He
181 added that even if they are not part of the intersection, the curb cut needs to be a certain distance
182 away. Mr. Goddard replied that they will look into that and contact NHDOT.

183
184 Mr. Goddard stated that there is a footnote in the Zoning Ordinance that the building footprint that
185 that side of Portsmouth Avenue should be 1,600 square feet or less and they are proposing larger
186 than that. He notes that the current office footprint is greater than what is proposed and they are
187 merging two lots. Mr. House replied that after demolition, the Zoning Ordinance must be fully
188 complied with. Mr. Goddard asked the Board's opinion on a waiver request for that. Mr. Zaremba
189 asked if that would be a Planning Board or Zoning Board of Adjustment process. Mr. Connors
190 replied that it depends if the existing properties were granted a variance, then they could probably
191 work under that variance, but the buildings likely pre-date the Ordinance, therefore it would require

192 a Variance from the ZBA. Mr. Scamman added he was involved in an expansion of one of the
193 buildings and he will research the process for that approval since the building is greater than 1,600
194 square feet.

195
196 Mr. House commented to make sure the office building height does not exceed 35 feet.

197
198 Mr. House asked if the Applicant is aware that this is a public water system. Mr. Goddard agreed.
199 Mr. House noted that the well radius includes development which is not allowed by NHDES. Mr.
200 Scamman replied that he believes some development is allowed.

201
202 Mr. House advised the Applicant talk to the fire department because he does not see any turn
203 around for fire trucks.

204
205 Mr. House asked Mr. Houghton how is the student population in town and if that is a concern. Mr.
206 Zaremba replied that the town needs more teachers. Mr. Houghton replied that any development
207 potentially adds to the school population and he does not see that as an issue. Mr. Canada does not
208 believe that is in the purview of the Board. Mr. House understands that but noted that this is a
209 consultation to discuss all potential issues.

210
211 Mr. House advised that the Applicant review trash service.

212
213 Mr. Goddard asked if a Conditional Use Permit is required for multi-family housing. The Board
214 replied yes. Mr. Goddard asked if the building separation requirement is 30 feet. Mr. Connors
215 replied that is determined by the fire code. Mr. Goddard replied the state building code is 20 feet.
216 Mr. House stated that the buildings can be closer than 20 feet if the exterior walls are constructed
217 to meet fire code.

218
219 Mr. Allison commented that this is a concept sketch and he expects the next plan to be revised with
220 regards to turn arounds. He asked if there would be one garage space and one parking space for
221 each unit. Mr. Scamman replied correct. With regards to public water supply, Mr. Allison
222 commented that his development was recently required to correct deficiencies in their public water
223 supply protection areas and there are some very strict requirements as to what can be within the
224 protection area. He recommends the Applicant take a close look at that.

225
226 Mr. Kunowski asked if there are plans for any outdoor residential spaces like patios, fences, or
227 courtyards and if there would be any issues with property line setbacks. Mr. Connors replied fences
228 are allowed up to 6 feet tall and patios would be allowed, but not a deck.

229
230 Mr. Allison asked why there is a lot of gravel at the property now. Mr. Goddard replied it is for
231 access for telephone pole replacement.

232
233 Mr. Zaremba asked if the Town has design requirements for this area like with the Gateway
234 District. Mr. Connors replied there are general town architectural site plan requirements but not as
235 specific as the Gateway. Mr. Zaremba asked Mr. Goddard if he will return with renderings. Mr.
236 Goddard replied that he has the residential design renderings as it is a design that he likes and he
237 has not completed any renderings yet for the office building. With his project at 94 Portsmouth
238 Ave he worked with the historic commission on design elements and he would do the same with
239 this property. He would like the office building to shield the residential units. He believes the

240 current buildings are obsolete and would like to improve the properties.

241
242 Mr. Zaremba requested that the concept consider pedestrian access to other properties in the area.

243
244 Mr. Allison asked if construction fencing could be installed between the property and the rear
245 parcel. Mr. Goddard replied that is possible and he is considering a permanent fence. Mr. Scamman
246 added there is a stone wall that runs along the back of the property. Mr. Allison noted that the wall
247 may accomplish the same goal as a construction fence.

248
249 Mr. Canada commented that the project appears to meet zoning and he agrees with Mr. Zaremba's
250 comments regarding pedestrian access. Mr. Goddard replied that the NHDOT right of way extends
251 far into the property and he is not sure that sidewalks could be installed. Mr. Canada replied that
252 NHDOT will allow a sidewalk in the right of way. Mr. Connors added that NHDOT will not
253 maintain the sidewalk, the Town would have to, but NHDOT will allow one to be constructed. Mr.
254 Scamman stated that in the properties where Emmanuel Engineering has designed them, NHDOT
255 asked that the sidewalks be placed outside of the right of way. Mr. Canada and Mr. House
256 encouraged the Applicant to have a discussion with NHDOT regarding sidewalks.

257
258 Mr. Houghton reiterated the Applicant should address fire access.

259
260 Mr. House asked the Applicant to describe the note on the plan about future access to Lot 13-21.
261 Mr. Scamman replied that is a potential spot to connect these parcels to the neighboring parcels if
262 Mr. Goddard's plan of developing all four parcels in the future is realized. Mr. Allison commented
263 he thought that area would be for the dumpster and asked where the dumpster would go. Mr.
264 Scamman replied straight in.

265
266 Mr. Goddard added that he will probably move away from triplexes and investigate the 20-foot
267 separation for duplexes to avoid a Conditional Use Permit. He added that middle units are not as
268 desirable and the property is limited with room due to setbacks, parking, building separation, etc.

269
270 Mr. House asked if Mr. Allison's question on the dumpster is for the office building. Mr. Allison
271 replied yes but assumes the residences need to be addressed as well. Mr. House stated he thought
272 the residential properties would have pickup like the rest of the town. Mr. Allison said that might
273 be the case, but property looks difficult for maneuvering. Mr. House and Mr. Allison agree that if
274 a truck turnaround area is created, that would be helpful. Mr. Goddard added that he thought his
275 approval for 94 Portsmouth Avenue indicated that the residential units are required to use a
276 dumpster. Nobody believes the Town's trash hauler would pull into private property. Mr.
277 Houghton noted that most condos have their own trash pickup.

278
279 Mr. House asked if the units will be condos or rental units. Mr. Goddard replied that he will sell
280 them as condos. Mr. House stated that the Board will need to review the condo documents. Mr.
281 Connors added that a condominium subdivision approval would be necessary and that could be
282 reviewed at the same time as the other applications.

283
284 Mr. House asked if there were any more questions for the Board. Mr. Goddard replied that he
285 needs to review the footnote about the 1,600 square foot limitation, but that he believes it only
286 applies to office buildings and not residential. He suggests if he keeps the parcels separate then he
287 can construct two separate office buildings. Mr. Zaremba stated that there could be a joint meeting

288 of the Planning Board and the ZBA to discuss that. Mr. Scamman asked what would be the process
289 for requesting approval of a larger footprint. Mr. Connors replied that the project would come
290 before the Planning Board and the Applicant would request a joint meeting which would be
291 scheduled. Mr. Connors replied it is an easier process and allows for open dialogue. Mr. House
292 commented that the Applicant needs to ensure that they can show a hardship.
293

294 Mr. Connors asked Mr. Scamman to show the aerial photo of the project and asked if they could
295 talk to the neighboring property about a shared driveway or if the wetlands impact is not as great,
296 could the entrance be moved to the other side of the property. Mr. Goddard replied that he believes
297 they can put a curb cut under the power line easement, just no structures, but he's not sure if the
298 neighbor will be amenable.
299

300 Mr. Scamman asked if there is any concern from the Board with the mixed use. Mr. House stated
301 it is allowed and they just need to review the public water system, building heights, and building
302 footprint.
303

304 Mr. Kunowski asked if the office space will be condominium units. Mr. Goddard replied that his
305 initial plan is to rent them but he would review the market and make a decision later. Mr. Scamman
306 added that if they are all on one lot, then they will be all condos, it's just a matter of whether Mr.
307 Goddard owns the office condos or not.
308

309 Mr. Connors asked if there are existing tenants in the two buildings. Mr. Goddard replied yes, that
310 there is one tenant in 91 Portsmouth who just completed a nice renovation and there are three
311 tenants at 89 Portsmouth. The tenant at 91 Portsmouth would like to move to the new building and
312 there are four tenants at 89 Portsmouth that he would like to shift temporarily to 91 Portsmouth.
313

314 **Mr. Zaremba made a motion to open the meeting to the public. Mr. Canada seconded the**
315 **motion. All voted in favor and the motion was approved.**
316

317 Mr. Deschaine of 31 Thornhill Road, commented that conceptually it is a great project. He added
318 that with regards to trash pickup, being a mixed use project, it should be spelled out in the
319 condominium documents and the owner should provide an easement to the Town and/or its
320 contractors to access the property. In the past, that needed to be completed retroactively for
321 condominium properties that the Town does service. His second comment is with regards to the
322 Portsmouth Avenue and Bunker Hill intersection and commented that NHDOT has suggested in
323 the past a round-about. Sidewalks are a great suggestion but with the grade change at the properties
324 they might have to go within the State right of way to make them practicable. Mr. Scamman replied
325 that having a connection between these properties and the neighbors could be important.
326

327 **Mr. Zaremba made a motion to close the meeting to the public. Mr. Kunowski seconded the**
328 **motion. All voted in favor and the motion was approved.**
329

330 Mr. Allison commented that with regards to the dumpster, if there is no central area for collection,
331 then a large turnout over by the pond might be a good idea. He recognizes this is a concept plan,
332 but he doesn't see how a truck can maneuver.
333

334 Mr. Goddard asked what Stratham's setbacks to wetlands are. Mr. Scamman replied that there are
335 different types of wetlands and the setbacks vary based on the type of wetland. Mr. Goddard asked
336 if that is a town regulation and have other site plans had leniency with, for example, a 75-foot

337 setback instead of 100 feet. Mr. Connors confirmed it is a town regulation and it would be a ZBA
338 decision. Mr. Scamman added that he would think that the existing pavement is a grandfathered
339 condition and asked if any improvement would be accepted by the Planning Board. Mr. Connors
340 replied that a driveway would require a conditional use permit and not a variance, but structures
341 would require a variance. Mr. Scamman asked which application would apply to parking. Mr.
342 Connors would need to research that. Mr. Scamman asked the Board's feelings on that proposal.
343 The Board feels the farther the setback from wetlands, the better.
344

- 345 c. Review of proposed red-lined amendments to Stratham Site Plan Regulations including to Sections
346 III Scope & Requirements, Section IV Application Procedures and Requirements, Section V
347 Design & Construction Requirements. The proposed amendments relate to application processes
348 and notification fees, criteria qualifying projects for site plan review, and required materials for
349 site plan applications.
350

351 Mr. Connors presented proposed amendments including the following:

- 352 • Updating the definition of abutter to include reference to the NH RSA abutter definition.
- 353 • Adding regular mail abutter notification for preliminary consultation applications.
- 354 • Clarifying the required application materials.
- 355 • Clarifying the timing of the site plan application submittal relative to the preliminary
356 consultation.
- 357 • Establishing a deadline for written abutter comments along with potential time limitations
358 for verbal comments.
- 359 • Adding regular mail abutter notifications for applications that require certified mailing.
- 360 • Updates to abutter and public notice fees for preliminary consultations and site plan
361 reviews.
- 362 • Amendments to the special investigative costs to include examples of potential costs.
- 363 • Updates to the recording costs to include the cost of town staff delivering materials to the
364 Registry of Deeds.
- 365 • Removing outdated language that references the Rockingham Planning Commission
366 Circuit Rider Planner.
- 367 • Requiring all plans under review to be stamped by a licensed surveyor and a professional
368 engineer.
- 369 • Clarifying plan requirements under review to include compliance with parking
370 requirements, locations of fire hydrants/ponds/cisterns, and wetlands stamped by a certified
371 Wetlands Scientist.
- 372 • Removing the requirement for a licensed landscape architect to stamp plans.
- 373 • Clarifying the lighting plan should be a photometric plan.
- 374 • Adding a 95-day review period for regional impact projects in accordance with State Law.
- 375 • Removing the requirement that the Select Board approve an application extension.
376

377 Mr. Zaremba asked with regards to the seven day postmark for preliminary consultations, if the
378 seven days is not met, will the consultation be heard. He likes the idea of notifying abutters, but is
379 concerned with strict interpretation of the deadline. Mr. Connors suggested removing the seven
380 day requirement and simplifying the language that notice will be sent in advance of the meeting.
381 Mr. Canada agrees notification is a good idea and he thinks it should occur in a timely manner.
382 Mr. Zaremba asked if the consultation would be delayed if we didn't meet the requirement and
383 what happens currently. Mr. Connors replied that certified mailings are different and need to be

384 completed more in advance. Mr. Allison stated this is just a courtesy. Mr. Zaremba countered it is
385 not a courtesy if it becomes regulation. Mr. Houghton does not believe seven days is onerous. Mr.
386 Zaremba asked if the mailings are completed by the applicant. Mr. Connors replied no, that they
387 are completed by town staff and that's why he suggested using the postmark. With that information
388 Mr. Zaremba is more comfortable with the requirement. Mr. Houghton commented that
389 preliminary consultations are non-binding. Mr. Zaremba agrees and was just looking to preserve
390 that. Mr. Connors explained some suggested changes to preliminary consultation application
391 materials including the base map, written narrative, architectural renderings, preliminary site plans,
392 and potential waiver requests.

393
394 Mr. Canada asked if the proposed wetlands scientist stamp on the site plan is related to the Board's
395 previous discussion regarding when a wetlands scientist would be required. Mr. Connors replied
396 no, this is only for site plan reviews. The previous discussion related to building permit applications
397 that are not under site plan review.

398
399 Mr. Kunowski asked what the process is to complete the site plan regulation updates and if a town
400 vote is required. Mr. Connors replied that for amendments to the Site Plan Regulations, the
401 Planning Board holds one public hearing and there is no town vote.

402
403 **d. Miscellaneous Community Planning Issues**

404
405 1. Conservation Commission/Open Space Plan Updates

406
407 Mr. Connors explained that the Open Space and Connectivity Steering Committee is working on
408 the Open Space Plan and the goals and strategies with draft materials proposed for next month.
409 There will be a public open house in January 2024.

410
411 Mr. Connors announced that the Conservation Commission has come to an agreement with the
412 landowner for a 17-acre land-locked parcel of land that abuts Stratham Hill Park and includes a
413 portion of the trail network. The Town is pursuing a grant to cover up to half of the cost to acquire
414 the parcel. The Conservation Commission will hold a public hearing on October 25, 2023.

415
416 2. Building Permit fee update

417
418 Mr. Connors explained that the Town is considering proposed changes to the Building Department
419 permit fees to simplify the fee structure for both the Town and applicants. The fee structure has
420 not been updated for several years. Mr. Connors presented examples of other towns' fee structures
421 and examples of the project fees within Stratham along with the proposed changes. Mr. Canada
422 commented that the example in the presentation is a considerable increase to the current fees and
423 that the Town should not be a profit center and stated that the building department exists to regulate
424 and help and it is a service the town should be offering as a break-even proposition. Mr. Connors
425 replied that some of the costs of providing the service will come from taxpayers if not from the
426 applicants. Mr. Canada replied that the office provides a public function and a certain amount of
427 tax dollars to support the office is acceptable. Mr. Connors presented the example of reducing the
428 fees for HVAC/plumbing permits for residential use and increasing them for commercial uses.
429 Currently the same value project would have a lower fee if commercial.

430
431 Mr. Canada asked if the Planning Board has any input on the fees or if this presentation is only
432 informational. Mr. Connors replied that the Select Board makes the decision, but if there are any

433 strong opinions from Planning Board members then he would note them prior to approaching the
434 Select Board. Mr. Canada stated that he does think the Building Department should be a profit
435 center for the town and that the example increase is scandalous. Mr. Connors explained the current
436 commercial fee structure is a decreasing rate when the scale of the project is increased. He
437 presented an example of the fee for a large commercial project in Stratham being one-third of the
438 cost compared to other towns.

439
440 Mr. Connors summarized that the current fee structure is complicated, more prone to mistakes in
441 calculation, difficult to explain, and has potential inequities between residential and commercial
442 projects. He presented a chart of how Stratham's proposed fees would compare to other towns (in
443 the middle). In summary, the town would maintain low, flat rates for relatively simple projects,
444 like fencing, residential window and roof replacement, etc., that do not require significant review
445 from the Building Inspector and have a cost per square footage minimum measure for projects
446 where estimated costs do not seem reasonable.

447
448 Mr. Zaremba commented that it makes sense to simplify to an extent and that using project cost
449 accounts for inflation, but he agrees with Mr. Canada that the fee structure should not be profit-
450 generating.

451
452 Mr. Allison asked if the fees include inspections. Mr. Connors replied yes.

453
454 Mr. Connors stated that Stratham does not see a lot of million dollar renovations, and that is an
455 example of where the fee will dramatically increase but there are minimal applications in that
456 category. He supports capping the fee for projects like roof replacements that do not use a lot of
457 the Building Inspector's time. Mr. Connors stated that the next step would be to review how the
458 revenue would change. He believes it will increase, but not drastically.

459
460 Mr. Kunowski asked if increasing the fees would be a barrier to submitting applications. Mr.
461 Connors replied that the Town would be in comparison to surrounding communities. Mr. Canada
462 commented that the Town is not in competition with other towns and instead the Town should
463 charge what it costs the Town to provide the service. He gave the example if another Town needs
464 \$25,000 to provide a service, but we can provide it for \$5,000, then we should charge \$5,000. He
465 added that we are not trying to foster or stifle development; we are trying to recoup the costs that
466 the development is done properly. Mr. Connors said he understands, but stated that the Town needs
467 to consider correcting the inequities in discounts for large commercial projects compared to smaller
468 projects.

469
470 Mr. Houghton stated this is an appropriate discussion, but he is not sure that the Town knows their
471 costs. He agrees that a larger commercial project with more inspections should not have a lower
472 fee than a residential project. He agrees the Building Department should not be a profit center, but
473 that the Town should cover their costs. He gave the example that a \$650,000 project with an
474 application fee of \$600 is not covering the Town's costs.

475
476 Mr. House asked if cost of living raises into the future are considered in the fee schedule. Mr.
477 Zaremba replied that's where the cost of project is a factor. Mr. Houghton gave an example of the
478 downside of using square footage that there are older properties in town where a 3,500 square foot
479 project could be \$1,000,000 and there have been new homes in Stratham constructed for
480 \$1,000,000 that are only 2,000 square feet. He thinks it is an important issue to pursue and the
481 debate is good and that the Town needs to find an equitable balance between commercial and

482 residential and the cost of providing service. Mr. Canada stated that the Town should be able to
483 determine cost of service for example, preparing Planning Board minutes and the cost of
484 inspections and the entire building permit process and asked how does the Town calculate an
485 equitable amount. Mr. Houghton replied that if the course of action is to seek parity with
486 surrounding communities then that is not really thinking about costs and it is reasonable for the
487 Town to pursue researching the cost of services. Mr. House suggested asking the Code
488 Enforcement Officer how long it takes to review an application. He added that he does not see the
489 cost of construction coming down any time soon, but it's still the same size building and simply
490 costs more due to materials and labor, but not necessarily more time of the Code Enforcement
491 Officer. Mr. House provided an example of the CEO looking at a faucet to determine if it is
492 functional is the same amount of time for every faucet regardless of material cost. Mr. Canada
493 added that there is importance with square footage with regards to inspection time from an
494 equitable point of view. He added that square footage is a verifiable figure and that there is no
495 mechanism for the Town to verify building costs. Mr. Houghton commented that the flip side to
496 that is more expensive homes can have more complex infrastructure. Mr. House asked if the
497 Building Inspector was consulted. Mr. Connors replied that the Town has an interim inspector and
498 he was consulted. He summarized that this is not a change that will be made in the immediate
499 future and that the process will include how any fee changes will impact revenues and what percent
500 of the total cost of running the office the proposed fees will cover. He said all of that information
501 would be presented and considered before any final decisions are reached.
502

503 **4. Adjournment**

504
505 **Mr. Canada made a motion to adjourn the meeting at 9:01 pm. Mr. Zaremba seconded the**
506 **motion. All voted in favor and the motion was approved.**



TOWN OF STRATHAM

Incorporated 1716

10 Bunker Hill Avenue · Stratham, NH 03885

Town Clerk/Tax Collector 603-772-4741

Select Board/Administration/Assessing 603-772-7391

Code Enforcement/Building Inspections/Planning 603-772-7391

Fax (All Offices) 603-775-0517

TO: Planning Board Members
FROM: Mark Connors, Town Planner
FOR: October 18, 2023
RE: Potential Zoning Amendments for 2024 Town Ballot

Staff continues to work on potential zoning amendment revisions for consideration on the 2024 Town Ballot. Most of the amendment language is still in the early phases or has not been drafted pending further discussions with the Board. The Board has until early December to post the amendments and public hearings are traditionally held in January. The memo from the September 20 meeting has been revised to reflect updates in the drafting process.

2024 Proposed Zoning Ordinance Amendments
September 18, 2023 *Revised October 17, 2023*

1. Clarify work that requires a building permit and the definition of ‘structures’ that must meet the Town’s property setback requirements.

a. Relevant Zoning Ordinance Sections:

- i. 2.1.79 Definition of “Structure”
- ii. 16.2.1 “Permit Required”

Discussion: The 2018 International Building Code exempts buildings under 200 square-feet from requiring a building permit. However, the Town has traditionally required building permits for such projects. Many towns exempt small sheds from needing to meet the side/rear setback requirements. Additionally, the Town’s definition of ‘structure’ is quite broad. In order to reduce confusion, staff would recommend the Board clarify what projects require building permits and must meet the Town’s setback requirements.

2.1.79 Structure: Anything constructed or erected with a fixed location on or in the ground, or attached to something having a fixed location on or in the ground. Structure including but not limited to, buildings, mobile home, bridges, trestles, towers, framework, hoop houses, tanks or group of tanks exceeding a total of 500 gallons (excluding septic tanks), tunnels, stadiums, platforms, shelters, piers, wharfs, **signs**, fences **over six-feet in height**, and retaining walls over **six-feet (6’)** in height, swimming pools, or the like. Where Stratham Zoning Ordinance is silent, then the most current edition of the State Building Code shall be assumed to apply. (Rev. 3/90, 3/11, 3/20).

Legal Requirements to Consider: Under a new state law, the Town must submit proposed amendments that relate to the Building Code to the State Building Code Review Board to confirm that they are not in conflict with, or less stringent, to the State Building Code. The Town cannot adopt requirements that are less stringent than the state code or in direct conflict with it, however it can make some regulations more stringent.

One necessary amendment to the definition of structure is to require 4-foot retaining walls to file a building permit. This is a requirement of the ICC Code and the Town cannot be more lenient than the State Building Code.

Questions for the Planning Board to consider:

- b. Is the Board amenable to reducing or eliminating the side and rear setback requirements for small accessory structures? *i.e. some towns exempt buildings under 120 square-feet and under 12-feet in height.*
- c. Is the Board amenable to exempting children’s play structures from the side/rear setback requirements? *Note that in 2021, the Zoning Board found that a swingset was not subject to the Town’s setback requirements.*

Potential new zoning section:

5.14 Small Accessory Structures

- i. Small accessory structures or sheds less than or equal to 120 square-

feet in area may be constructed within five (5) feet of a side and/or rear property line if all criteria in 5.14.2 are met.

- ii. Criteria:
 - a. The shed shall not contain a poured concrete foundation or slab.
 - b. The height of the shed shall not exceed 12 feet as measured to the roof peak.
 - c. A maximum of one shed per parcel shall be allowed under this section.
 - d. The shed shall not be constructed within the 50-foot vegetated buffer strip that is required to be maintained along the external perimeter or property line of a Residential Open Space Cluster Development.
 - e. A building permit application shall be submitted and approved by the Building Inspector prior to the start of construction.

Staff would also recommend some modifications to the Shoreland Protection District to allow small accessory structures meeting all of the above criteria within wetland setback areas.

2. Clarify when a property survey/wetland delineation is required for smaller building projects?

Discussion: For smaller residential building projects, the Building Inspector has traditionally permitted an older plan or aerial image with property boundaries to serve as documentation that the application meets the property and wetland setback requirements. However, it is impossible to confirm with certainty that a project meets the setback requirements, including the wetland setback requirements, without a property survey. This is particularly relevant for wetlands as they can change over time. It is not uncommon for information to come to light that past building projects were constructed that encroach into property setbacks.

However, a survey requires a substantial investment and may be a hardship for some homeowners.

Based on the Planning Board discussion at the September 20, 2023 meeting, there appeared to be support on the Board to revise the language to make clear that the Building Official has the authority to require a survey plan to verify that a building permit application does not conflict with the Zoning Ordinance requirements, including the structural setback requirements.

To accomplish this, staff would recommend amending the Building Ordinance as follows

BUILDING ORDINANCE - ARTICLE III: PERMITS

3.5 No building permit shall be issued until the Building Inspector has certified that the proposed building or structure and its intended use comply with the provisions of ~~this~~ the Stratham Zoning and Building Ordinances.

3.10 Before issuance of a Building Permit, the Building Inspector may require that property lines be properly established when not readily apparent, in accordance with the Town's Subdivision Regulations, by a registered surveyor. (Rev. 3/90)

3.10 Prior to the issuance of a building permit, the Building Inspector may require, at his or her sole discretion, that a plan be prepared and stamped by a licensed surveyor to confirm that the application meets the requirements of the Stratham Zoning and Building Ordinances, including all relevant dimensional requirements (4.2 Table of Dimensional Requirements). The Building Inspector may also require that a plan be prepared and stamped by a licensed wetland scientist to confirm that the application meets the requirements of the Stratham Wetlands Conservation District and Shoreland Protection District of the Stratham Zoning Ordinance.

3. Clarify Home Occupation permit approval process including process for renewals.

Discussion: Stratham requires most home occupations to obtain a Special Exception from the Zoning Board of Adjustment and to undergo a renewal process every three years. Staff would recommend that the Ordinance clarify the process to begin operating a home occupation, including that the use meets applicable building/life safety code requirements and meet any required conditions required by the ZBA and obtain a Certificate of Occupancy before beginning operations. Additionally, staff would recommend the Ordinance outline the timeframe necessary for submitting a renewal application and require an inspection at the time of renewal to confirm that the home occupation is operating in accordance with its approvals.

Other proposed modifications: Cap the size of a home occupation at no more than 1,000 square-feet (the Ordinance currently allows any size home occupation so long as it does not exceed 25 percent of the size of the residence), and allow home occupations exempt from the Special Permit requirements to be served by periodic deliveries (the Ordinance currently restricts such home occupations from all vehicle traffic).

Red-lined edits are included below:

5.12.2 (excerpt)

- a. The total area occupied, including storage in accordance with “f” below, by a home occupation shall utilize an area of no more than twenty five percent (25%) of the total floor area of finished floor space of the dwelling, including the basement if finished as habitable space, **or no more than 1,000 square-feet (whichever is less)**, and does not change the residential character of the premises thereof. (Rev. 3/19)

5.12.3 (excerpt)

- b. Before special exception is granted, mandatory building inspections shall be made by the Code Enforcement Officer **for any home occupation regulated under this Section.**~~if the public is to be served at the proposed location or if hazardous materials are to be stored there.~~ **At or immediately subsequent to the inspection, the Code Enforcement Officer will make the applicant aware of any life safety/building code improvements necessary to operate the home occupation.** In addition, a formal site plan review by the Planning Board may be required if deemed necessary by the Zoning Board of Adjustment and/or Code Enforcement Officer.
- c. Upon the granting of the special exception, **the applicant shall be required to address any conditions of the special exception and other necessary improvements required by the Code Enforcement Officer. Prior to the**

start of operation, the applicant shall schedule a final inspection with the Town. If the proposed use meets all requirements of the special exception and those required under life safety/building codes, the Code Enforcement Officer shall issue a Certificate of Occupancy for the home occupation. Only home occupations with a valid Certificate of Occupancy may operate in Stratham. ~~an application for a home occupation permit shall be made to the Building Department on a form provided by the Building Department.~~

- d. All home occupation permits shall be issued for a period of three (3) years and may be renewed provided there is no violation of the provisions of Section 5.12. Requests for renewals shall be submitted to the Building Department **within three years of the date of the original Certificate of Occupancy** accompanied by the renewal fee as approved by the Select Board. The Code Enforcement Officer shall conduct an inspection of the home occupation prior to the approval of a renewal to ensure the use is operating in conformance with its Town approvals. **The Town will mail one notice alerting the applicant of the need to renew the permit. The applicant shall be provided a 90-day grace period to file a renewal application. If no renewal application is filed within this period, the Certificate of Occupancy shall expire, and the home occupation must cease operation.**

5.12.4 Exemptions from Special Exception Application Requirements:

- ~~a. Home occupations in which neither customers nor vehicles, apart from periodic business deliveries, come to the location where the business activity takes place and at which no sign is displayed and no outside person is to be employed and there is no outward appearance of business activity.~~
- b. Home occupations which meet all of the following criteria shall be considered exempt from these requirements and may operate without a special exception:
 1. The business activity does not generate any additional traffic, including no customer and/or supplier traffic, apart from periodic business deliveries. Periodic business deliveries shall be defined as not more than five deliveries a week by vehicles weighing less than 26,000 pounds.
 2. The business activity does not employ anyone who does not have a primary residence at the property.
 3. No sign associated with the business activity is displayed at the property.
 4. There is no outward appearance of a business activity on the property nor any noxious odors or noises produced by the home occupation.
 5. No hazardous materials, including measurable quantities of flammable or combustible materials, associated with the home occupation are maintained at the property.

4. Consider amendments to the Residential Cluster Open Space Development zoning provisions

Consider reducing the minimum lot area for a Cluster Open Space Subdivision from 20-acres to 10- or 12-acres. Discussion: There are increasingly fewer 20-acre+ parcels remaining open for development in Stratham. This change would provide some of the

Require property that is subject to the 50-foot non-disturbance buffer area requirement in cluster developments to be owned and maintained by the Homeowners Association and not individual property owners. Discussion: Encroachments into such buffer areas are a common code enforcement challenge in Stratham. Some property owners claim they are not aware of such restrictions and/or have difficulty accepting such prohibitions on their own property.

Consider setting a minimum lot-size in Cluster Open Space Subdivisions. Discussion: Homeowners in cluster developments typically desire the same types of property improvements that are common across Stratham including pools, decks, accessory structures, and additions. However these features can be extremely difficult to accommodate on very small lots. The Board might require setting a minimum lot size of 0.75 acre, 0.8 acre, 1.0 acre, and 1.2 acre.

The Town might also further limit lot size for properties with on-site well and septic facilities or where wetlands occupy more than 10% of the lot area.

Require property that is subject to the 50-foot non-disturbance buffer area requirement to be owned by the Homeowners Association and not individual property owners.

5. Consider adopting more stringent building requirements for building projects within the FEMA 100-year floodplain.

Discussion: FEMA classifies land that has a 1 percent chance or more of flooding in a given year as part of the 100-year floodplain. Stratham has several low-lying areas adjacent to water bodies classified as part of the floodplain concentrated mostly along College Avenue and Squamscott Drive and along the Squamscott River shoreline. As part of a recent Insurance Services Organization (ISO) Building/Code Enforcement evaluation, Stratham was limited because it does not enforce additional regulations on building in the floodplain.

You can review the FEMA flood maps in interactive format using the following link:

<https://msc.fema.gov/portal/home>

Type in Stratham, NH in the search bar

If the Board is open to pursuing this, staff would not suggest restricting development within the floodplain, but might make development within such areas subject to a special review process, including potentially requiring for a Conditional Use Permit for such development with requirements that development in such areas be elevated above the ground level or potentially not include habitable spaces on the ground level.

Based on input from the Planning Board, staff has further researched this issue and will provide sample regulatory language from other communities for consideration by the Planning Board.

6. Conditional Use Permit Revisions and Simplification

The Planning Board reviewed and largely endorsed proposed changes to the Conditional Use Permit criteria at its August 16, 2023 meeting in order to simplify and expedite the review process for these very common applications and in order to reduce redundancies and duplicative review criteria. Staff will outline all of the changes discussed in a red-lined draft to be reviewed at the Board's October 4 meeting.

7. **Gateway District Zoning Revisions *In Progress***

8. **Route 33 Heritage District**

As part of the implementation of the Route 33 Heritage District, residential densities were revised to stimulate investment in properties that have not seen significant investment. The Ordinance allows up to three units per acre and as properties become available, there is more interest in these allowances. However, some properties stretch many hundreds of feet beyond Route 33 and staff would suggest limiting development to within 800-feet (or some similar distance) of the roadway. Also, staff would suggest the Board consider the density allowances. If the Board would like to maintain the three-unit-per-acre standard, staff would suggest explicitly noting that wetlands, steep slopes, and areas protected by easement cannot be considered in the density calculation. Alternatively, the Board could reduce the standard to two-units-per-acre but provide potential relief for lots that are 1.5 acre or less.

Two proposed language options are offered below depending on the preference of the Board:

3.10.9 Land Uses:

- b. Multi-Family Housing: Multi-Family and Workforce Housing is permitted in the Heritage District by Conditional Use Permit. Multi-Family and Workforce Housing shall be designed such that these uses, as viewed from the Route 33 right-of-way, are indiscernible from the single-family housing and agricultural uses that characterize the Corridor.
 - i. Multi-family housing development density shall not exceed a **maximum** density of three units per acre. **Wetlands, steep slopes, and areas protected from development by conservation easements must be excluded from the lot area in calculating the maximum density potential of a parcel.** In a multi-family development of five or more units, a minimum of 20 percent of the units must be set aside as workforce housing units. **All multi-family housing structures must be located within 800-feet of the Route 33 frontage.**
 - ii. Senior housing, or any form of housing that is restricted to specific age demographic, is prohibited in the Heritage District.

3.10.9 Land Uses:

- b. Multi-Family Housing: Multi-Family and Workforce Housing is permitted in the Heritage District by Conditional Use Permit. Multi-Family and Workforce Housing shall be designed such that these uses, as viewed from the Route 33 right-of-way, are indiscernible from the single-family housing and agricultural uses that characterize the Corridor.
 - i. Multi-family housing development density shall not exceed a **maximum** density of ~~three~~ **two** units per acre. **On lots smaller than 1.5 acres, the Planning Board may approve the construction of up to three units on a single lot as part of a Conditional Use Permit.** In a multi-family development of five or more units, a minimum of 20 percent of the units must be set aside as workforce housing units. **All multi-family housing structures must be located within 800-feet of the Route 33 frontage.**

ii. Senior housing, or any form of housing that is restricted to specific age demographic, is prohibited in the Heritage District.



TOWN OF STRATHAM

Incorporated 1716

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Code Enforcement/Building Inspections/Planning 603-772-7391

Fax (All Offices) 603-775-0517

TO: Planning Board Members
FROM: Mark Connors, Town Planner
FOR: October 18, 2023
RE: PREP 2023 State of the Estuaries Report and MS4 Requirements

The recent release of the Piscataqua Region Estuaries Partnership State of Our Estuaries report, which heavily focuses on Great Bay, is a good reminder about the importance of best practices related to stormwater control and runoff reductions. Staff will provide some highlights from the 2023 Report and the Town's responsibilities under the EPA's MS4 Permit program.

STATE OF OUR ESTUARIES 2023



Great Bay Estuary

Morse Hall
Suite 113
8 College Road, Durham, NH 03824

STATEOF4ESTUARIES.ORG



A Letter From PREP

DEAR FRIENDS AND PARTNERS,

Welcome to the 2023 State of Our Estuaries report.

Over the last few years, we have all been acutely aware of how things can change and of how those changes — both big and small — alter the way we live. In a way, this report is also about change. It tells a story of how our shared home — the Piscataqua Region Watershed — is changing and of how those trends are affecting our estuaries and the countless species that live there. It tells of stress and recognizes that while the challenges we face are significant, so too is our ability to bring about positive change. That is a critical part of this report: we can make a difference. Toward the end of this letter, you will learn about our commitment to protecting and restoring our estuaries and how YOU can help!

This State of Our Estuaries report demonstrates our ability to collaborate over 100 partners, with dozens of experts authoring indicator sections, and PREP staff serving as both contributors and editors. It would not be possible without the collected data, technical expertise, and inexhaustible effort from all those who contribute, and we at PREP are truly grateful to all of you.

Finally, speaking of changes, PREP staff have seen many since our last State of Our Estuaries report. In October of 2021, after 11 years of inspirational leadership as Director, Rachel Rouillard departed PREP to join the New Hampshire chapter of The Nature Conservancy. Fay Rubin, the former Director of NH GRANIT at UNH, joined us as Interim Director and has remained as our Special Projects Manager. Kalle Matso, previously the Coastal Scientist, was named Director in May of 2022. Abigail Lyon is now Manager of our Community Engagement Program and Trevor Mattera manages the Habitat Program. Lastly, we're very excited to welcome Sierra Kehoe as PREP's new Communications Coordinator!

Always feel free to reach out to us personally to chat about these systems that are so critical to our lives. You can find out more about each of us at PREP by visiting our website. There you will also find links to other excellent resources, such as our Eelgrass Dashboard and the Piscataqua Watershed Data Explorer. These sites give you the ability to access and quickly graph the data most interesting to you.

We have a separate website (StateOfOurEstuaries.org) that houses our State of Our Estuaries reports as well as the much longer "Extended Report" that includes more details

on data and methods for each indicator. In addition, you will find special features not included in this printed report, such as new information related to Green Crabs. As you read through the State of Our Estuaries report, you will see plenty of reminders in the indicators about extra information found in the Extended Report.

In addition, StateOfOurEstuaries.org contains our latest "Municipal Guide" with information specific to municipal volunteers and staff. This site also houses our "Residential Guide" for people seeking ways to keep our estuaries healthy.

In order to bring about the positive change we want to see in our Great Bay and Hampton-Seabrook Estuaries, PREP — your National Estuary Program — intends to act on the findings in this report through:

- ▶ **Expanding our resources and support to all interested parties across the Piscataqua Region Watershed**
- ▶ **Maintaining a transparent science and monitoring program and improving access to existing and future data**
- ▶ **Supporting our habitats and partners in restoration and conservation efforts across the Piscataqua Region Watershed**

From all of us at PREP, thank you for caring about our shared estuaries!

Kalle, Abigail, Trevor, Fay, and Sierra



To learn more about PREP, visit PREPestuaries.org and for more information and to explore the State of Our Estuaries report interactively, visit StateOfOurEstuaries.org.

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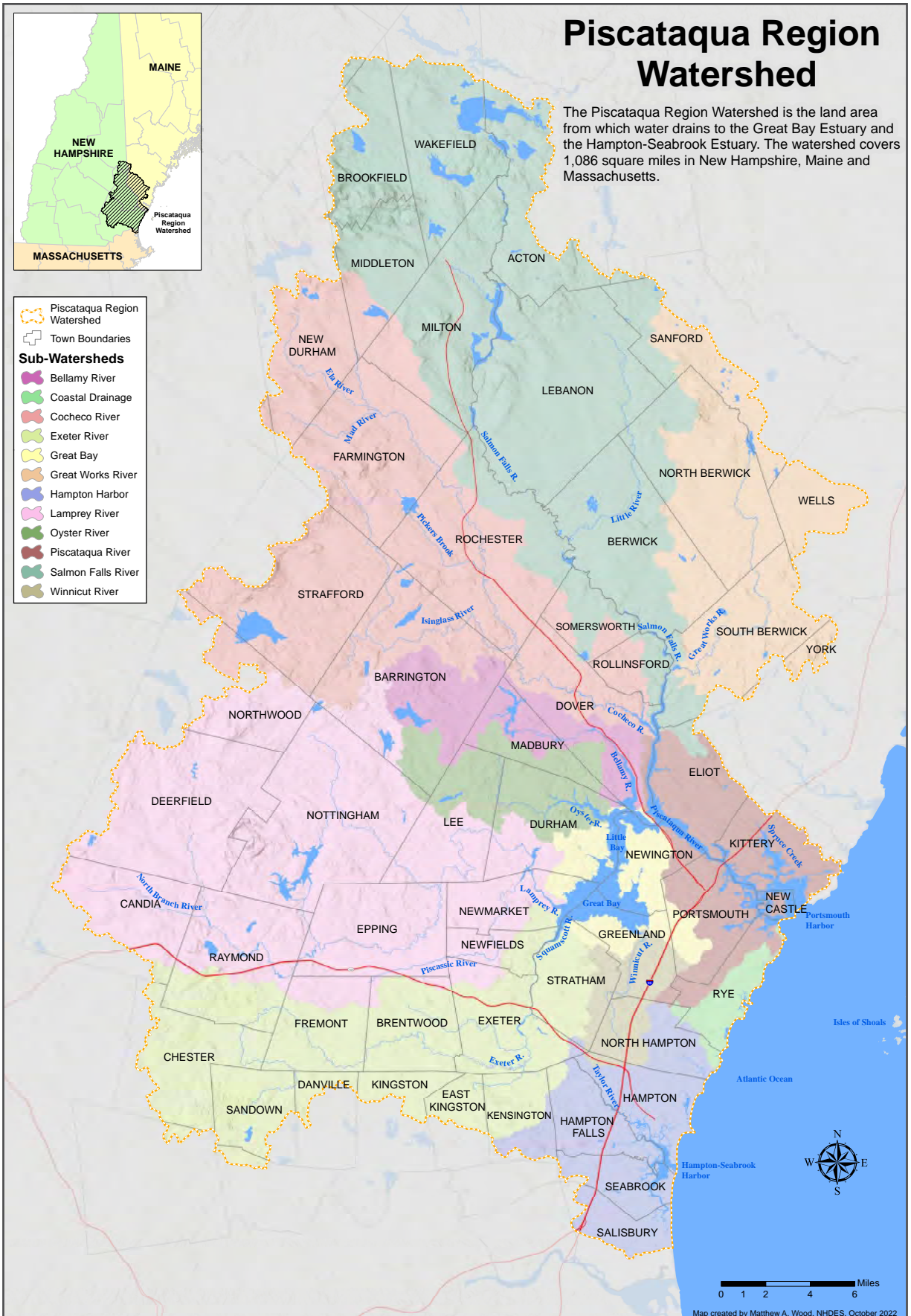
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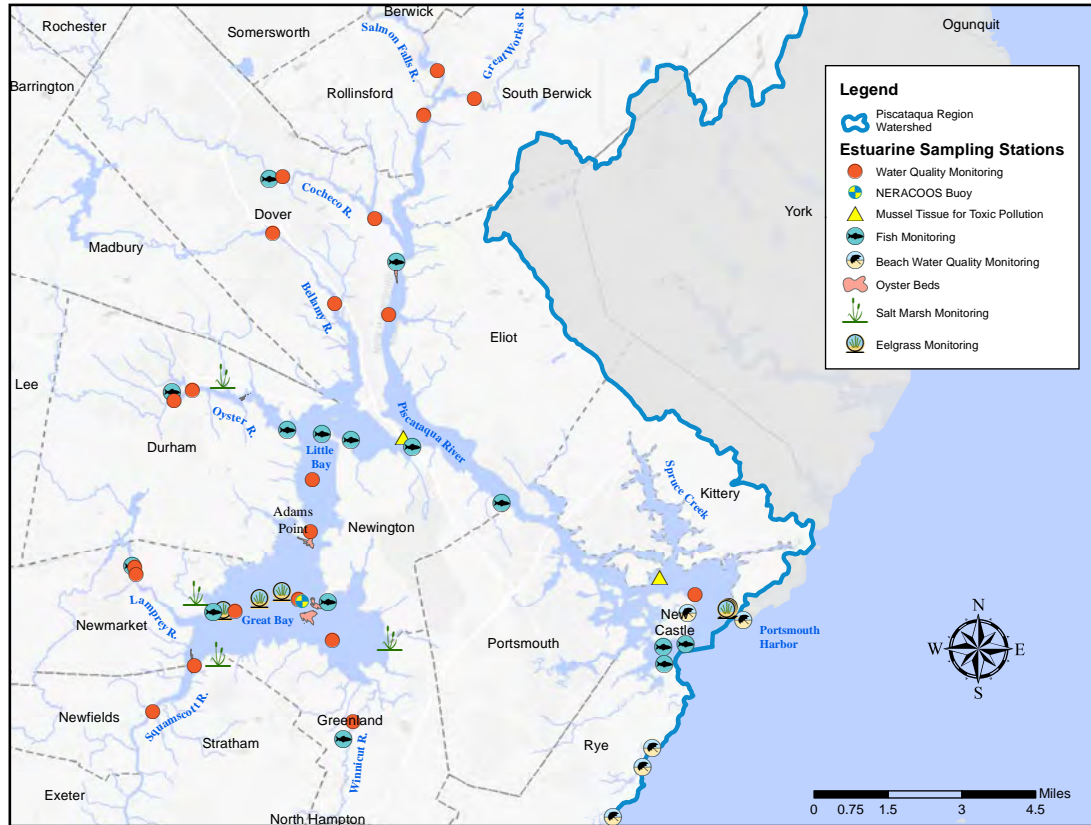
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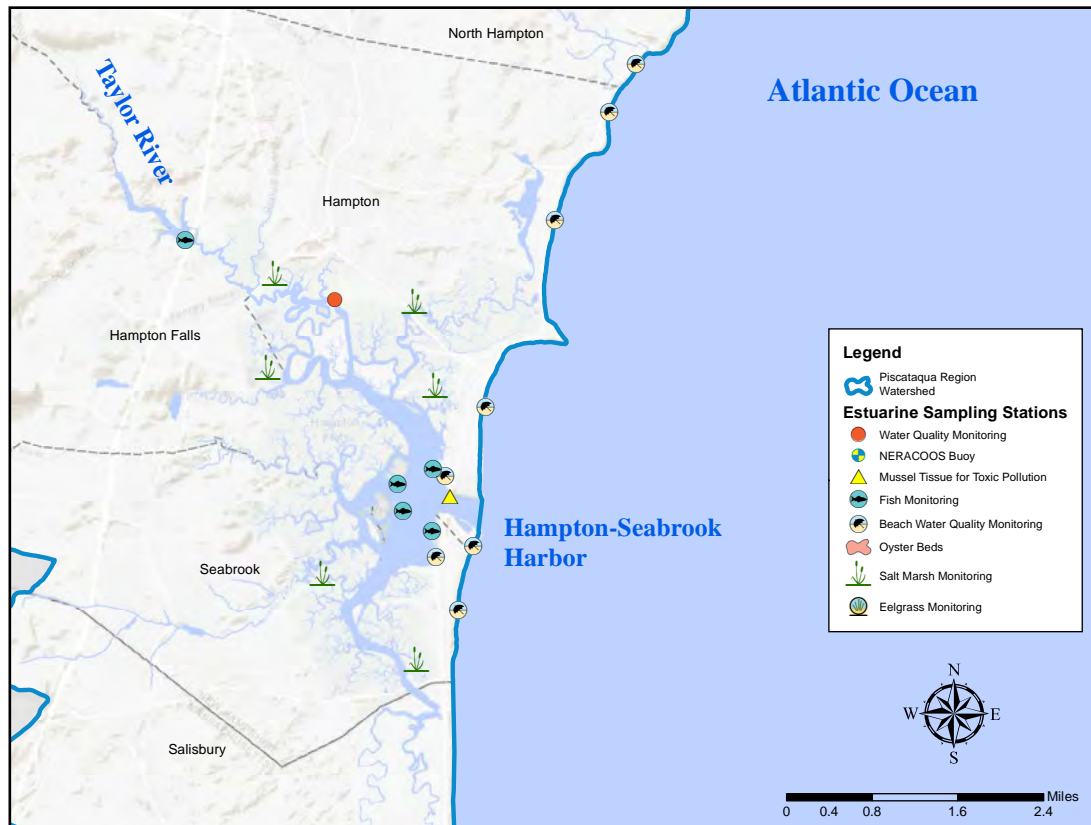
Watershed Map

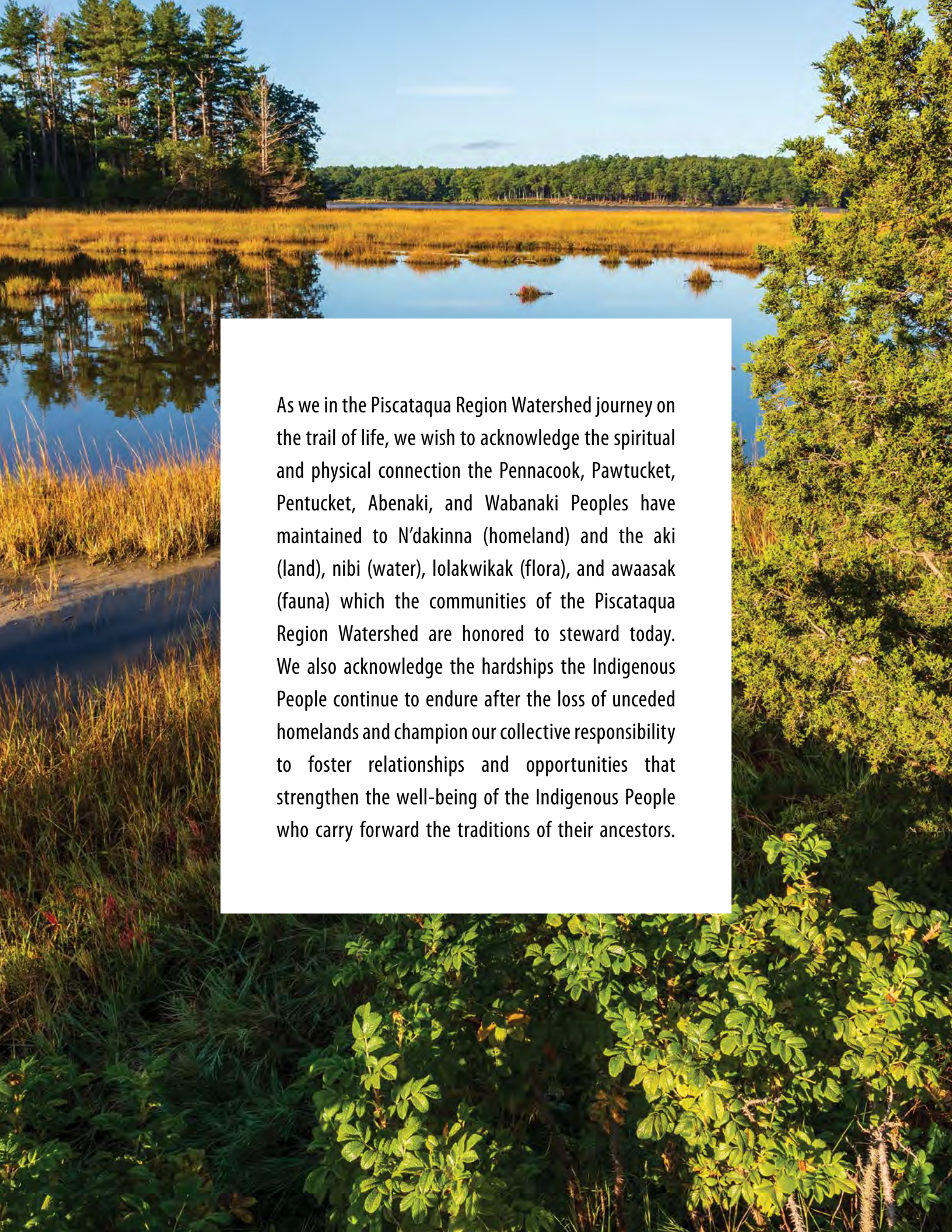


GREAT BAY ESTUARY



HAMPTON-SEABROOK ESTUARY





As we in the Piscataqua Region Watershed journey on the trail of life, we wish to acknowledge the spiritual and physical connection the Pennacook, Pawtucket, Pentucket, Abenaki, and Wabanaki Peoples have maintained to N'dakinna (homeland) and the aki (land), nibi (water), lolakwikak (flora), and awaasak (fauna) which the communities of the Piscataqua Region Watershed are honored to steward today. We also acknowledge the hardships the Indigenous People continue to endure after the loss of unceded homelands and champion our collective responsibility to foster relationships and opportunities that strengthen the well-being of the Indigenous People who carry forward the traditions of their ancestors.

Executive Summary

The 2023 State of Our Estuaries report documents the magnitude of the challenges that face our Great Bay and Hampton-Seabrook Estuaries as well as the Piscataqua Region Watershed. At the same time, it reflects the notable increase in effective collaboration among Piscataqua Region partners over the last five years. Throughout these pages, you will encounter these two themes: the challenges we face are significant, AND so is our power to bring about positive change. To protect and restore our estuaries, we must continue working together toward positive change.

In the following pages, join us for a journey from the perspective of a juvenile river herring to learn about the stressors facing our estuaries. This is a new way to experience what the data tell us about habitats like seagrasses, shellfish, and salt marshes, which continue to struggle with warming waters, extreme weather, and rising seas.

After reading about the herring's journey, you will notice other additions to this report, such as the "Gulf of Maine Regional Perspective." These regional trends remind us that our estuaries are part of and interact with a larger system. For example, monitoring in the Gulf of Maine indicates that warmer waters are impacting a copepod, a type of plankton, that provides food for everything from right whales to herring. Conversely, what we do in the Piscataqua Region Watershed affects our estuaries and in turn the Gulf of Maine.

Also new to this report is a long overdue analysis of changes in water clarity, or light, as it relates to eelgrass health. This analysis is an important complement to studies of Total Suspended Solids and Phytoplankton, two indicators with a significant influence on light penetration. The critical message here is that if we can promote light penetration in deeper waters, perhaps we can compensate for shallower waters getting warmer and more stressful for eelgrass.

In this report, as we review the status and trends of our indicators, the story that develops is both concerning and encouraging. Examples of concerning trends include:

- ▶ **Nitrogen loading from non-point sources increased from the previous period by 15%, influenced in part by increased precipitation in 2017 and 2018. Given forecasts for continued extreme weather, this emphasizes the need to continue improving stormwater management.**
- ▶ **New contaminants of emerging concern are being found in blue mussel tissue at multiple sites in our estuaries; impacts on ecosystem and human health are currently being investigated.**

Examples of encouraging developments include:

- ▶ **Since 2017, 16 more NH communities have adopted more protective stormwater management standards; overall 35 out of 52 communities in the Piscataqua Region Watershed have some level of stormwater standards.**
- ▶ **Nitrogen loading from point sources such as wastewater treatment facilities is at its lowest level since we began regular reporting of this metric in 2003.**
- ▶ **Starting in 2014, eelgrass acreage in the Portsmouth Harbor region has continued to increase.**
- ▶ **There were 5 million oysters at six natural reefs in the Great Bay Estuary in 2020 and 2021. The last time we had more than 5 million oysters was 1998. The region's oyster aquaculture industry has never been more vibrant; it produced nearly a million oysters in 2021, and 30% of those were used for restoration efforts.**
- ▶ **Finally, propelled by the dam removal in Exeter, total migratory fish returns in the watershed are the highest we've seen since 1992!**

In our 2018 Executive Summary, PREP made the case that we needed to work together more effectively. That has certainly happened. For example, the Municipal Alliance for Adaptive Management has improved permit-related decisions between multiple municipalities, the Conservation Law Foundation, U.S. Environmental Protection Agency, and New Hampshire Department of Environmental Services. Now, in 2023, our challenge is to remain vigilant and continue to push the boundaries: both in terms of effective resource management and in terms of effective science to track and understand our changing estuaries.

Indicator Summary

POSITIVE

The trend or status of the indicator demonstrates improving conditions, generally good conditions, or substantial progress relative to the management goal.

TOTAL: 6

CAUTIONARY

The trend or status of the indicator demonstrates possibly deteriorating conditions, a mixture of positive and negative trends, or moderate progress relative to the management goal.

TOTAL: 13

NEGATIVE

The trend or status of the indicator demonstrates deteriorating conditions, generally poor conditions, or minimal progress relative to the management goal.























TOTAL: 3



INDICATOR

STATUS/TREND

STATE OF THE INDICATOR

Impervious Cover		Five subwatersheds and ten towns across the Piscataqua Region Watershed have greater than 10% impervious surfaces. There was no decrease in the number of towns with less than 5% impervious surfaces but the Bauneg Beg Pond-Great Works River and Isinglass River subwatersheds increased from 5% to 5.1% and from 4.8% to 5.1% respectively.
Housing		Since 2015, average housing permit approvals were 515 for multi-units and 549 for single-family units per year. In 2020 multi-units housing permits fell to 361 while single-family permits increased to 628. Housing stock increased by 20% between 2000 and 2020, with 50,446 new units built.
Stormwater Management Standards and Funding		As of 2022, 25 of 42 New Hampshire communities have adopted some level of stormwater standards while the 10 Maine communities continue to follow a state standard. Currently no communities have adopted a stormwater utility.
Salt Marsh		There are currently 5,711 acres of salt marsh in the Piscataqua Region Watershed. While there has been little change in acreage since 2017, marshes are being impacted by sea-level rise and the spread of the invasive common reed (<i>Phragmites australis</i>).
Conserved Lands (General)		As of April 2022, 18.1% of the total land area in the Piscataqua Region Watershed is under conservation. For the 22 coastal communities in the Piscataqua Region Watershed, 22.3% is conserved, surpassing the PREP goal of 20%.
Conserved Lands (Focus Areas)		As of 2022, 29.3% of Conservation Focus Areas (CFAs) are conserved in the Piscataqua Region Watershed based on the 2021 New Hampshire Coastal Watershed Conservation Plan. More progress is needed to achieve our goal of 75% of total acres in the CFAs.
Nitrogen Loading (Point Sources)		Nitrogen loading from point sources for the period from 2017 through 2020 was the lowest (196.9 tons N per year) it has been since consistent monitoring began in 2003.
Nitrogen Loading (Non-Point Sources)		Nitrogen loading from non-point sources increased from the previous period, of 2013 – 2017, by 15%, influenced in part by increased precipitation in 2017 and 2018; further reductions are needed to meet management goals. On the other hand, this is the second lowest level since 2003 and the overall trend is improving.
Nutrient Concentrations		Nitrogen concentrations at most stations are comparable to the lowest measurements on record. Although the Squamscott and Lamprey Stations show increasing concentrations overall, the wastewater treatment facilities in those rivers were recently upgraded, which should have a positive impact going forward.
Dissolved Oxygen		Trends for dissolved oxygen are neither increasing nor decreasing in the Great Bay and Hampton-Seabrook Estuaries. In the bays, dissolved oxygen generally remains above the threshold of 5 mg/L; however, some tributaries experience many days with dissolved oxygen below 5 mg/L.
Seaweed		Although nuisance species of seaweeds continue to compete with eelgrass, especially in the Great Bay, overall trends show that seaweeds seem to be decreasing, especially relative to eelgrass.
Eelgrass		Eelgrass acreage and biomass in the Great Bay Estuary remain low in comparison to historical values; however, the Portsmouth Harbor region has been on a generally positive trend since 2014.
Phytoplankton		Chlorophyll-a levels are mixed, with increasing trends at some stations and decreasing trends at others. Most data show decreasing concentrations in recent years, even at the stations with increasing long-term trends.
Total Suspended Solids		Levels of total suspended solids in both the Great Bay and Hampton-Seabrook Estuaries are high relative to other estuaries, and the data at Adams Point indicate a statistically increasing long-term trend despite some signs of recent decreases.
Bacteria		With the exception of <i>Vibrio</i> spp. increasing due to warmer water temperatures, fecal-indicating bacteria show a statistically significant decreasing trend.
Shellfish Harvest Opportunities		The percentage of possible acre-days has been on a statistically significant upward trend for the period 2006 to 2021 due to wastewater treatment facility upgrades and expanded testing programs.
Oysters		Although restoration activities and commercial aquaculture are both increasing, natural oyster reefs remain approximately 80% down from 1993 levels, despite some improvements in recent years.
Softshell Clams		Clam populations in the Hampton-Seabrook Estuary remain below management goals even during relatively good years, a consistent declining trend since the peak in 1997.
Beach Advisories		Between 2017 and 2021 there was a significant increase in the number of beach advisories, switching this indicator from “positive” in 2018 to “negative” in 2023.
Migratory Fishes		In 2021, total migratory river herring returns in both estuaries were at their highest since 1992. However, three of the six tributaries monitored continue to have negligible counts.
Toxic Contaminants		While some contaminants are declining, some (e.g., mercury and PCBs) remain high enough to warrant concern. Also, many contaminants of emerging concern (e.g., PFAS) are impacting our communities and have yet to be monitored sufficiently.
Stewardship Behavior		Total volunteer hours decreased in 2020 likely due to COVID-19 to 6,810 hours, a 76% decrease compared to 2019 average, and the total number of volunteers decreased by 64%. However, in 2021, volunteer hours increased to 15,088, from 582 volunteers across 63 events.

The Journey Through Our Watershed: A Fish Story

Barrington

Dover

INTRODUCTION

In this story, you are invited to follow along with a juvenile river herring during its first few months of life from hatching in a freshwater river through its journey in the Great Bay and out to the Atlantic Ocean. This section is also a journey through the many challenges that threaten our watershed and two estuaries of national significance: Great Bay Estuary and Hampton-Seabrook Estuary. Be forewarned: the list of stressors is long! We list these stressors because we can not solve a problem if we do not accurately define what's happening. Given the magnitude of these stressors, it's the view of the Piscataqua Region scientific community that we must improve habitat quality

using **every** tool we **can** control to compensate for factors we **cannot** control.

Science indicates that we *can* make a difference; indeed, we *are* making a difference. You will read about how nitrogen loading from point sources — “point source” refers to pollution that comes from an identifiable localized source, such as a wastewater treatment plant — is lower than at any other time in our data record. You will see that in some places, oysters are making a modest comeback. Data also indicate that migratory fish returns are higher than they've been since 1992. This is what it means to make a difference!


South

Newmarket

New

Stratham





Help us continue to make a difference for our estuaries. Let your local government know you are concerned about the resilience of the Great Bay and Hampton-Seabrook Estuaries. This is the single most important thing you can do to protect these critical ecosystems! More specifically, here are some primary actions we can take together to build their resilience.

- ▶ Conserve land to preserve open space
- ▶ Maintain, adopt, and enforce riparian buffers (vegetated areas near streams and rivers)
- ▶ Manage stormwater to reduce pollution and flooding
- ▶ Better manage nutrient pollution from septic systems and wastewater treatment facilities
- ▶ Reduce your own contributions to pollution

More information on how to support these efforts is available in the State of Our Estuaries sub-publications: "Municipal Guide" and "Residential Guide." With that, please take a deep breath and plunge into a journey through the Piscataqua Region Watershed!



The Journey Through Our Watershed: A Fish Story

FOLLOWING THE HERRING



It's spring and a new generation of river herring has hatched in the upper reaches of the Exeter River (1), the freshwater portion of what becomes the Squamscott River before it empties into the Great Bay. Only a few years ago, this leg of the journey would have been impossible, but with the removal of the Great Dam (2) in 2016, herring now have free run of the lower Exeter River for the first time in 400 years.

These herring are actually two species of migratory fish: the blueback herring (*Clupea aestivalis*) and the alewife (*Clupea pseudoharengus*) (Figure 1). Later in the summer, the juvenile fish will swim toward the saltier waters of Great Bay, where they will seek cover and food in its salt marshes, intertidal rocky areas, eelgrass meadows, and oyster reefs. Those that survive will migrate to the Gulf of Maine, where they will live for approximately four years before returning to freshwater rivers like the Exeter to spawn and restart the cycle.

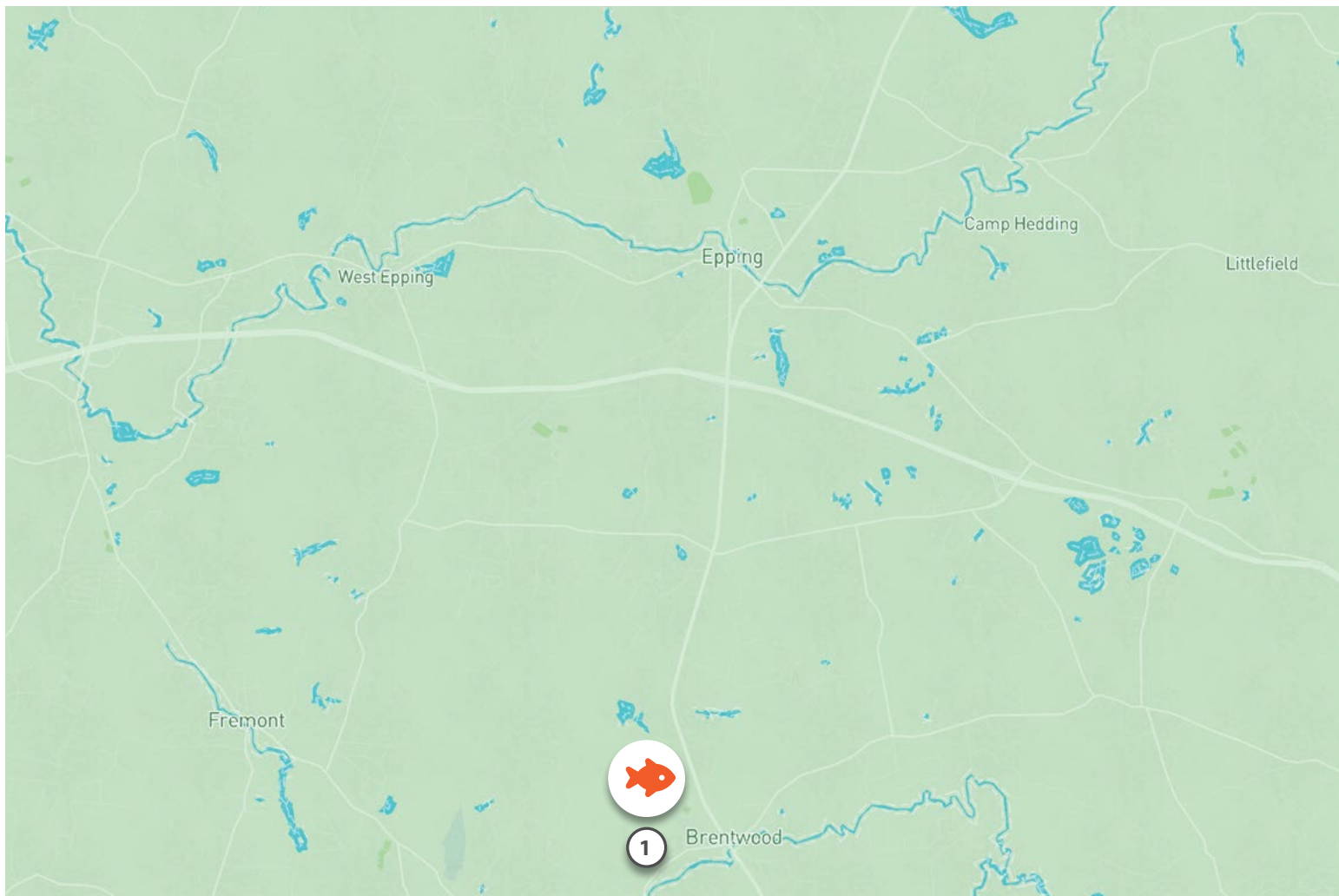


Alosa aestivalis
Blueback Herring



Alosa pseudoharengus
Alewife

Figure 1: Two herring species utilize the Great Bay Estuary as they move throughout their life cycles. Data source: Integration and Application Network, University of Maryland, Center for Environmental Science



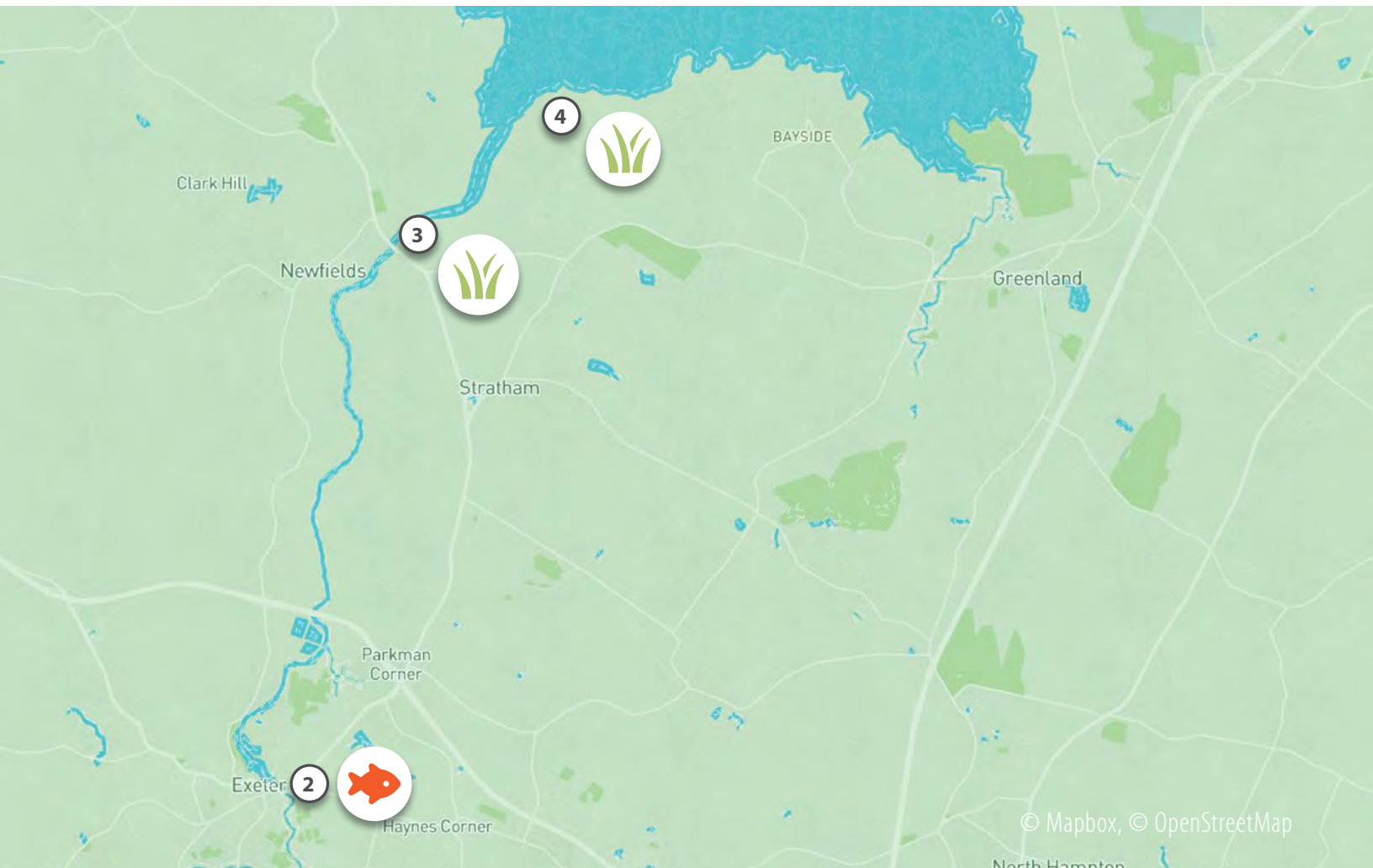
FEWER HABITATS



As the juvenile fishes make their way to the ocean where they will spend the next four to five years, they might encounter the beautiful and extensive salt marsh at Chapman's Landing (3), where small mysid shrimp — one of their favorite foods — thrive. Before they enter Great Bay, they may spend some time in the Estuary's largest oyster bed at the mouth of the Squamscott River, where there were over 4 million oysters in 2021! These shellfish provide safe places to hide from predators and plenty of food, such as barnacle larvae. From there, the young herring swim into Great Bay, where, at high tide, they take refuge in smaller fringing marshes, such as those in front of the Great Bay Discovery Center in Greenland, New Hampshire (4). At low tide, they leave the marsh edges in search of deeper water habitats, such as eelgrass beds, where shrimp are also plentiful, or they may venture to oyster beds near Nannie Island and Woodman Point in western Great Bay. The

herring continue this tidal dance among habitats as they move through the estuary.

In the mid-1990s, young herring would have had a lot more habitat to use for food and shelter during their journey. While oysters and eelgrass still exist in the Great Bay Estuary, particularly south of Adams Point, they are far less abundant and healthy than they were 30 years ago. These days, the juvenile herring must spend more time moving across much larger stretches of bare estuary bottom where they are more vulnerable to predation. The story is the same for Little Bay and the Piscataqua River. Only 25 years ago, a young herring could travel from the eastern shores of Little Bay to the Piscataqua River and under the I-95 bridge in Portsmouth/Kittery, all the while remaining mostly under the cover of either eelgrass or oysters. Today, those habitats are greatly diminished and there are more extensive stretches of bare mud.



The Journey Through Our Watershed: A Fish Story

WARMER WATERS



Throughout their journey, herring today are also swimming in warmer waters. An analysis of water temperatures taken in August at the Adams Point Station in Great Bay (5), where the time series goes back to 1988, shows a statistically significant warming trend through 2021. This is concerning since the warmest waters occur in August and September, which are the months when juvenile herring are beginning to move downstream. Warmer waters speed up the fishes' metabolism, so they need more food to stay alive, increasing their reliance on food sources found in marshes, eelgrass beds, and oyster reefs.

Higher water temperatures also adversely affect water quality. For example, certain harmful bacteria such as *Vibrio* species — which cause gastroenteritis and wound infections — are on the rise (see “Bacteria”). Warmer waters also nourish parasites that are reducing the lifespan of oysters in our estuaries. Finally, warmer waters impact eelgrass, another habitat on which juvenile river herring depend. In the warmest months, water temperatures in the shallow regions of Great Bay and Little Bay can rise above 25° C — that's equal to 77° F — the threshold at which temperatures become harmful to eelgrass (Figure 2).

In general, science shows that temperatures higher than 23° C are less than optimal for eelgrass; temperatures as high as 25° C lead to considerable stress, and 28° C is lethal. Some research has found that six consecutive days over 25° C is enough to lead to eelgrass die-off. More data and discussion on water temperature and eelgrass can be found in the “Eelgrass” section of the report.

Even in the deeper waters of the Gulf of Maine, river herring will encounter waters warming faster than any place on the planet (see “Regional Perspective”). Herring population declines in the Gulf of Maine have been attributed to these warmer temperatures and shrinking populations of an important copepod, *Calanus finmarchicus*

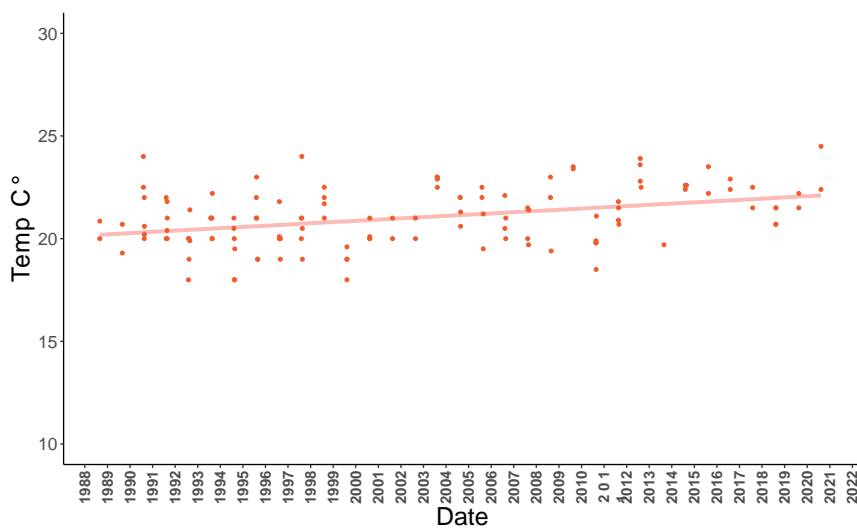


Figure 2: Water temperature taken at various tide stages at Adams Point Station during August, from 1988 to 2020. The increasing trend is statistically significant. Although the temperatures in this graph are below 25° C, temperatures in shallower areas, where eelgrass grows, are frequently above 25° C (see “Eelgrass”).

Data source: Jackson Estuarine Laboratory, UNH

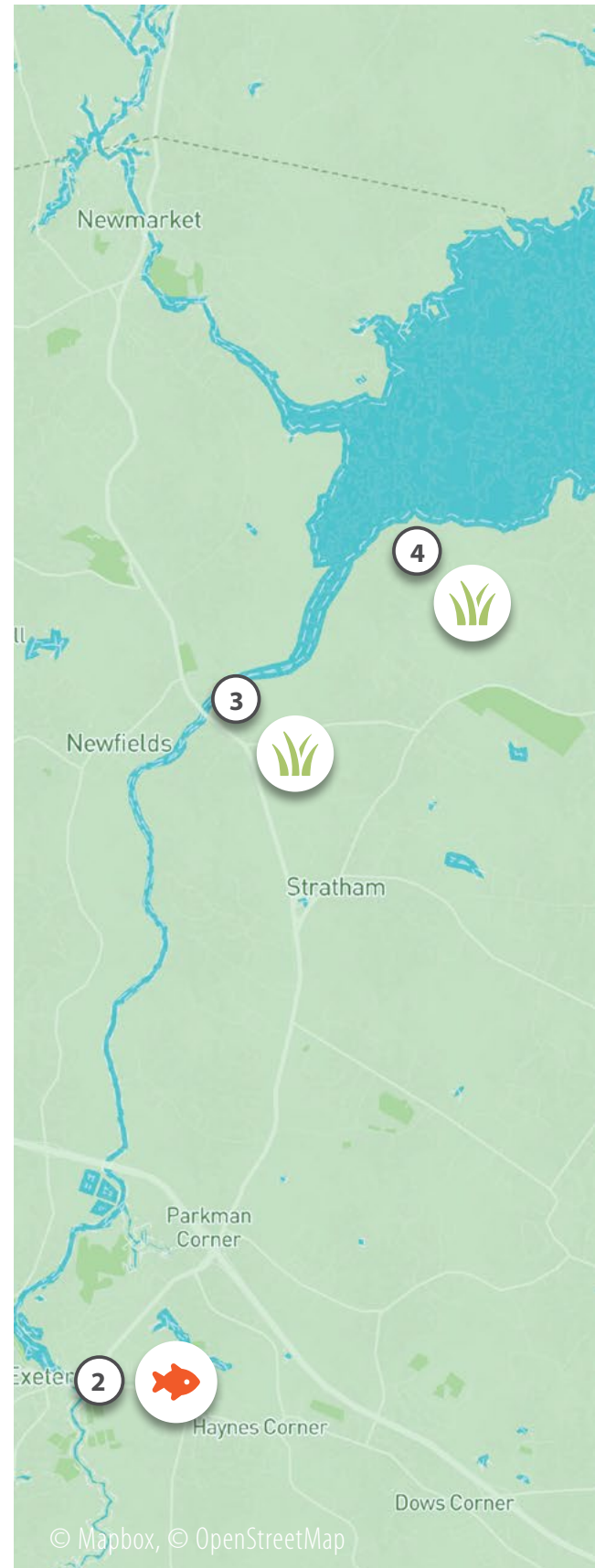




Figure 3: *Calanus finmarchicus* (body about 2 mm long).

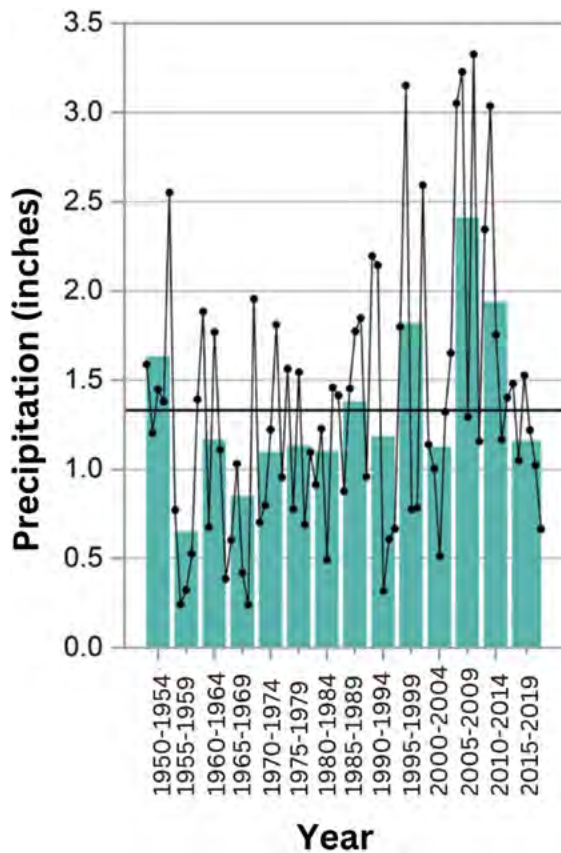


Figure 4: Extreme precipitation events. Black dots represent annual values, in some cases averaged over multiple stations. Green bars indicate averages for 5-year periods.

Data source: adapted from NOAA Climate Summaries

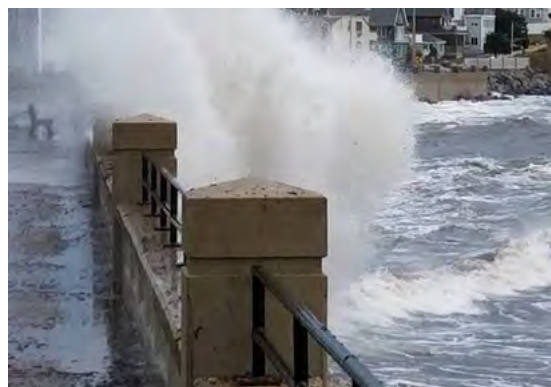


Photo by Vicki Thompson

(Figure 3), a significant prey species for everything from herring to whales.

But the story does not end when herring reach the Gulf of Maine. Their journey runs in reverse when herring reenter the Great Bay Estuary and make their way up the rivers to spawn. Once again, they are dependent on healthy waters and available habitat in order to create the next generation

MURKIER WATERS

The herring’s journey is not only warmer, with fewer places of refuge, it’s also murkier. At Adams Point, on the border of Little Bay and Great Bay, data collected since 1988 show that concentrations of both total suspended solids and phytoplankton began to increase after the 1990s. It isn’t surprising then to see that light conditions have worsened over time (see “Light”) since total suspended solids and phytoplankton are the main factors that determine water clarity.

Lower light is a problem for many organisms but especially for eelgrass. This problem becomes worse under higher water temperatures, which increases eelgrass’ metabolic rate. This means eelgrass plants require more photosynthesis and thus, more light when the water is warmer. Given that we have few tools, if any, to reduce water temperature, keeping waters clear takes on a greater importance.

STORMIER WATERS



The young herring — and their habitats — will most likely experience a stormier estuary. If we look at extreme precipitation events since 1960 (Figure 4), we see that the Piscataqua Region is experiencing more of these events, a trend forecasters agree will continue.

More storms generate more runoff, washing more nutrients, sediments, and toxic contaminants off impervious surfaces and lawns into our estuaries — all of which negatively impact herring. As we consider our stormwater management strategies for the future, precipitation increases need to be part of our calculations.

The Journey Through Our Watershed: A Fish Story

RISING WATERS



Since 1998, sea levels have risen by over 2 mm a year and the rate is increasing. In our region, salt marsh is the habitat most impacted by sea-level rise (see “Salt Marsh”). But rising seas are eroding stream banks as well as marshes, increasing total suspended solids, and worsening light attenuation. This creates problems for herring, and also creates problems for humans who depend on salt marshes and other buffers for protection of their property from wave erosion and storm surge.



Photo by Todd Selig

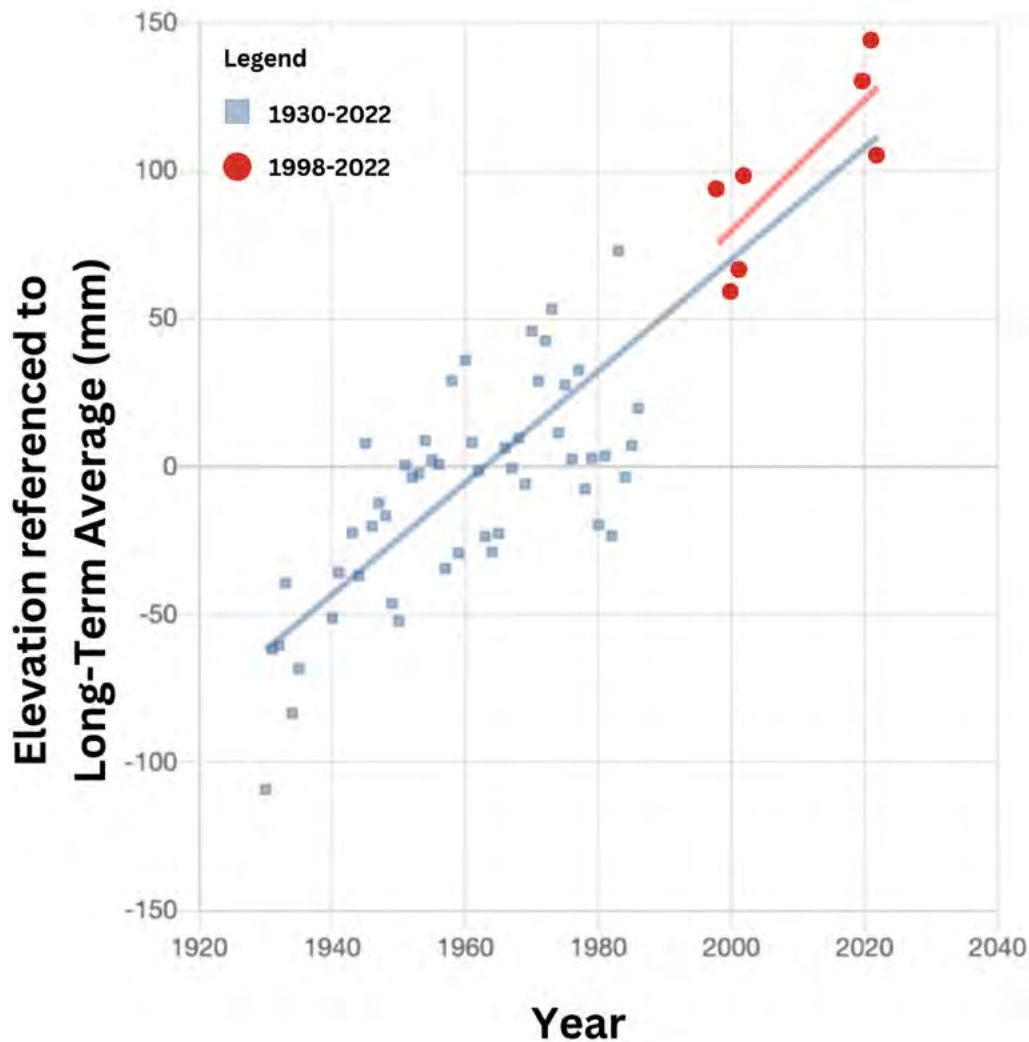


Figure 5: Sea-level rise measured at the NOAA Station located at the Portsmouth Naval Shipyard.
Data source: Maine Sea-Level Rise Dashboard

DOING WHAT WE CAN

With such significant physical changes occurring throughout our estuaries, protecting the herring of the future can seem like a daunting challenge. Stresses are increasing at a pace that could outstrip the slow recovery of estuarine habitats that support not only herring, but many other species and also our Piscataqua Region Watershed economy!

What can we do to protect the herring, their habitats, and the other benefits that healthy estuaries provide?

The solution is straightforward, though accomplishing it is difficult. **We must improve water and habitat quality using everything we can control to compensate for factors that we cannot control.** Things we can not control include the changes we've made to the landscape that are difficult to undo; they also include stressors related to climate change (Figure 6). But we can control future changes in the landscape by developing in a more low-impact manner, reducing pollution through stormwater management and redevelopment, and conserving open space.

Success will be easier if we use a proactive rather than reactive approach. This strategy recognizes that even if we can reduce chronic stresses (e.g., pollution), the future could have episodic stresses (e.g., storms) in store for us. A proactive approach will result in estuaries that are both more resistant and more resilient to stress. Healthy estuaries — those in Quadrant 4 — are so well balanced that when a

BEYOND THE FRONT PAGE HEADLINES

In this report, we focus on the big, clear stories. But there are also many important stories that are more nuanced; they require more space to discuss sufficiently. For example, we reviewed decades of data related to the wind, wind direction, sunlight, and pH. The results of these analyses are covered in detail in the Extended Report at StateOfOurEstuaries.org

stressful condition arises, the reaction is seamless and we may not even notice (high resistance). And when healthy estuaries do experience a challenge such as a hurricane, they are able to bounce back (high resilience) when the stress is alleviated (Figure 7).

We all want our estuaries to be in Quadrant 4 of Figure 6, which represents "Good" condition. But climate change and the region's increasing population are adding further stress

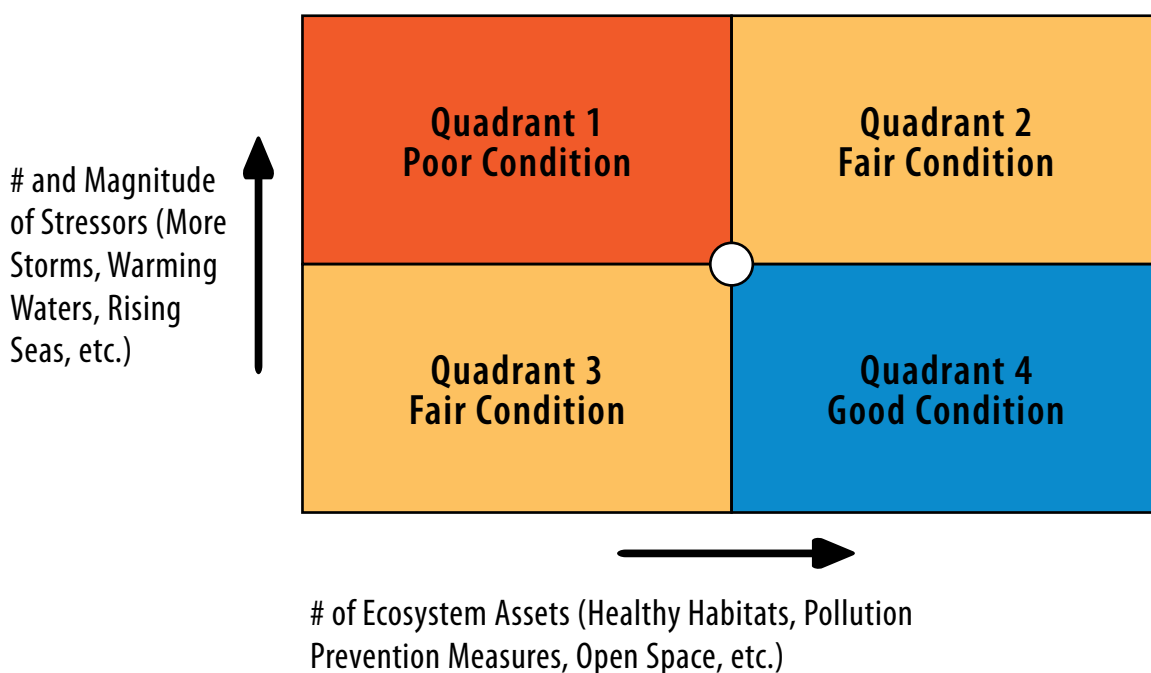


Figure 6: The Stressor - Asset Matrix breaks the condition of our estuaries into four quadrants based on the number and magnitude of stressors (vertical axis) and assets (horizontal axis). The white circle in the center is our hypothetical current position. To maintain our estuaries in "Fair" condition (Quadrant 2 or 3), we must either add to our assets or decrease stressors. The only way to reach Quadrant 4, which has "Good" condition, is to simultaneously increase assets and decrease stressors. Conceptual model: PREP

The Journey Through Our Watershed: A Fish Story

on the system. Likewise, impervious cover, which contributes to increased nutrient loads, continued to increase 0.2% since 2015 (see “Impervious Cover”). Using the knowledge presented in this report we can make decisions that address these trends and improve the condition of our estuaries.

Around the watershed, work to turn the tide is happening. The Exeter Dam removal in 2016 is an excellent example of how a community can wrestle with difficult decisions and ultimately take action to decrease stress and add ecosystem assets. There are also actions underway like the major culvert restoration project near Rye Harbor that restore hydrology to impacted wetlands (Figure 8). Many communities around the region are implementing more effective stormwater management programs in their efforts to reduce nutrient loading and mitigate flooding.

Initiatives like these provide support to our struggling habitats. Though the latest eelgrass data are mixed, there are some signs of recent improvement, such as new acres of eelgrass in the Portsmouth Harbor region. For the 21 years between 1999 and 2019, we had less than 5 million oysters in the Great Bay Estuary; we’ve had more than 5 million for the last two years for which we have data (see “Oysters”). In 2021, over 260,000 river herring returned to Piscataqua Region tributaries (see “Migratory Fish”); that number of returns has not occurred since 1992!

Scientists are often criticized — occasionally for good reason — for emphasizing what they do not know instead of what they do know. So let’s finish this story by emphasizing what we, the Piscataqua Region scientific community, do know. We know that our key habitats are struggling much more



Figure 8: Surveyors plan a culvert restoration in Rye, NH, as part of the “Resilient Tidal Crossings” project. Designs call for this 3.5-ft wide culvert to be replaced in 2024 with a 15-ft wide structure, restoring natural hydrology to critical salt marsh habitat on the Seacoast. Photo by Kevin Lucey

than we want them to be. We know that there are some signs that we could be having a positive impact on fish and shellfish and the habitats on which they rely. We know we have a long way to go to reach our goals, and we know that we have many continuing and newly emerging challenges. We know from attempts to restore other estuaries that recovery is possible and that it takes persistence and incredible effort.

The staff of PREP look forward to working with all of you to continue this huge but rewarding endeavor. For the river herring, for the other plants and animals in our estuaries, for our local economies, for all of us who enjoy clean water and abundant wildlife...let’s make sure that, in five years when the next State of Our Estuaries Report is issued, we can reflect on the benefits of another half decade of impressive work!

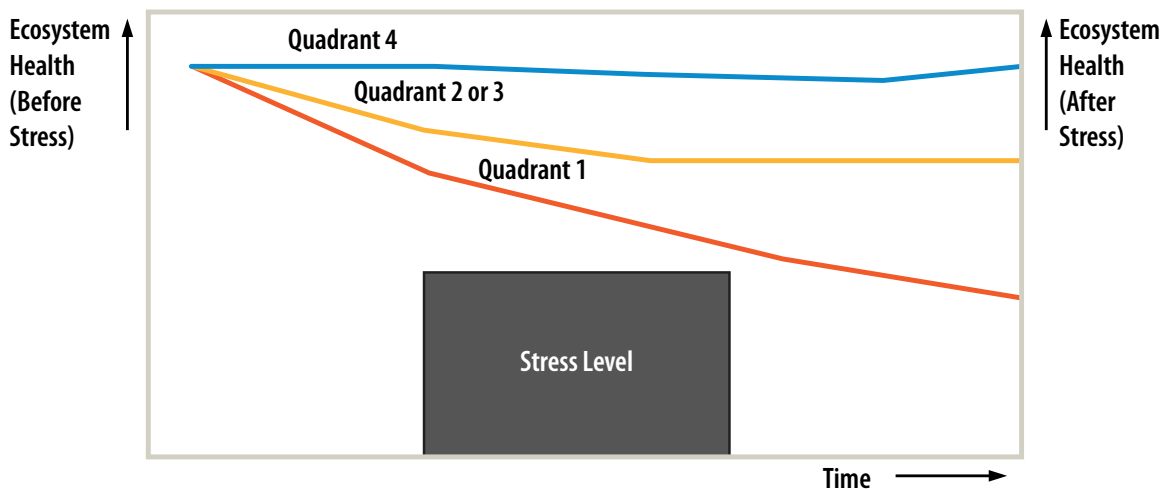


Figure 7: Conceptual model showing estuaries in different conditions reacting to stress. The Quadrant 4 Estuary (Good Condition) resists stress with very little change in health and returns to its original state when the stress is removed. Estuaries in Quadrants 2 or 3 (Fair Condition) are less able to resist stress and settle into a new, but less healthy, stable state when the stress stops. The Quadrant 1 Estuary (Poor Condition) is unable to resist stress, unable to improve its health, and experiences continued decline even when the stress is removed. Conceptual model: PREP



Gulf of Maine Regional Perspective

Conditions in our estuaries are shaped by local processes but are also influenced by ecosystem dynamics operating at larger scales such as the Gulf of Maine. The following is a brief overview of key changes detected by the regional ocean observing system managed by the Northeastern Regional Association of Coastal Ocean Observing Systems (NERACOOS) as part of the U.S. Integrated Ocean Observing System (IOOS), the backbone of which is a network of buoys stationed along the Gulf of Maine coastline and at selected offshore locations (Figure 9). Data from the buoy network are supplemented by autonomous underwater gliders, land-based high-frequency radar stations, coastal sensors, ship-based surveys, and other tools. For more information, visit NERACOOS.org

LONG-TERM REGIONAL TRENDS

It has long been documented that the Gulf of Maine is warming faster than almost any other ocean ecosystem on Earth. This trend continued in 2021 as the most significant marine heat wave since 2012 was felt across the Gulf. By mid-January 2021, daily average temperatures on the Eastern Maine Shelf began to reach or exceed the maximum values observed over the past 20 years, and temperatures did not fall below the 20-year average the entire year except for one brief instance (Figure 10). Air temperatures during the winter of 2020-2021 were not abnormally warm and the water



Figure 9: The Great Bay Buoy has been in operation since 2005. The original buoy was replaced in 2022 through contributions from NHDES, PREP, UNH, the Alliance for Coastal Technologies, IOOS, and NERACOOS. The buoy and associated sensors collect critical data for understanding differences between estuarine dynamics and those of the Gulf of Maine ecosystem. Photo by Jackson Estuarine Lab, UNH

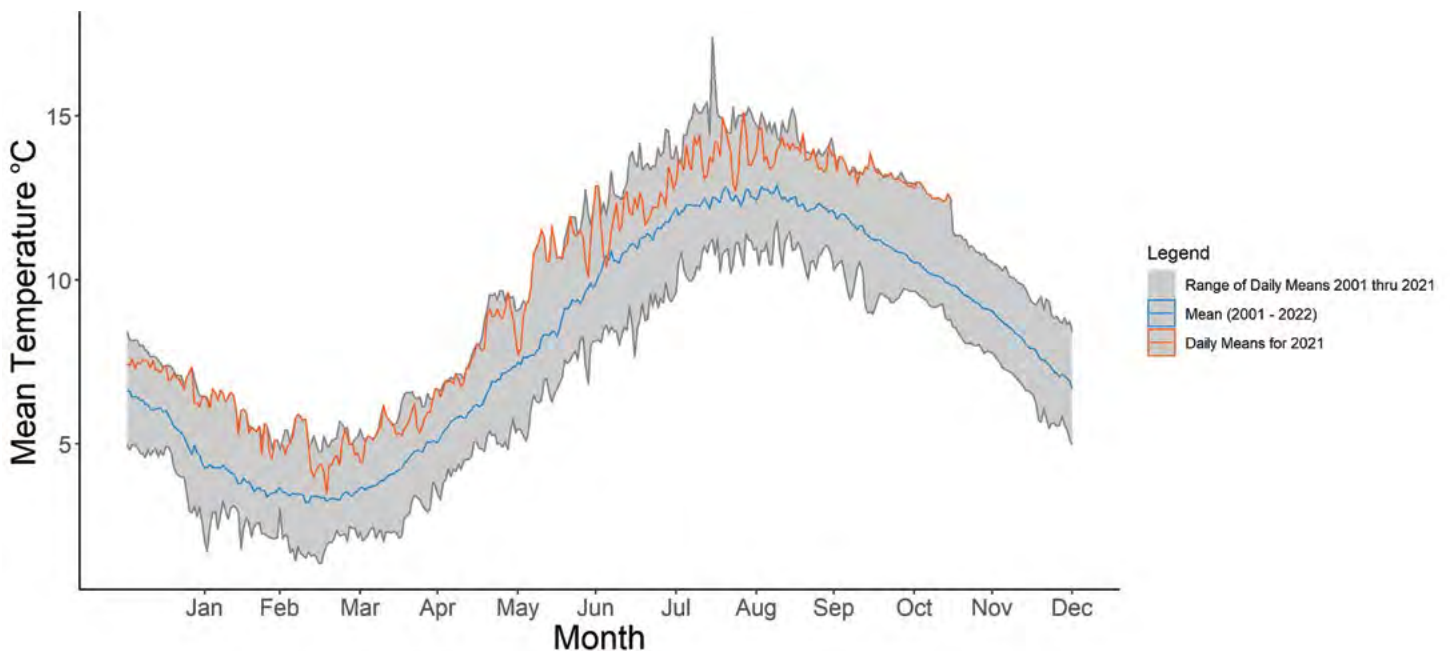


Figure 10: Daily average surface temperatures at NERACOOS Buoy I on the Eastern Maine Shelf in 2021 (orange line) relative to the daily 20-year average (blue line) and range (gray shaded area).
Data source: NERACOOS

temperature anomaly was observed throughout the water column rather than solely at the surface, suggesting that the marine heat wave was driven by oceanic rather than atmospheric influences. Furthermore, extreme temperatures were observed at stations progressively downstream along the Maine Coastal Current, following the dominant counterclockwise circulation trend in the Gulf.

Partly due to changes in temperature, an ecological change that is becoming increasingly clear in the Gulf of Maine is a fundamental restructuring at the base of the food web. In particular, the lipid-rich copepod, *Calanus finmarchicus*, has long been a dominant species of zooplankton that is respon-

sible for vital trophic linkages between primary producers (e.g., phytoplankton) and higher-level predators. *Calanus* are the major prey for the critically endangered North Atlantic right whale as well as forage fishes such as Atlantic herring and sand lance. In turn, these fishes are important prey for humpback whales, Atlantic cod, and other economically important marine mammals and fishes. Monitoring reveals that *Calanus* abundance in the Gulf of Maine has been below average in recent years (Figure 11), corresponding to shifting temperatures, salinity, and other environmental conditions. If *Calanus* abundance declines to a level that is too low to consistently support fishes and whales, there are likely to be critical consequences for river herring and striped bass, as

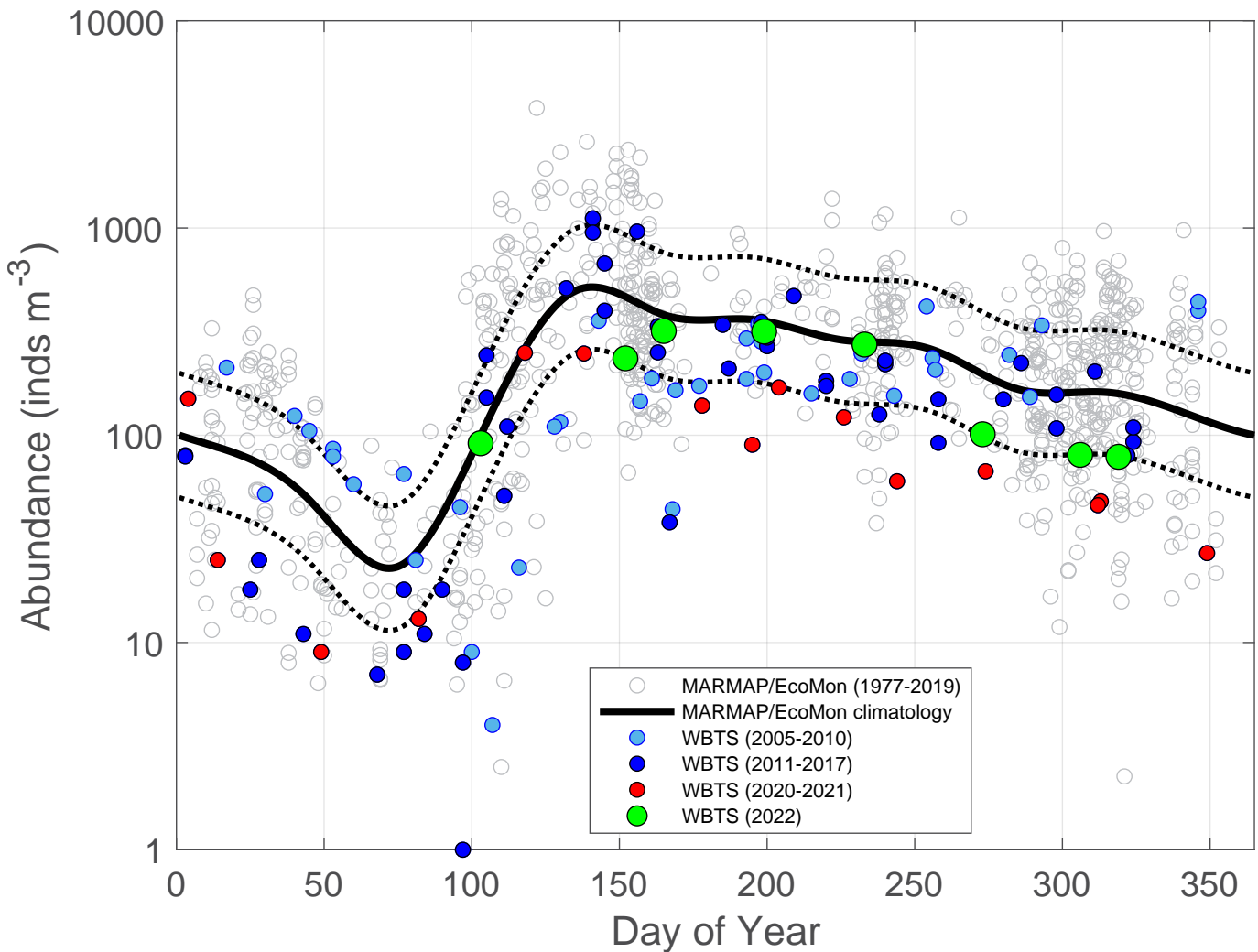


Figure 11: Long-term trends (top) in abundance of the copepod *Calanus finmarchicus* measured by the NOAA MARMAP and EcoMon programs, and at the Wilkinson Basin Time Series (WBTS) Station. Newer WBTS data points from the sampling program implemented by the Integrated Sentinel Monitoring Network, with support from the Marine Biodiversity Observation Network, are colored red (2021) and green (2022) to illustrate the low abundance observed in recent years. Note that this abundance is expressed on a logarithmic scale. Data source: NOAA and Woods Hole Oceanographic Institution

Gulf of Maine Regional Perspective

well as industries that depend on these and other affected species (especially fisheries and ecotourism).

EMERGING ISSUES

Although Harmful Algal Blooms (HABs) are not a new phenomenon in the Gulf of Maine, there are signs that they are becoming more problematic. This is due to the emergence of new HAB species in the region, notably the first documentation of *Pseudo-nitzschia* in 2012, as well as changing conditions that can promote increased frequency and severity of blooms of all HAB species. Warmer water temperatures foster the development of HABs, as do increasing precipitation rates. Increases in temperature and precipitation also affect nutrient dynamics, which in turn drive HAB dynamics. More frequent and severe HABs have important implications for human health, recreation, and seafood production.

Another emerging issue is the rising concentration of CO₂ in the atmosphere and oceans, which is contributing to ocean and coastal acidification (OCA). Increased acidity in our coastal and ocean waters can pose a problem for

shell-forming species (e.g., lobsters, oysters, clams, etc.), slowing the growth of new shell and, under extreme conditions, degrading existing shell. While the dynamics of OCA and its linkages to factors such as freshwater inputs and changing precipitation patterns are complex, understanding the impacts of OCA will be crucial given the high importance of these species to fishing communities and shellfish growers in the Northeast.

Finally, high-tide flooding constitutes another emerging issue warranting attention. An analysis of the first eight years of data from a tidal gauge at the mouth of the Hampton-Seabrook Estuary revealed that high tide flooding (greater than 10 ft above mean lower-low water) occurred on 36% of days monitored (Figure 12), with prospects for more frequent flooding as sea-level continues to rise. Sea-level rise interacts with long-term tidal cycles, making it harder to discern different signals and underscoring the importance of long-term time series.

Acknowledgment and Credit Jake Kritzer (NERACOOS)

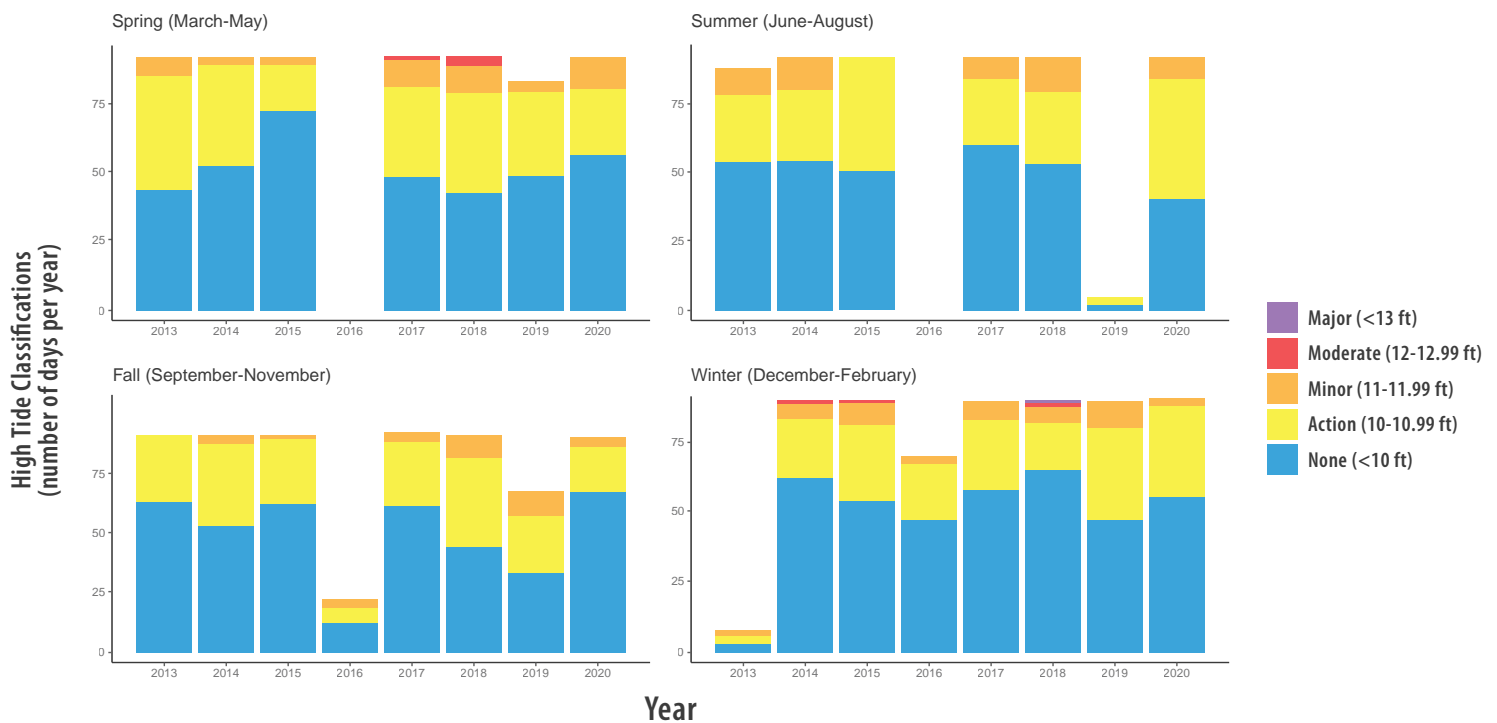


Figure 12: Number of days of each tide classification per season per year. There were large data gaps in 2016 and 2019 that resulted from equipment failure. The data record begins at the end of winter 2012, so there was incomplete data for this season of the year. Data source: NHDES



Indicators



Impervious Cover



How much of the Piscataqua Region Watershed is currently covered by impervious surfaces and how has it changed over time?

Five subwatersheds and 10 towns have greater than 10% impervious cover, including the Middle Cochecho River subwatershed which increased from 9.9% to 10.3% in 2021. Impervious cover in the Town of Exeter increased from 9.8% to 10.1%. There was no decrease in the number of towns with less than 5% impervious surfaces but the Bauneg Beg Pond–Great Works River and Isinglass River subwatersheds increased from 5% to 5.1% and from 4.8% to 5.1% respectively. As of 2021, 5.8% of the land area of the Piscataqua Region Watershed was covered by impervious surfaces. This is an increase of 1,834 acres of impervious cover or 0.2% of the watershed land area since 2015.

Goal

No increase in the number of subwatersheds and towns with greater than 10% impervious cover and no decrease in the number of subwatersheds and towns with less than 5% impervious cover.

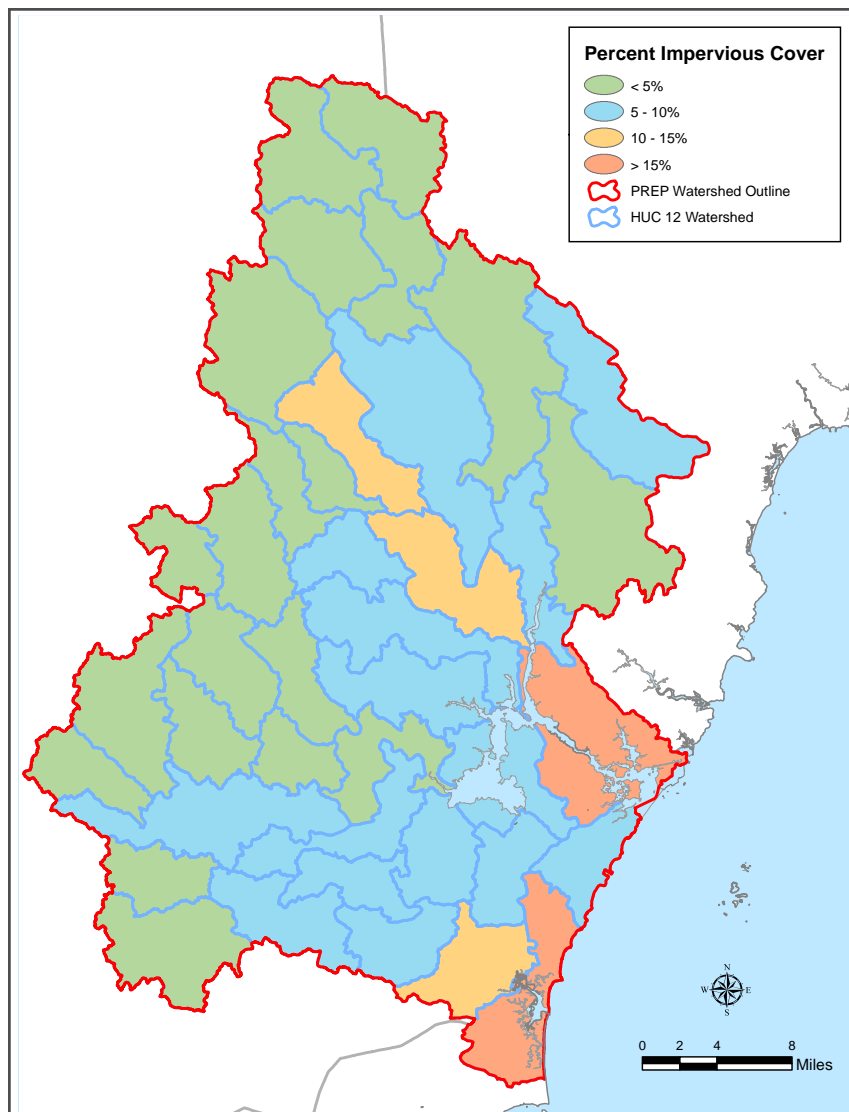


Figure 1.1: Percent impervious cover by subwatershed (HUC 12) in the Piscataqua Region Watershed as of 2021. Data source: UNH Earth Systems Research Center

Why We Track This Indicator

Impervious surfaces are human-made features, such as parking lots, roads, and buildings, that do not allow precipitation to soak or infiltrate into the ground. When precipitation falls on impervious surfaces, a large proportion runs off into nearby waterways, carrying pollutants and sediments. More impervious surfaces also lead to higher peak flows and increased stream channel erosion. When watersheds have more than 10% impervious cover, water quality impacts become increasingly severe,¹ with some research showing impacts at less than 5% impervious cover.²

Explanation

The 2021 update to this dataset is the second iteration of mapping the entire 52-town Piscataqua Region Watershed using high resolution, 1-foot/60-cm

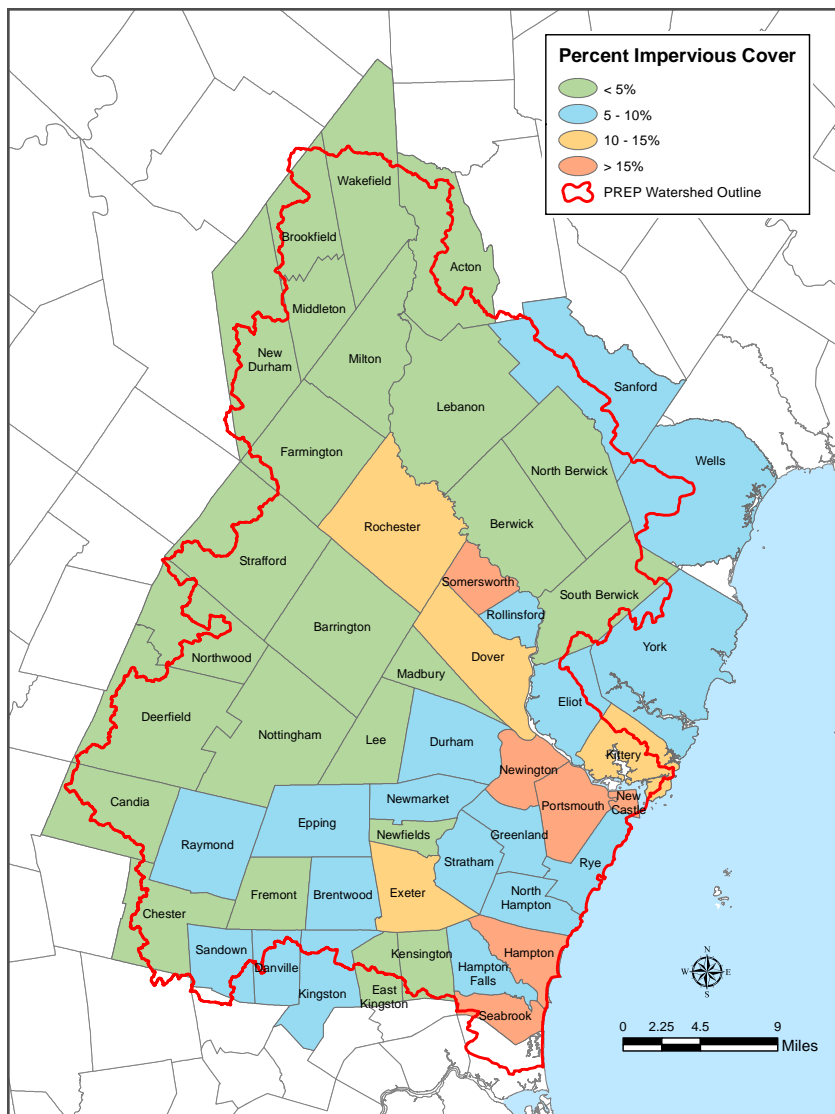


Figure 1.2: Percent impervious cover by town in the Piscataqua Region Watershed as of 2021.
Data source: UNH Earth Systems Research Center

orthoimagery. Impervious cover estimates using this approach represent 48,428 acres or 5.8% of the land area. This is an increase of 1,834 acres of impervious cover (0.2% of the Piscataqua Region) since 2015 (when there were 46,594 acres). Watersheds with greater than 10% impervious surface coverage of land area are concentrated in the vicinities of the Hampton-Seabrook Estuary, the Piscataqua River and the Route 16 corridor along the Cocheco River. Impervious surfaces in 2021 in each of the Piscataqua Region subwatersheds are shown as a percentage of land area in Figure 1.1.

Goals for impervious cover were not met. Two subwatersheds that previously had less than 5% went over the threshold (Bauneg Beg Pond-Great Works River and Isinglass River) and one subwatershed went over the 10% impervious threshold (Middle Cocheco River). Communities with the highest overall impervious cover percentages continue to be Portsmouth (27%), New Castle

(21%), and Seabrook (21%), and the largest increases of impervious surfaces between 2015 and 2021 occurred in Wells (160 acres), Rochester (155 acres), Dover (109 acres), York (91 acres), Epping (72 acres), and Sanford (67 acres). Communities with the smallest increases in impervious surfaces included New Castle (2 acres), East Kingston (4 acres), and Portsmouth (4 acres) (Figure 1.2). Small increases in impervious cover in urbanized areas may be a result of limited availability of buildable lots. For information on housing trends in the watershed refer to the “Housing Permits” indicator section of this report. Town-by-town information on impervious surfaces in 2021 is shown in Figure 1.2.

Between 2015 and 2020 the population in the Piscataqua Region Watershed increased 3.9% (15,039 people), and impervious cover increased 4% (1,834 acres). This means that for every one person increase in population, impervious cover increased 0.13 acres or 5,663 square feet; however, impervious cover is not evenly distributed across the watershed. For more discussion on the relationship between municipal populations and impervious cover, see the Extended Report.

Acknowledgments and Credit

David Justice and Chris Phaneuf (NH GRANIT, Earth Systems Research Center), with contributions from Abigail Lyon (PREP) and Kalle Matso (PREP). Graphics from NH GRANIT.

Extended Report

These data were developed using 2021 National Agriculture Imagery Program (NAIP) orthophotography. See the Extended Report for a broader description of that data and how they differ from data used to generate previous impervious surface coverage estimates.

Housing



How many single and multi-family new housing permits were issued by communities in the Piscataqua Region Watershed from 2016 – 2020? How many new housing units were built from 2000 – 2020 in Rockingham, Strafford, and York Counties in the Piscataqua Region Watershed?

Since 2015, average annual housing permit approvals were 515 for multi-units and 549 for single-family units. In 2020 multi-unit housing permits fell to 361 while single-family permits increased to 628. Since 2000, there were 50,446 new housing units built, a 20% increase from 252,796 units in 2000 to 303,242 units in 2020. The expansion of the housing stock can lead to environmental consequences even if managed sustainably.

Why We Track This Indicator

Housing permit approvals and total housing offer context for tracking the impact of development on the watershed and estuaries. Development often increases impervious surfaces which can lead to more stormwater and sediment runoff and nutrient loading (see “Impervious Cover” and “Nutrient Loading”).

Explanation

Those who live in the Piscataqua Region Watershed know that it is a desirable place to live. Since 2015, this region has experienced an increase in population of 3.9%. While there are substantial economic and cultural benefits of a growing community, increased population can lead to a variety of issues if not managed properly. New construction often increases impervious cover, leading to increased runoff and nutrient loading into the watershed. Improper fertilizer use on lawns, like applying more than is needed or before a rain event, can contribute to increased nutrient loading to our estuaries. Septic systems constructed too close to waterbodies, poorly maintained, or failing can also introduce harmful bacteria into local waterbodies and contribute to nutrient loading. Additionally, an increasing population and more housing results in more strain on municipal services and utilities.

In this section, the terms “housing units” and “housing permits” will be used frequently, and it is important to note the difference. “Housing permits” are permits issued by each municipality but do not indicate whether or not a structure was, in fact, built. “Housing units” refer to units that have been permitted and physically built.

The number of housing permits issued between 2000 and 2020 rose and fell reflecting economic trends (Figure 2.1). In the early 2000s, single family permits constituted the majority issued, with a high in the year 2000 of 1,513 permits. Since then, variables such as economic health and available land have shifted the metric. Following the 2008 recession, multi-unit permits have been rising from 216 permits issued in 2009 to a high of 727 permits issued in 2018. In the year 2020, coinciding with the pandemic, multi-unit permits fell to 361 and single-family permits increased to 628.



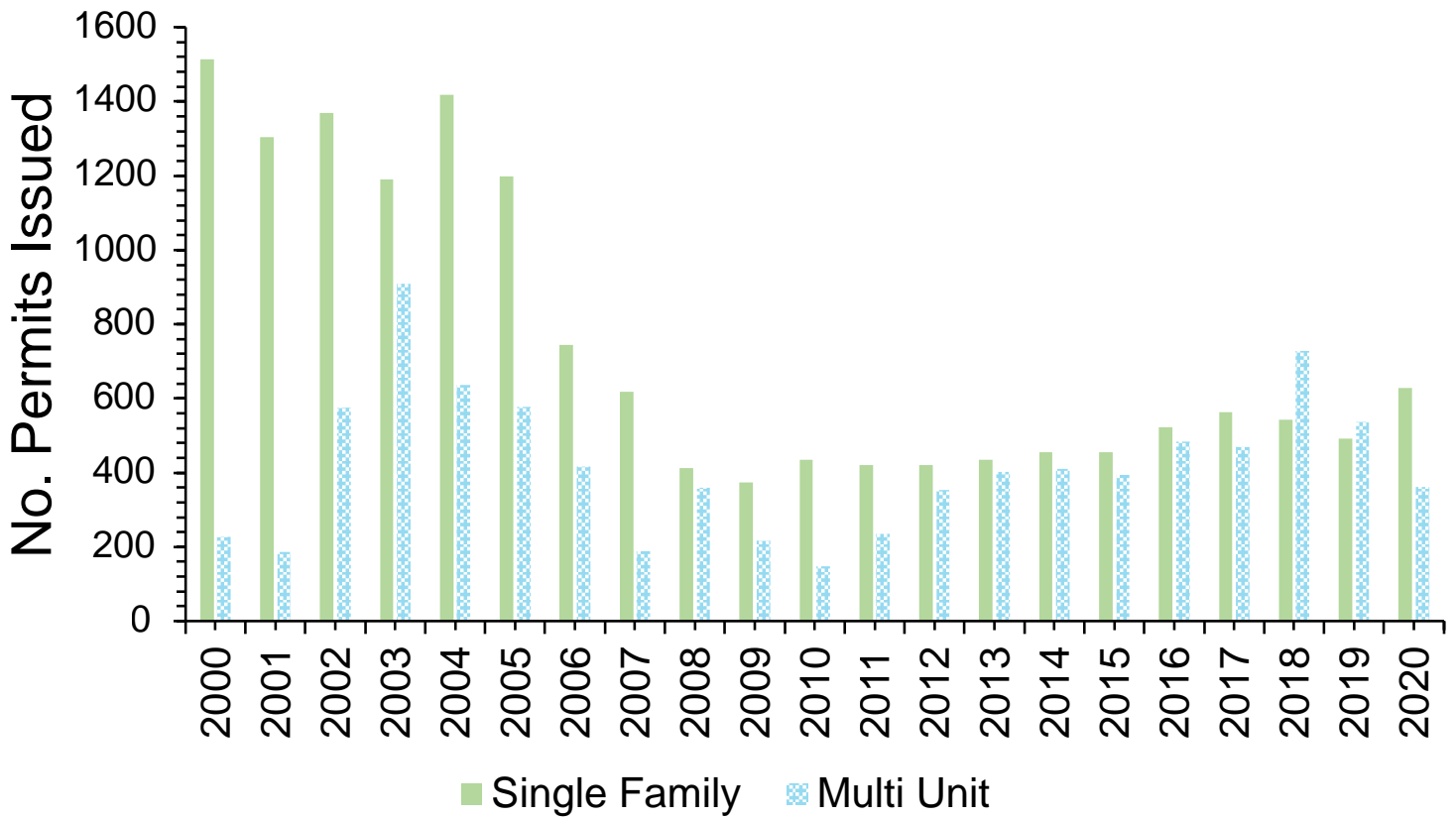


Figure 2.1: Housing permits issued in New Hampshire in the Piscataqua Region Watershed between 2000 and 2020, for both single and multi-family units. Data source: NH Department of Business and Economic Affairs

Total housing units encompass all housing permitted and built from 2000 to 2020, including single-family, multi-unit, manufactured homes, and conversion of existing single units into condominiums and apartments. Currently there are a total of 303,242 housing units in the three counties (Rockingham, Strafford, and York) across the Piscataqua Region Watershed (Figure 2.2). This equates to a 20% increase in total units since 2000 and a 7% increase since 2010. Also included in these figures are unoccupied housing units, which are defined as units that are kept as second homes, vacant, condemned, or for sale with no current residents.

Single family homes make up most of the new and existing housing in the area (Figure 2.1). Rockingham, Strafford, and York Counties all have between 60–75% of their housing stock reported as single-family units. Multi-units make up 20–30%, and manufactured homes account for less than 10% in all three areas. “Manufactured” refers to

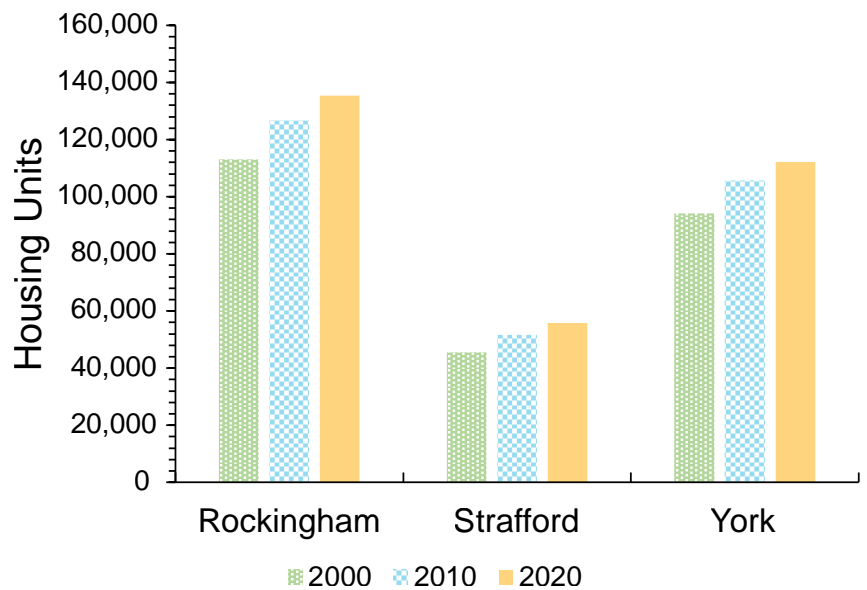


Figure 2.2: Total housing units in Piscataqua Region Watershed 2000 to 2020. Data source: US Census, 2020, 2010, 2000

Housing

County	New Units (2000)	New Units (2020)	Annual Increase 2000 – 2020	Percent Increase 2000 – 2020
Rockingham	113,023	135,338	1,115	19.7%
Strafford	45,539	55,706	508	22.3%
York	94,234	112,198	898	16.0%

Table 2.1: Housing unit change in counties of the Piscataqua Region Watershed.
Data source: US Census, 2020

prefabricated homes (including but not limited to trailers) that are not built on site.

A 2021 report stated a goal to build 13,500 new housing units by 2024 to meet the current market demand in New Hampshire.³ Although this includes the entire state, we know that the population density and economic centers fall disproportionately in the Rockingham and Strafford County areas, two of the three counties in the Piscataqua Region Watershed. Rockingham County has seen an increase in housing units of 1,116 units per year since the year 2000. Strafford County sits at about half of this with 508 units per year, and York County housing units have increased by an average of 898 units (Table 2.1).

In order to meet housing needs, it is also important to consider occupancy of existing housing stock. For example, in 2020 there were an estimated 37,077 unoccupied housing units in the Piscataqua Region Watershed (Figure 2.3). Unoccupied housing includes second or vacation homes, vacant properties, condemned properties, and for-sale units (with no current residents). Unoccupied housing reached a peak in 2010 and has decreased only slightly in the past decade.

In York County, 20.7% of all the housing units fall into the ‘unoccupied’ category, meaning more than 1 in 5 housing units has no permanent residents (Figure 2.4). This metric is lower in both New Hampshire counties where the percent unoccupied is 7.1% and 7.6% for Rockingham and Strafford, respectively.

Acknowledgments and Credit

Nathaniel Gruen (PREP/UNH), Abigail Lyon (PREP), and Kalle Matso (PREP).

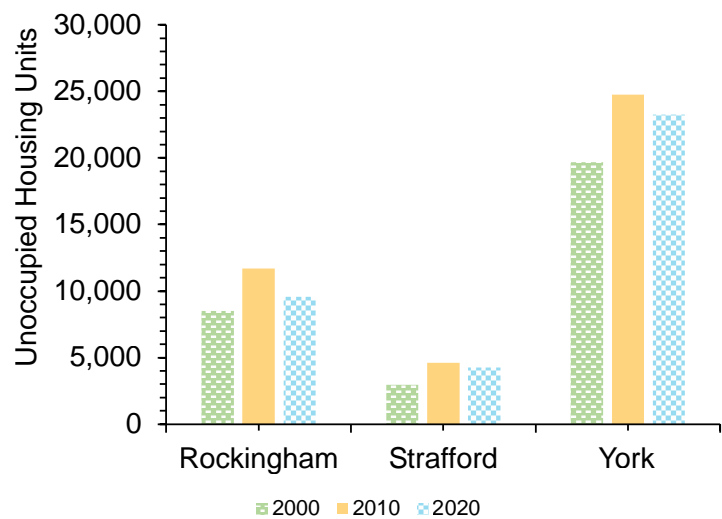


Figure 2.3: Unoccupied housing units in the Piscataqua Region Watershed by county.
Data source: US Census, 2020

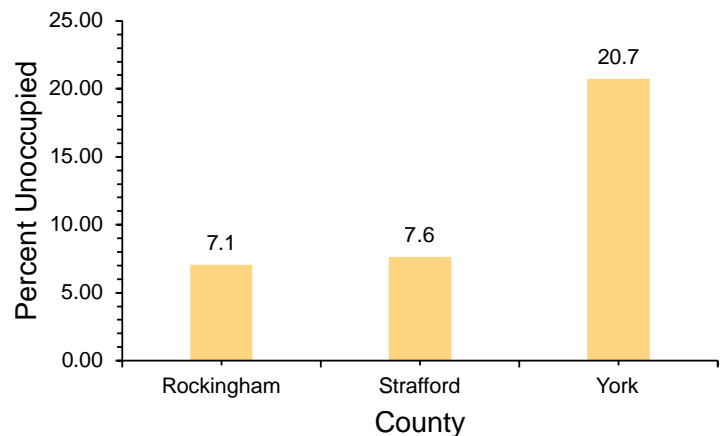


Figure 2.4: Percentage of unoccupied housing units in the Piscataqua Region Watershed by county.
Data source: US Census, 2020



Photo of Hampton Beach, by Jerry Monkman

Stormwater Management Standards and Funding



How many of the 52 communities in the Piscataqua Region Watershed have adopted the Southeast Watershed Alliance Model Stormwater Standards for Coastal Communities or similar standards? Additionally, how many communities in the watershed have adopted a stormwater utility?

As of May 2022, 24 of the 42 (57%) New Hampshire municipalities in the Piscataqua Region Watershed have adopted the complete set of the Southeast Watershed Alliance (SWA) model or similar stormwater management standards, two communities are in the process of adoption, one community has partial or a different set of standards, and 15 communities have not yet adopted stormwater standards. The 10 Maine communities in the watershed adhere to state-level stormwater management regulations. Although there is community interest in exploring alternate stormwater funding mechanisms, currently no communities have adopted or implemented a stormwater utility. Stormwater projects, operations, and maintenance remain funded by a combination of local taxes, property development costs, grants and loans, and fees.⁴

Why We Track This Indicator

Stormwater runoff is a significant source of non-point source pollution that contributes to water quality degradation. When rain falls and snow melts on impervious surfaces like roads, parking lots, and buildings, pollutants on the surface run off into groundwater and directly into local waterbodies. Also, undersized and aging stormwater infrastructure can worsen flooding. Adopting and enforcing up-to-date stormwater management standards to improve stormwater infrastructure can reduce both pollution and flooding. Additionally, establishing a dedicated funding mechanism, like a stormwater utility, can support stormwater operations and maintenance and help communities plan for necessary upgrades to existing infrastructure to support water quality goals.

Explanation

Successful stormwater infrastructure directs rainfall to a treatment area where water soaks or infiltrates into the soil or, in some cases, to an outfall on a local waterbody. Impervious cover has a negative impact on streams and groundwater supplies and contributes to nutrient loading and pollution runoff into surface waters. Improvements in stormwater infrastructure include approaches to reduce flow and pollution and to increase infiltration. This helps to recharge groundwater supplies, purify water, and slow the rate of water entering streams that might otherwise increase erosion and the risk of flooding.

Adopting local stormwater management standards helps communities balance development while improving existing site conditions and preventing or reducing future water quality impairments. There are also financial benefits and savings for adopting stormwater management regulations early to avoid higher future costs of installing stormwater retrofits to restore impaired waters.⁵ New Hampshire state statute enables municipalities to adopt regulatory standards for stormwater management projects not captured under



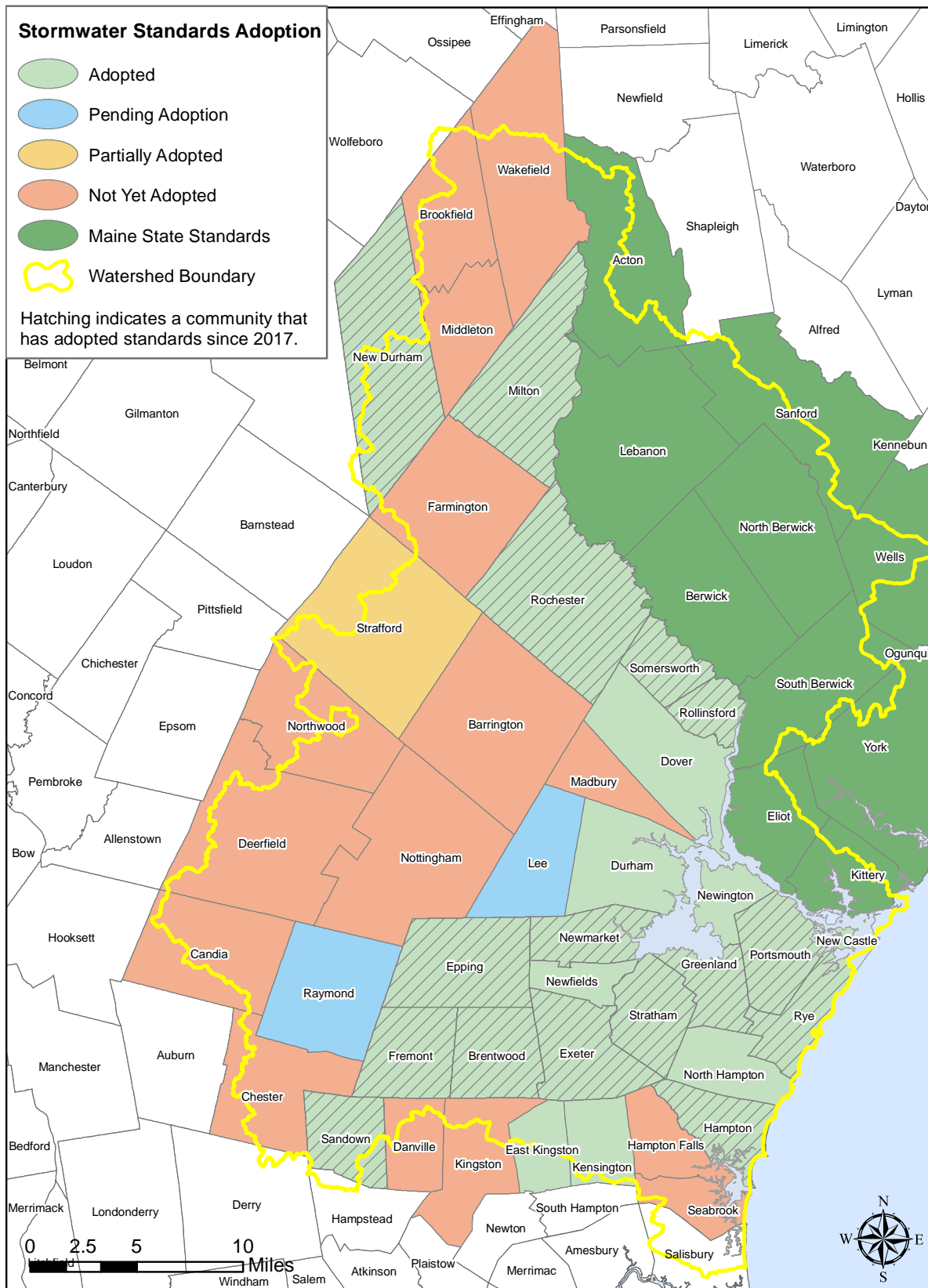


Figure 3.1: Status of stormwater management standards adopted in the Piscataqua Region Watershed.
 Data source: Strafford Regional Planning Commission and Rockingham Regional Planning Commission, May 2022

Stormwater Management Standards and Funding

state Alteration of Terrain regulations.⁶ Similarly in Maine, the state stormwater management law provides stormwater management standards for development that communities must implement for projects exceeding one acre of disturbance.⁷

The SWA model stormwater standards provide a comprehensive and tailorable approach that can be adopted as part of a community's zoning ordinance or land development regulations. The list below is a summarized version of key components of the SWA Model Stormwater Standards for Coastal Watershed Communities (elements B-D).⁸ Including these four components in local regulations minimizes further water quality impairments, and in the case of redevelopment, can improve existing conditions.

- ▶ **Threshold for applicability** — Creates a minimum threshold area for disturbance for new development projects that requires full compliance with stormwater standards.
- ▶ **Performance measures** — Improves water quality by requiring the removal of an established percentage of Total Suspended Solids, Total Nitrogen, and Total Phosphorus.
- ▶ **Groundwater recharge** — Promotes use of infiltration practices (groundwater recharge) to reduce runoff caused by a project and replenish groundwater supply.
- ▶ **Redevelopment criteria** — Requires improvements in stormwater management and treatment for redevelopment projects on existing properties.

To assess stormwater management progress across the Piscataqua Region Watershed, PREP monitors which municipalities have adopted enhanced stormwater standards. As of May 2022, the SWA model or similar stormwater standards has been adopted by 24 communities, one community has adopted a partial set of the recommended regulations without redevelopment standards, two communities have regulations pending, and 15 communities have not yet adopted stormwater regulations (Figure 3.1). Overall, 35 out of 52 communities in the Piscataqua Region Watershed have adopted some level of stormwater standards including the 10 Maine communities in the watershed that adhere to Maine state standards. This represents an increase of 16 communities (31%) that have adopted enhanced stormwater management standards since 2017.

Local stormwater management standards are a step toward reducing non-point source pollution and better managing stormwater in a community. Regulations alone will not solve all water quality concerns and flooding, but enforcement of these

standards is key to seeing improvements on the ground. The model stormwater standards also only address new and redevelopment and not existing impervious surfaces. Communities can begin to address existing impervious cover on both public and private land by establishing a dedicated stormwater funding mechanism like a stormwater utility.

Stormwater utilities generate dedicated funding for stormwater management through user fees that are often based on a property's impervious area.^{9,10} Fees based on impervious surface area can incentivize green infrastructure and the reduction of impervious surfaces by property owners, further improving water quality and alleviating flooding. This dedicated funding can also be used to maintain or upgrade existing stormwater infrastructure like catch basins and outfalls, develop drainage plans, construct flood control measures, and enhance water quality programs. In addition to providing a dedicated funding source, stormwater utilities can improve the equity of funding stormwater management by basing the fee on impervious surface area rather than property value in cases where property taxes are used to generate stormwater funding.

More than 2,000 communities across the country implement a user or service-based fee program to fund stormwater management and flood resilience programs.¹¹ Currently, none of the 52 communities in the Piscataqua Region Watershed have adopted stormwater utilities; however, several communities are exploring the possibilities. In August 2020, the City of Dover established the Ad Hoc Committee to Study Stormwater and Flood Resilience Funding (Committee) to investigate, study, identify, and make recommendations to the City Council concerning various funding opportunities with respect to existing needs and future stormwater and flood resilience management planning. In January 2022, the Committee voted unanimously to recommend the City of Dover pursue establishment of a Stormwater and Flood Resilience Utility with considerations for crediting to offer rate payers the opportunity to reduce their fee by making site improvements that reduce stormwater runoff and/or improve the water quality of stormwater runoff from their property. Other communities, including Rochester and Portsmouth, have expressed interest in exploring stormwater funding mechanisms/utilities.

Acknowledgments and Credits

Nathaniel Gruen (PREP/UNH) and Abigail Lyon (PREP) with contributions from Fay Rubin (PREP)



Salt Marsh



How many acres of salt marsh are there in the towns of the Piscataqua Region Watershed and how are the marshes responding to sea-level rise?

There are 5,711 acres of tidal marsh habitat in the New Hampshire portion of the Piscataqua Region Watershed. These acres are distributed among 16 towns, with the greatest amount in Hampton (1,429 acres) and Seabrook (1,189 acres). Between 1900 and 2010, an estimated 1,045 acres of salt marsh in New Hampshire was lost to development or inadequate tidal flow.¹² Although changes in overall acreage since the 2018 report are negligible, existing salt marshes are threatened by sea-level rise and the spread of the invasive common reed (*Phragmites australis*).



Why We Track This Indicator

Salt marshes are among the most productive ecosystems in the world. They support recreational and commercial fisheries, protect shorelines from erosion, provide long term carbon storage, reduce flooding, protect water quality, and provide essential wildlife habitat. While salt marsh extent and health are impacted by sea-level rise, they are also impacted by management decisions related to land use and water quality.

Explanation

The 2018 State of Our Estuaries report focused on acreage, and there has been little change in the number of acres of salt marsh in the Piscataqua Region Watershed. However, new data allowed for better assessment of marsh resilience to sea-level rise, which is the most immediate stressor for salt marshes. Not surprisingly, the areas with the most extensive marshes, such as Rye and the Hampton-Seabrook Estuary, are also the areas showing the most resilience to sea-level rise. On the other hand, marshes surrounding the Great Bay Estuary as well as marshes in the Portsmouth and Newington areas, are the least resilient to rising seas. This indicator focuses on salt marshes in New Hampshire as we do not have sufficient data for Maine at this time.

Metrics that indicate resilience to sea-level rise include: the relative proportion of high to low marsh; the ratio of unvegetated to vegetated areas; and the acreage of marsh migration pathways, which show potential for a marsh to move inland in the future.

Proportion of High to Low Marsh, by Region and Community

The boundary between high and low marsh is notable as a vegetative demarcation of local mean high-water level. Changes in the location of this boundary are one of the earliest ecological indicators of climate change. If there is enough suspended sediment available, salt marshes can build up peat and maintain their elevation relative to rising sea levels. Salt marshes can also migrate inland as sea-level rises. If barriers prevent migration and the marsh cannot accrete vertically at a rate that keeps up with sea-level rise, change will take place in two stages. First, the relative proportion of low marsh will increase and slowly take over the area occupied by high marsh. Second, eventually the entire marsh will become “squeezed” against the barrier and slowly convert to intertidal mudflat.

Regionally, the Great Bay Estuary has the highest proportion of low marsh. These systems could be starting to experience flooding and may not be able to keep up with sea-level rise (Figure 4.1). Thus, projects that aim to enhance marsh resilience in this Estuary are particularly important to pursue.

Extensive high marsh meadows can be found in Rye and the Hampton-Seabrook Estuary, in contrast to the mainly fringing marshes along many of the tidal rivers and Great Bay shorelines. Meadows in Exeter, Portsmouth, and Stratham have a greater proportion of high marsh and are currently keeping

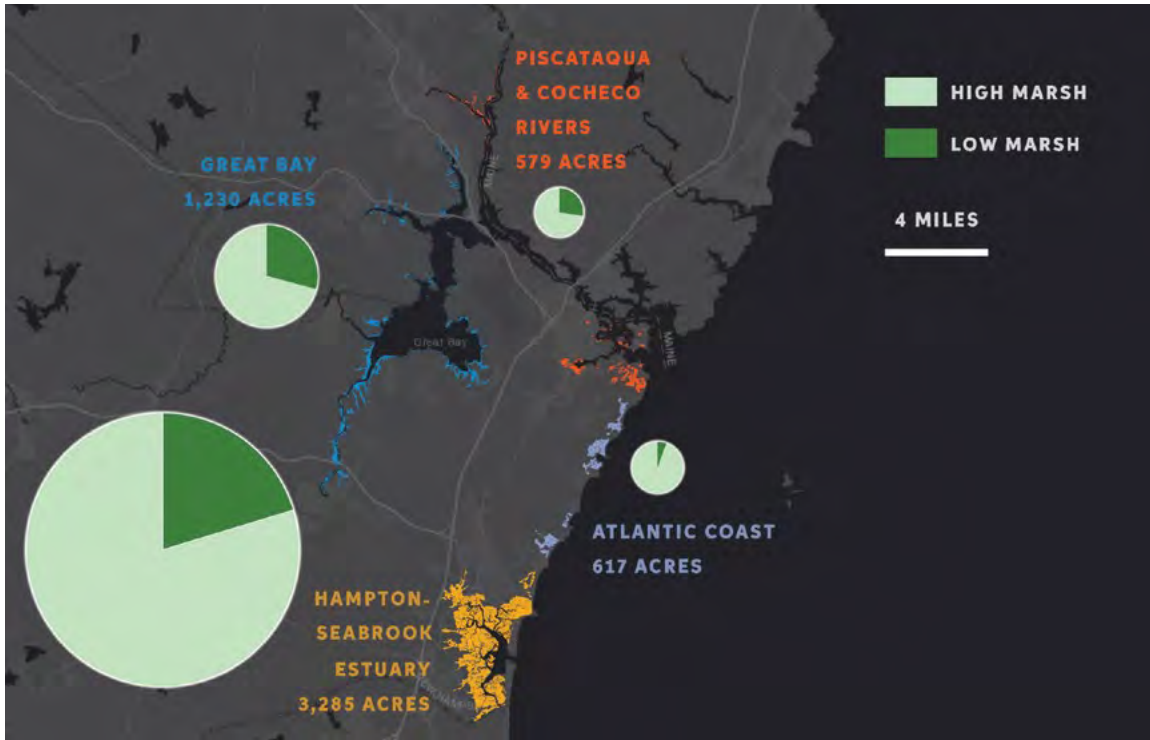
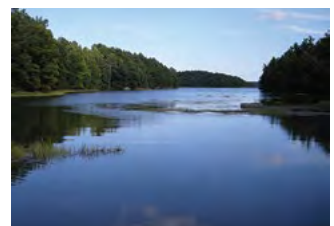


Figure 4.1: Overall acreage and proportion of high and low salt marsh in different regions of New Hampshire. Marshes in Great Bay have the highest proportion of low marsh showing they are least able to keep pace with sea-level rise. Data source: Great Bay National Estuarine Research Reserve

A Detailed Look at Salt Marsh Response to Sea-Level Rise

Field data from three marshes encircling the Great Bay indicate that marshes are changing over time due to increased tidal flooding. As a result, they are becoming wetter, with low marsh plants dying off and high marsh looking more like low marsh. Evidence of this change is most notable at transition areas between low and high marsh because it is the lower limit of stress from tidal flooding for most plant species. The transition area at Great Bay Farms marsh (Figure 4.5), located on the eastern shore in Newington, shows a drastic change between 2010 and 2022 with the high

marsh dominant salt hay (*Spartina patens*) being almost completely replaced by its more flood tolerant cousin, smooth cordgrass (*Spartina alterniflora*). Supporting these changes in plants, a local study found Great Bay marshes were not building up as fast as sea-level rise.¹⁵ Finally, a recent regional study including data from Great Bay shows more extreme changes towards a wetter and less vegetated environment, as in southern New England marshes, which may be a sign of the future of Great Bay marshes.¹⁶



Salt Marsh

up with sea-level rise more effectively than those in Dover (Figure 4.2). An example of a marsh that is dominated by low marsh, demonstrating it is not keeping up with sea-level rise, can be seen when driving on Route 4 along Bunker Creek in Durham. Over 80% of this site is low marsh; it cannot migrate inland due to the high-sided natural topography of the surrounding upland.

The Unvegetated to Vegetated Ratio of a Marsh

The amount of plant coverage on a salt marsh in comparison to the amount of bare earth and standing water is an important indicator of its vulnerability to relative sea-level rise. This Unvegetated to Vegetated Ratio (UVVR), has been found to be highly correlated with net sediment budget and helps to determine if a marsh is building up vertically and laterally or eroding and starting to “drown.” It has been found that marshes with a UVVR above 0.15 start to become unstable and are at a tipping point to drowning and/or lateral contraction.¹³

Over 89% of marshes in New Hampshire have a UVVR of 0.15 or less, so most New Hampshire marshes are not showing signs of vulnerability to sea-level rise according to this metric (Figure 4.3). Portsmouth and Newington have marshes with the highest average UVVR values of 0.38 and 0.32 respectively. The marsh that fringes the eastern portion of South Mill Pond in Portsmouth has the highest UVVR by far in the state of New Hampshire. It is bounded by roads, a parking lot, and a tennis court.

Marsh Migration Potential

If a marsh abuts low-lying topography, it has potential to migrate inland and keep up with relative sea-level rise. Consequently, these migration pathways are good places to target land protection projects.

Rye and Hampton have the largest acreage of migration pathway and, therefore, have the highest potential for new salt marsh formation (Figure 4.4). The largest unhindered area in New Hampshire is the low-lying forest surrounding Fairhill Marsh in Rye. In Great Bay, the largest migration pathways lie at the mouth of the Squamscott River.

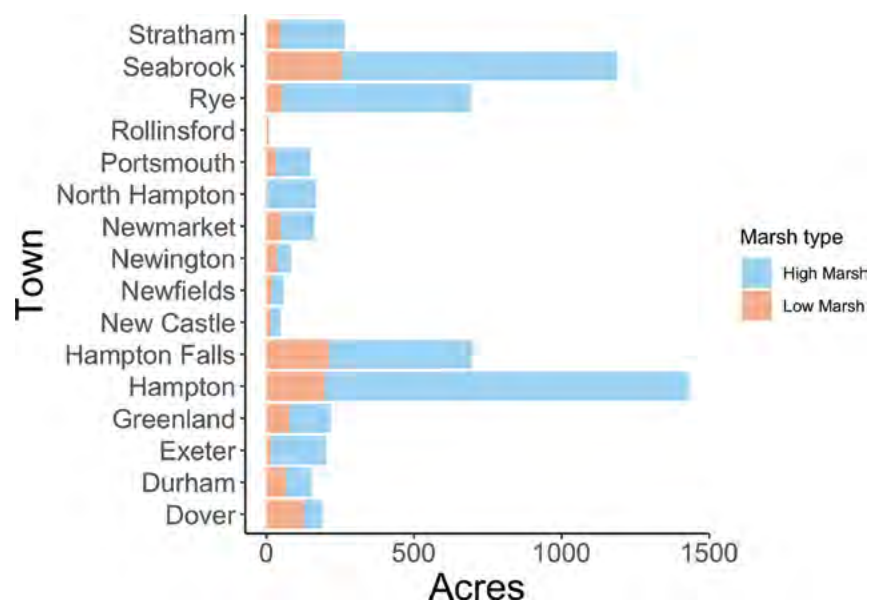


Figure 4.2: The acreage of salt marsh in coastal communities of New Hampshire. Data source: Great Bay National Estuarine Research Reserve

Beyond the size of marsh migration space, land cover type within this low-lying upland edge determines how easily a tidal wetland can migrate inland.¹⁴ For example, it is much easier for a salt marsh to spread into a neighboring brackish or freshwater marsh as sea-level rises than a low-lying developed area such as a paved parking lot.

Acknowledgments and Credits

Rachel Stevens (GBNERR/NHFG), with contributions from Katie Callahan (NHFG), Chris Peter (GBNERR/NHFG), David Burdick (UNH), Kevin Lucey (NHDES), Adrienne Kovach (UNH), Neil Ganju (USGS), and Alyson Eberhardt (NH Sea Grant/UNH Extension). Graphics by Rachel Stevens.

Extended Report

UNH researchers have been investigating nesting success and habitat of the saltmarsh sparrow, a species of special concern in New Hampshire. Read more about these results and other salt marsh monitoring in the Extended Report.

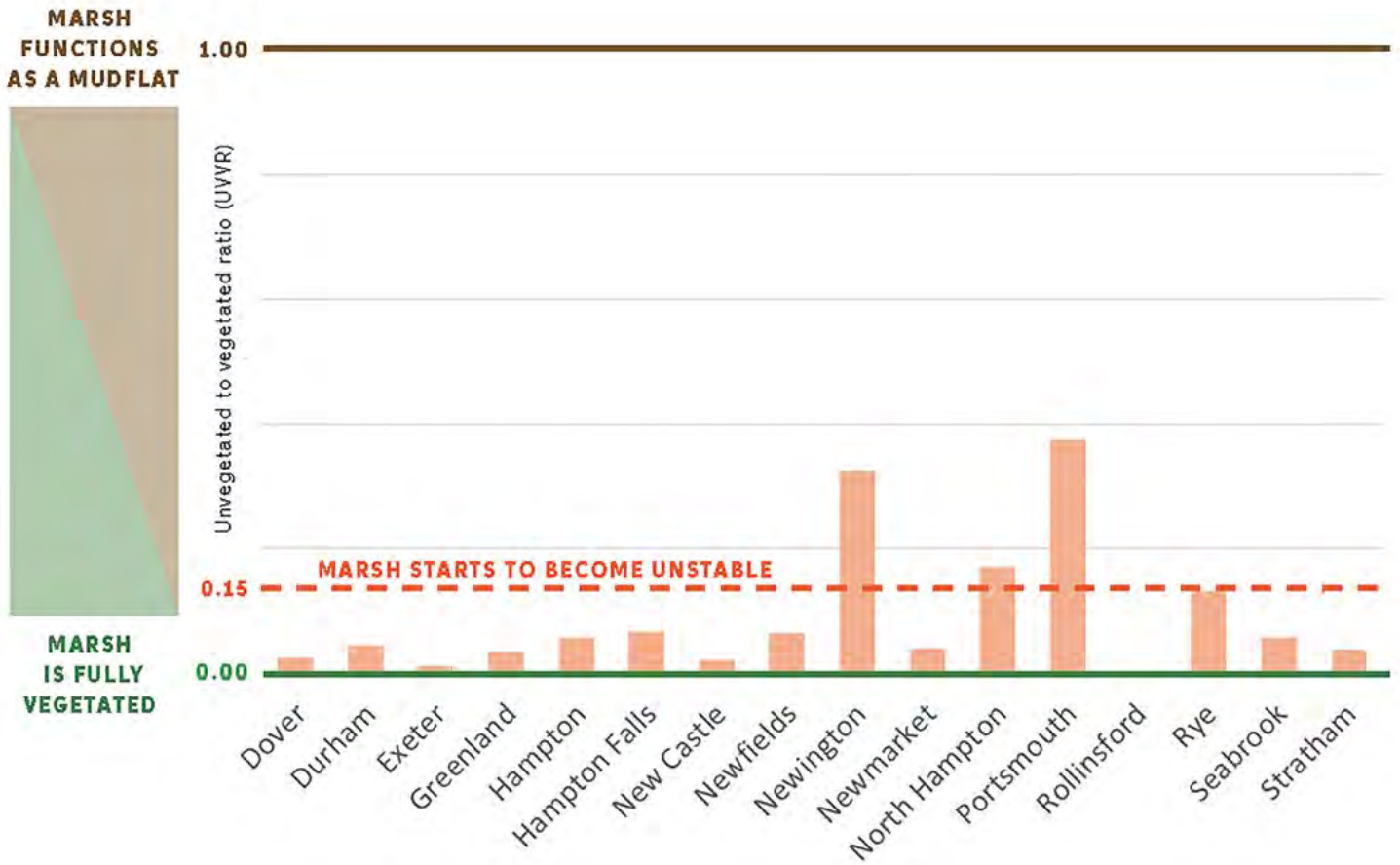


Figure 4.3: The unvegetated to vegetated ratio of marshes for communities in New Hampshire. A marsh with a UVVR of 0.0 is entirely covered by vegetation, while a marsh with a UVVR of 1.00 or more is so sparsely vegetated it is effectively functioning as a mudflat.
 Data source: Great Bay National Estuarine Research Reserve

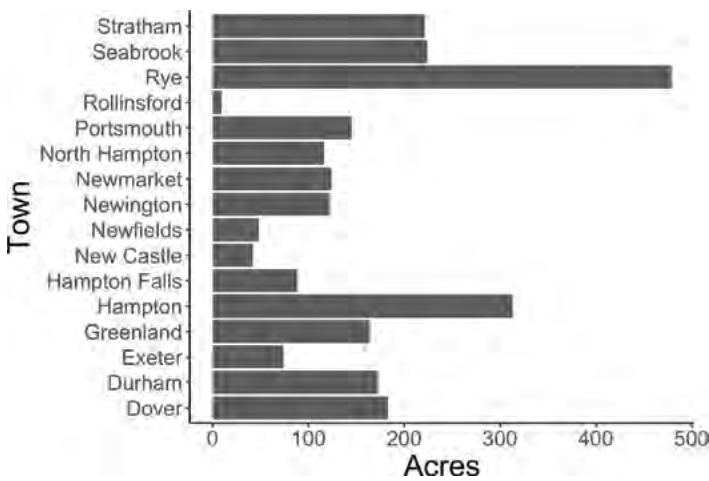


Figure 4.4: The acreage of potential salt marsh migration pathway in coastal communities of New Hampshire using a 2m (6.6ft) sea-level rise scenario at the year 2100.
 Data source: Great Bay National Estuarine Research Reserve

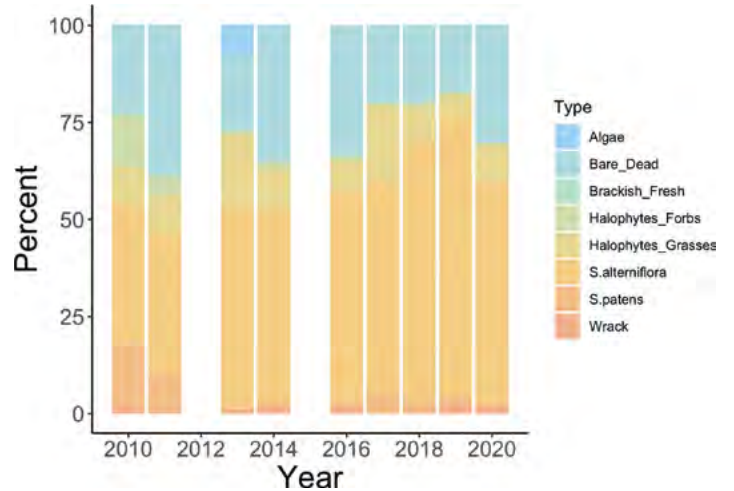


Figure 4.5: Field data collected from Great Bay Farms marsh in Newington, NH within transition plots (area between low and high marsh).
 Data source: Great Bay National Estuarine Research Reserve

Conserved Lands (General)



How much of the land in the 52 communities that make up the Piscataqua Region Watershed is permanently conserved or considered public lands?

As of April 2022, 18.1% of the total land area in the watershed (151,978 acres) was conserved, representing an increase of 2.6% in new land area coming under conservation (21,676 acres) since 2017. An additional 16,024 acres must be conserved in the watershed to meet the PREP goal of 20% of the total land area conserved.

Goal

Conserve 20% of the total land area in the Piscataqua Region Watershed.

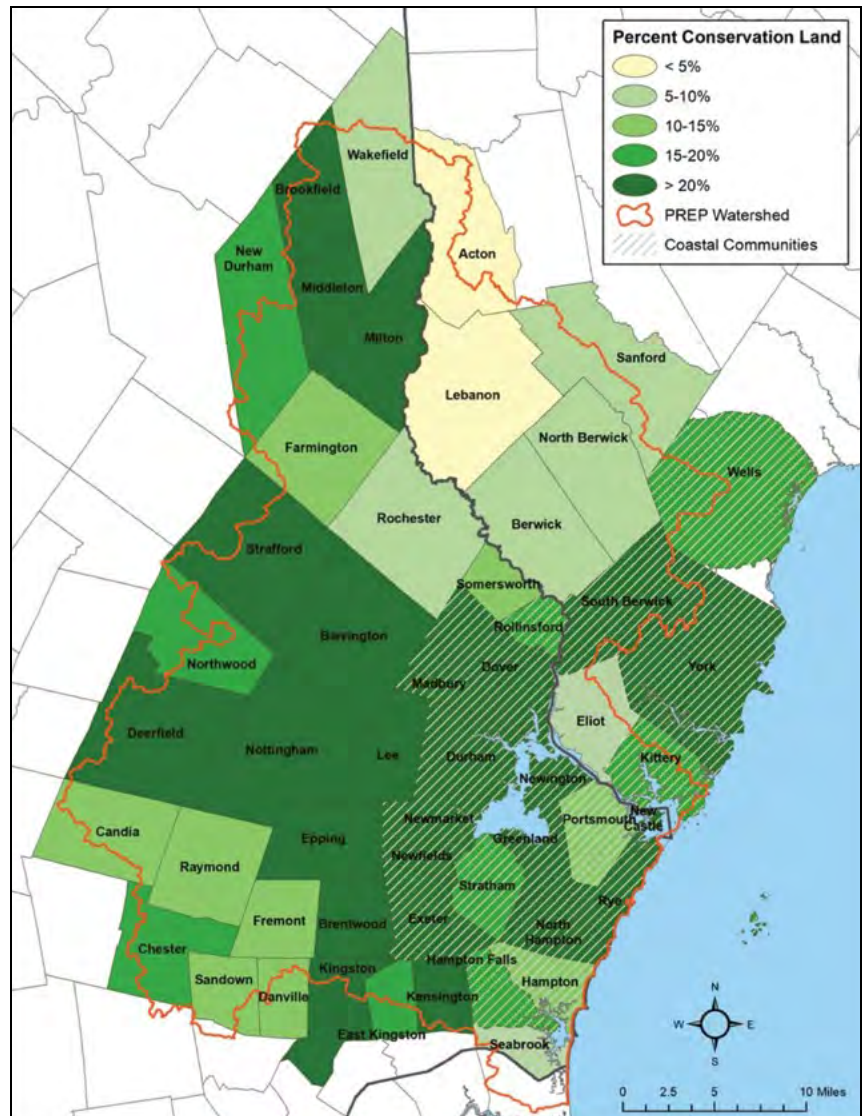


Figure 5.1: Land conservation percentages for each Piscataqua Region Watershed community. Data source: NH GRANIT, Earth Systems Research Center



Why We Track This Indicator

The Piscataqua Region Watershed is under pressure from population growth and associated development. Conserving a network of natural lands across the region is the most effective action we can take to ensure clean water and healthy and abundant wildlife populations, minimize flood damages, and provide a diversity of quality recreational opportunities.

Explanation

As of April 2022, 18.1% of the total land area in the Piscataqua Region Watershed (151,978 acres) was conserved. This represents an increase of 2.6% in new land area coming under conservation (21,676 acres) since the last report in 2017. Of the acreage considered conserved, 86% is under permanent protection. Across

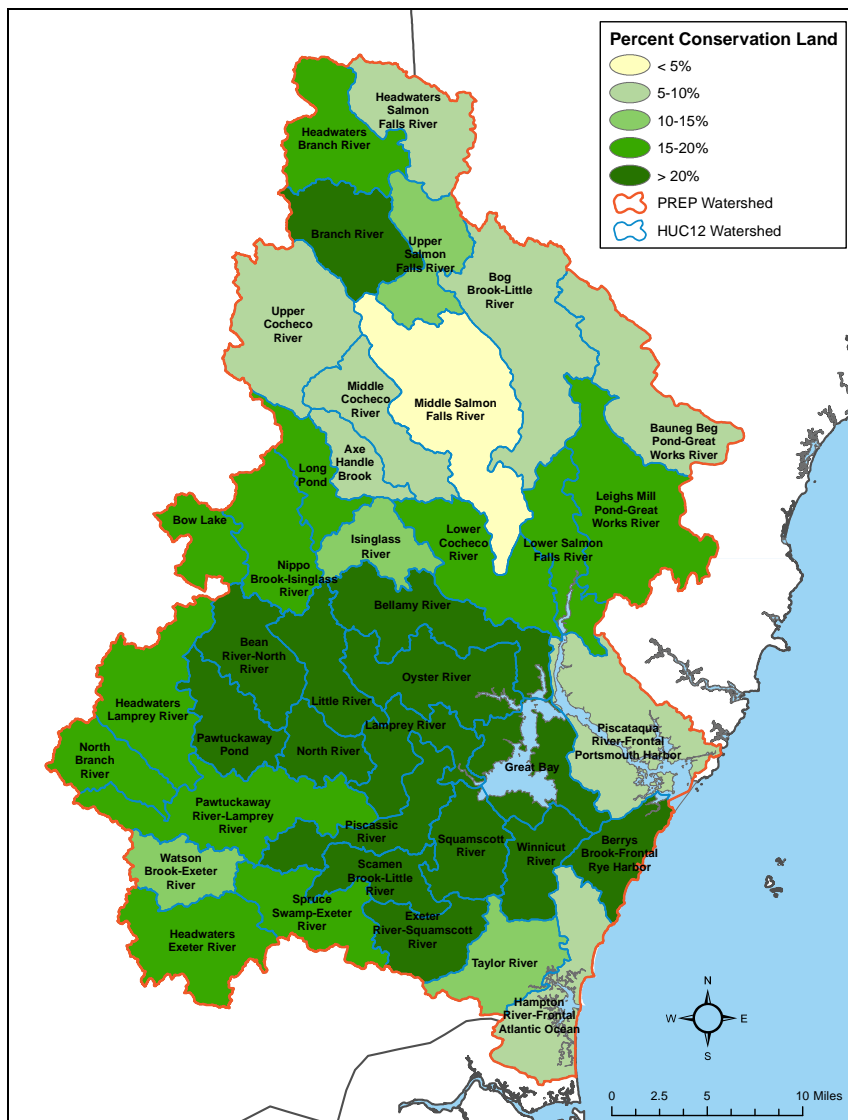


Figure 5.2: Land conservation by percentage of total area for each HUC-12 (sub-watershed level).
Data source: NH GRANIT, Earth Systems Research Center

the 22 coastal communities in the region (those adjacent to tidal waters), a total of 56,907 acres of land has been conserved. This represents 22.3% of the total land area in those 22 towns.

In 2017, 28 communities had achieved greater than 15% of their land in conservation. As of 2022, six additional communities have conserved greater than 15% of their land area for a new total of 34 communities (Figure 5.1). Of those, 26 communities have met or exceeded the PREP goal of 20% of total acreage conserved. Overall, conservation lands have increased across most of the region. But there remain places where conservation lands, as a total percentage of the community's land cover, are less than 5%. At the subwatershed level (HUC-12 analysis; Figure 5.2), areas where conservation efforts have been high (greater than 30% of total land area) include Branch River, Exeter-Squamscott, Great Bay,



Lamprey River, Oyster River, Pawtuckaway Pond, and Scamen Brook-Little River. Conversely, areas where conserved lands lag include Bauneg Beg Pond-Great Works River, Bog Brook-Little River, Middle Cochecho River, and Middle Salmon Falls River.

Although land protection continues to progress, there is work to do to reach the PREP goal of conserving 20% of the land area. Land protection for the 22 coastal communities in the aggregate has exceeded 20%, but an additional 16,024 acres must be conserved to meet the 20% level for the entire watershed.

Acknowledgments and Credit

Trevor Mattera (PREP), David Justice, and Chris Phaneuf (NH GRANIT, Earth Systems Research Center) with contributions from Abigail Lyon (PREP)

Conserved Lands (Focus Areas)



Photo by Jerry Monkman

How much of the Conservation Focus Areas in the Piscataqua Region Watershed are permanently conserved or considered conserved public lands?

As of 2022, 32.6% of Conservation Focus Areas (CFAs) in New Hampshire and 14.1% of CFAs in Maine were conserved. This represents a total of 29.3% of conserved CFA acreage in the watershed. Given the challenges associated with conserving these important lands, the PREP goal of conserving 75% of total acres in the CFAs will take additional effort to achieve.

Goal

Conserve 75% (199,026 acres) of lands identified as Conservation Focus Areas.



Photo by Jerry Monkman

Why We Track This Indicator

The Piscataqua Region Watershed is home to exceptional unfragmented natural areas and corridors supporting important wildlife populations, water filtration capacity, and protection against flooding and storms. CFAs represent highly prioritized areas for conservation that maximize these benefits. Due to development and growth pressures in our region, it is increasingly important to protect these areas to ensure they will continue to provide benefits for future generations.

Explanation

The 2021 New Hampshire's Coastal Watershed Conservation Plan (Plan) is a science-based, regional conservation master plan that identifies 265,368 acres of CFAs in the Piscataqua Region Watershed across New Hampshire, Maine, and Massachusetts.¹⁷ These CFAs encompass conservation priorities for maintaining ecological function and integrity for wildlife and habitat, coastal water resource protection, coastal resilience, and climate adaptation. The Plan identified CFAs by synthesizing and weighting previous conservation datasets used to prioritize land conservation and protect the specific benefits and values mentioned.^{18–23} The CFAs in the new Plan integrate, update, and replace the 166,212 acres of CFAs identified in The Land Conservation Plan for New Hampshire's Coastal Watersheds (2006)²⁴ and The Land Conservation Plan for Maine's Piscataqua Region Watersheds (2010)²⁵ and used for the 2018 State of Our Estuaries report.

Of the 265,368 acres that fall within designated CFAs, 29.3% (77,629 acres) has been permanently protected (Figure 6.1), representing progress toward the PREP goal of conserving 75% of total CFA acres in the region (199,026 acres) but still falling far short. As there have been incremental updates but no substantial, comprehensive updates to the conservation lands datasets since 2017, conserved acres may be underrepresented in the data after this point. Nonetheless, the data we have suggests the need for continued, focused efforts in protecting valuable lands in our region to meet our goal.

Acknowledgments and Credit

Trevor Mattera (PREP), with contributions from Anna Ormiston and Peter Steckler (TNC) and David Justice and Chris Phaneuf (NH GRANIT, Earth Systems Research Center). Graphics from Anna Ormiston and Peter Steckler.

Extended Report

See the Extended Report for a breakdown of total and protected CFA acreage across towns in the Piscataqua Region Watershed. Looking to take the next step protecting lands in your community? Check out www.Connect-Protect.org for more information.

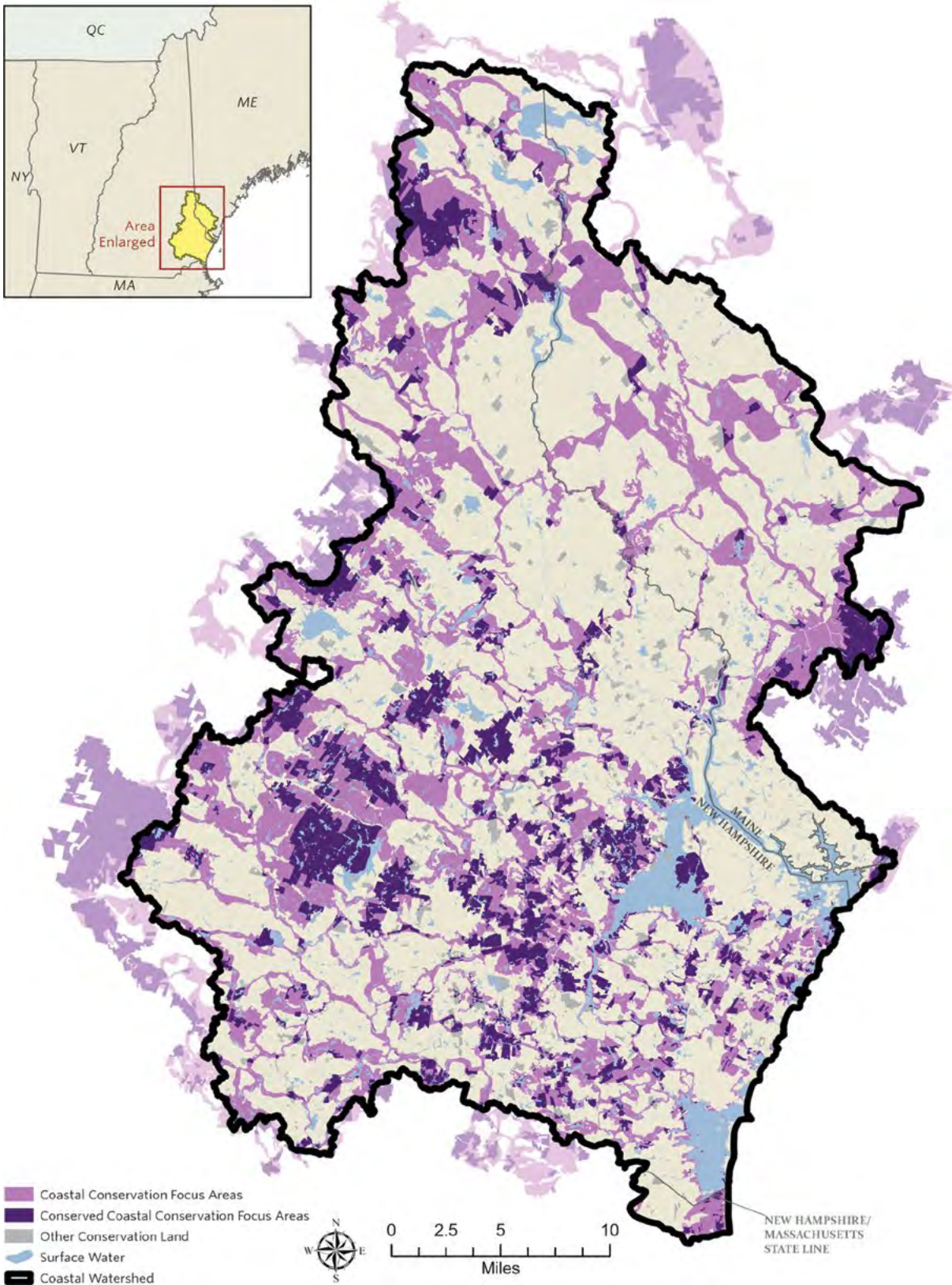


Figure 6.1: Conservation Focus Areas (CFAs) in the Piscataqua Region. CFAs that are conserved are shown in dark purple and CFAs that are not conserved are in light purple. Conserved land not identified as CFAs are in gray.
 Data source: The Nature Conservancy

Nitrogen Loading



How much nitrogen is coming into the Great Bay Estuary and how has loading changed over time?

Estimated annual total nitrogen load from 2017 to 2020 averaged 895 U.S. tons, which is similar to the 2012 to 2016 average (903 tons per year), but lower than the high point from the mid-2000s. Comparing 2012 to 2020, there was a 64% decrease in overall point source nitrogen loading from wastewater treatment facilities. This resulted directly from the actions of several municipalities to make substantial improvements to their wastewater treatment facilities to reduce the amount of nitrogen they discharge. Non-point source nitrogen loading — nitrogen from diffuse sources that are difficult to pinpoint — in 2017 to 2020 averaged 699 tons per year, which is 15% higher than the 2012 to 2016 average (607 tons per year). Nitrogen loading data for Hampton-Seabrook Estuary are currently being developed and will be reported in future documents.

Goal

Manage nitrogen loads to minimize adverse consequences.

Why We Track This Indicator

Nitrogen is one of the primary nutrients that are essential to all life. Nitrogen “loading” involves measurement of the rate at which nitrogen is being added to estuarine water from various sources, such as the land and atmospheric deposition. This differs from nitrogen “concentration,” which is simply a snapshot of the amount of nitrogen present in the water at any given time (see “Nutrient Concentrations”). Nitrogen loading levels that are too high can cause problems in an estuary such as excessive growth of phytoplankton, epiphytes, and nuisance seaweeds. When these organisms die, bacteria and other decomposers use the available dissolved oxygen to break down the dead organic matter, decreasing oxygen availability for other organisms, including fish and shellfish. In addition, excessive phytoplankton, epiphytes, and seaweed growth can have negative impacts on sediment quality, water clarity, eelgrass, and benthic invertebrates.

Explanation

Estimated annual total nitrogen load from 2017 to 2020 averaged 895 tons, which is similar to the 2012 to 2016 average (903 tons per year), but lower than the high point from the mid-2000s (Figure 7.1). In 2020, the most recent year that we have estimates for, the average annual load was 627 tons, which is the lowest on record. Figure 7.1 indicates a trend in nitrogen reductions, especially compared with the 2005–2007 period, when nitrogen loading peaked.

However, nitrogen loading remains higher than the amount recommended by the EPA in the Great Bay Total Nitrogen General Permit, issued in 2021. To meet that long-term goal, nitrogen loading would have to be further reduced by approximately 39% from the 2020 level. While reduction efforts continue, it is acknowledged that the goal in the permit is subject to change based on active research into the relationship between nitrogen loading and adverse effects on the ecosystem, such as seaweed blooms and loss of eelgrass. Results of this research could lead to adjustments (up or down) in the loading goal.

Figure 7.1 indicates a great deal of variation over the time series. This variation should be looked at in the context of the two types of loading: from point sources versus non-point sources. Point sources of nitrogen are predominantly from wastewater treatment facilities, while non-point source nitrogen enters into our streams, rivers, and estuaries in three main ways: 1) from stormwater runoff, which includes nitrogen from atmospheric deposition (including

This section focuses on the Great Bay Estuary, where nitrogen loading has been estimated since 2003. Nitrogen loading protocols are currently being established for the Hampton-Seabrook Estuary and will be covered in future reports.

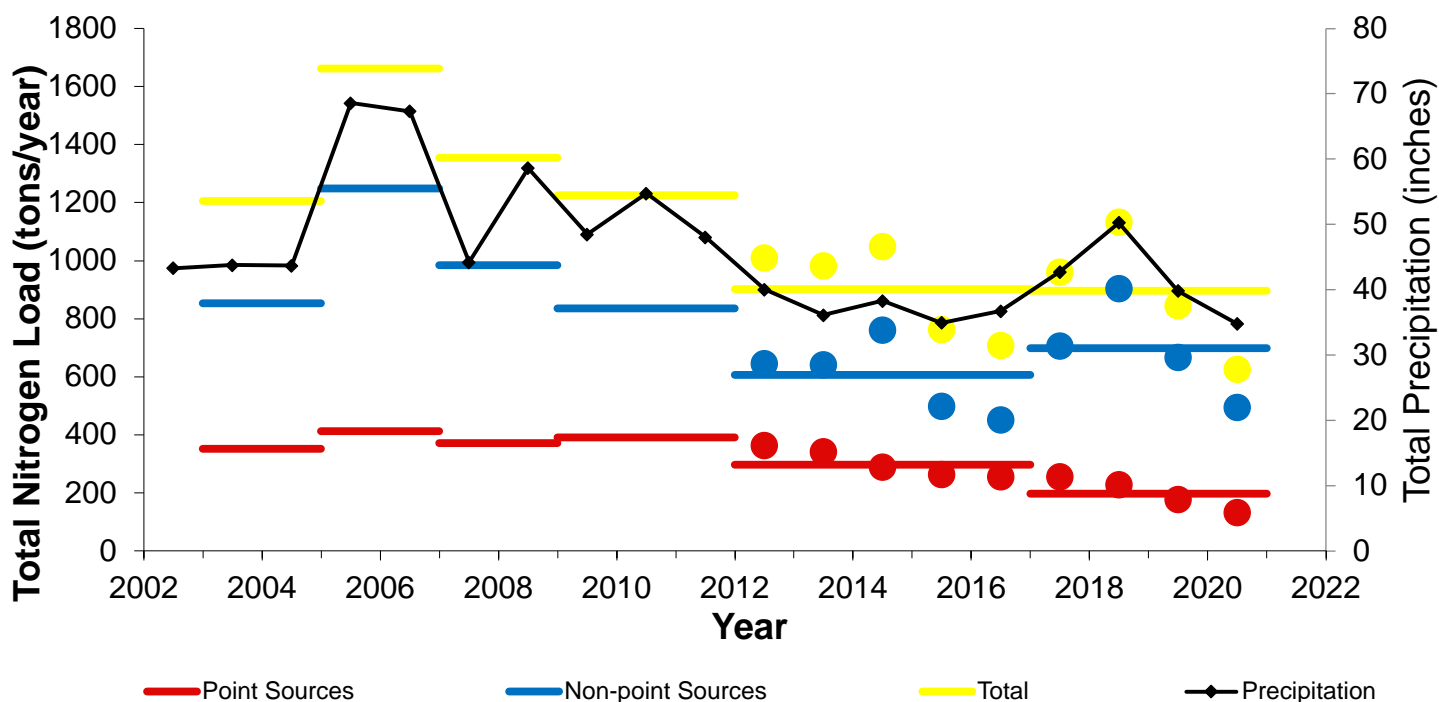


Figure 7.1: Nitrogen loads to the Great Bay Estuary, shown separated by source as well as the combined total nitrogen load. Loads are based on an estuarine surface area of 13.4 square miles. (Lower Piscataqua River not included. See the Extended Report for details.) Colored circles indicate annual loads for 2012 through 2020. Annualized data were not available for 2003 – 2011, thus multi-year averages are presented for the entire record. Precipitation data are from the Portsmouth (Pease/KPSM) weather station. Data sources: EPA, Municipalities, USGS, PREP, and Water Quality Analysis Lab (WQAL)

transportation and industrial emissions), fertilizers, and animal waste; 2) from groundwater contribution, which carries nitrogen from septic systems, sewer leakage, infiltrated fertilizers, and animal waste;^{26,27} and 3) from direct atmospheric deposition.

Between 2003 and 2011, most of the variability in nitrogen loading was related to non-point source inputs, while the contribution from point source inputs was relatively stable during that period (Figure 7.1). The highest loads since 2003 were in the 2005 to 2007 period (1,662 tons per year), a time that coincides with the highest total annual precipitation. In comparison, the lower rainfall during 2012 to 2020 contributed to the lower total and non-point source loading during this period.

Non-point sources of nitrogen in 2017 to 2020 accounted for 78% (Figure 7.2) of the total nitrogen load. During the fall seasons of 2016 and 2020, most of the watershed experienced extreme drought conditions.²⁸ This underscores the association between nitrogen loading and stormwater run-off. Precipitation records and forecasts²⁹ suggest that our region will continue to

see periods of extreme high and low precipitation, which will continue to impact non-point source nitrogen loads.

In terms of point sources, the 17 municipal wastewater treatment facilities accounted for 22% of the total nitrogen load in 2017 to 2020 (Figure 7.2). The 2017 to 2020 point-source loads were lower than in any other reporting period since 2003 despite increased population. This is a result of substantial investment in upgraded wastewater treatment by several municipalities in the watershed to reduce the amount of total nitrogen they discharge. There has been a 64% decrease in overall point source nitrogen loading from wastewater treatment facilities between 2012 and 2020.

Total nitrogen load includes dissolved inorganic nitrogen, dissolved organic nitrogen, and particulate nitrogen (PN). Of the 895 tons of nitrogen entering the bay annually (on average) from 2017 – 2020, 50% (444 tons per year) was dissolved inorganic nitrogen, which is comprised of the most biologically available forms of nitrogen. The 2017 to 2020 dissolved inorganic nitrogen load was 12% lower than the average dissolved inorganic

Nitrogen Loading

nitrogen load in 2012 to 2016 (506 tons per year). In earlier reporting periods, point source and non-point source dissolved inorganic nitrogen each accounted for approximately half of the dissolved inorganic nitrogen load (Figure 7.3). In 2017 to 2020, 34% of the DIN load was point source and 66% was non-point source (Figure 7.3). This reduction in point-source dissolved inorganic nitrogen loading could reduce the excessive biological activity of problematic seaweeds in Little Bay and Great Bay given that seaweeds generally uptake dissolved inorganic nitrogen preferentially over organic nitrogen.

Acknowledgments and Credit

Michelle D. Shattuck (UNH), with contributions from Aneliya Cox (UNH), Miguel Leon (UNH), and Kalle Matso (PREP).

Extended Report

Nitrogen loads were estimated based on monthly wastewater treatment facility discharge and concentration data, monthly tributary concentration data, weekly nitrogen deposition in precipitation, and daily streamflow (using Loadest³⁰). To read a detailed description of methods used to estimate 2017 – 2020 nitrogen loads and a further breakdown of the point and non-point source loads, see the Extended Report.



Photo by Jerry Monkman



Photo by Jerry Monkman

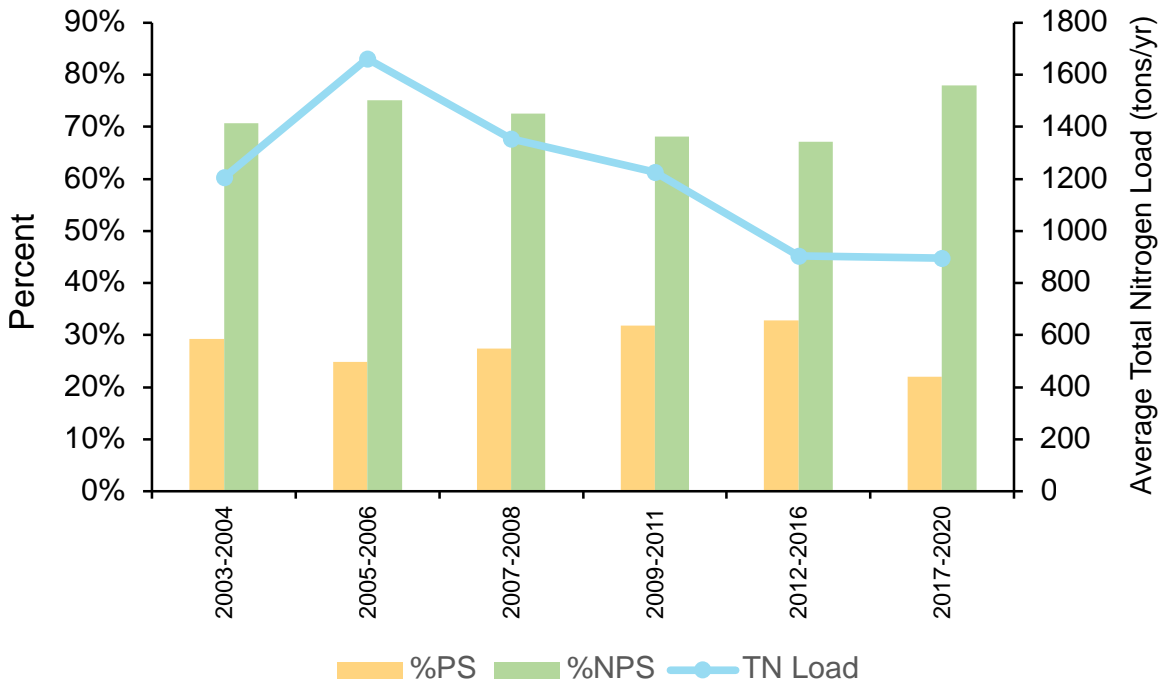


Figure 7.2: Estimated average for total nitrogen (TN) loads to the Great Bay Estuary point-sources (PS) and non-point sources (NPS). Loads are based on an estuarine surface area of 13.4 square miles. (Lower Piscataqua River not included. See the Extended Report for details.) PS and NPS values for each time period amount to 100% of total loading. Data sources: See the Extended Report for nutrient loading

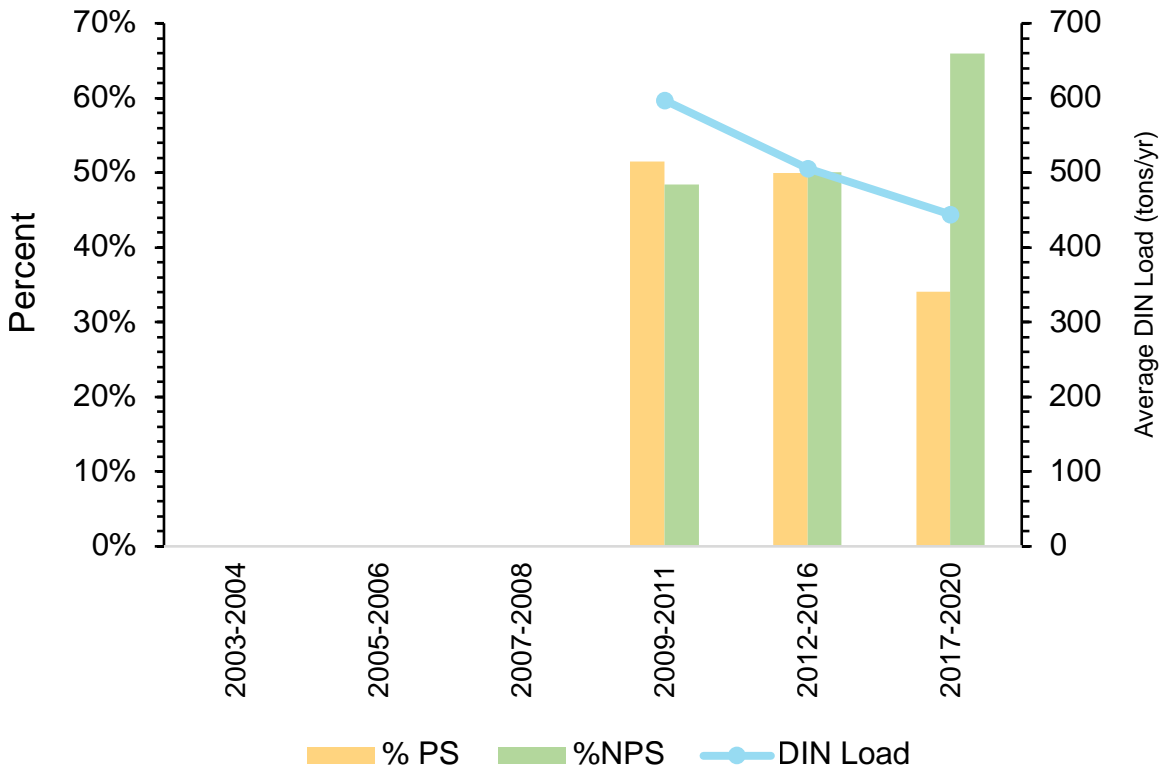


Figure 7.3: Estimated average for dissolved inorganic nitrogen (DIN) loads to the Great Bay Estuary from point sources (PS and non-point sources (NPS). Loads are based on an estuarine surface area of 13.4 square miles. (Lower Piscataqua River not included. See the Extended Report for details.) PS and NPS values for each time period amount to 100% of total loading. DIN loads were not available for 2003 – 2008. Data sources: See the Extended Report for nutrient loading

Nutrient Concentrations



How have the concentrations of nutrients in the waters of the Great Bay and Hampton-Seabrook Estuaries changed over time?

Dissolved inorganic nitrogen concentrations have been trending lower over recent years, despite higher levels between 1998 and 2016 for several stations. As a result, there are no increasing trends in dissolved inorganic nitrogen, but three stations have decreasing trends. Dissolved inorganic nitrogen is an important form of nitrogen because it is most readily taken up by eelgrass, seaweed, and phytoplankton. Total nitrogen is another form of nitrogen that incorporates particulate and living matter. Total nitrogen concentrations at Adams Point have significantly decreased since 2004, while Squamscott River is the only monitoring station that had a statistically significant increasing trend between 2003 and 2021. However, given the recent upgrade of the Town of Exeter Wastewater Treatment Facility, this trend may change in the near future. The Hampton River Station has the shortest time series and the second lowest levels of the seven stations listed.

Goal

No increasing trends in nutrient concentrations.

Why We Track This Indicator

Nutrients, like nitrogen, are critical for estuarine ecosystems; some are needed, but an overabundance leads to problems. Nutrient “concentration” measures the amount of nutrients present in the water at the time of sampling and represents a snapshot of how much remains after eelgrass, seaweeds, plankton, and microbes use the nutrient for growth plus any released from estuarine sediments. This is compared to “loading” which measures the rate at which a nutrient is being added to the system from the land, air, and tributaries. Although all nutrients are important, nitrogen is emphasized here because it is most often the limiting nutrient in estuarine watersheds.

Explanation

Nutrient concentrations in the water are affected by nutrient loading from the watershed, hydrodynamic mixing, and all the complex uses and transformations by living resources. Although all nutrients are important, nitrogen is most often the limiting nutrient in estuarine watersheds, and therefore, is currently emphasized in our estuaries. As noted in “Nitrogen Loading,” nitrogen inputs since 2012 have been reduced in the Great Bay Estuary in part due to consecutive years of low annual rainfall. In addition, since 2014, several municipalities have improved their wastewater treatment facilities. These changes are expected to have some influence on the concentrations of nitrogen, discussed below.

Although dissolved inorganic nitrogen is an important form of nitrogen because it is taken up most readily by plants and algae, total nitrogen is considered a more accurate measure of the nitrogen status of an estuary because it includes the portion in living biomass.

At the Adams Point Station (Figure 8.1) — the site with the longest time series — the earliest and most recent dissolved inorganic nitrogen data are low relative to the rest of the dataset, with the highest values between 1998 and 2016. Median values for dissolved inorganic nitrogen from 2016 to 2020 ranged from 0.10 to as high as 0.15mg/L and were comparable to median values for the years 1974 to 1981. For reference, the EPA National Coastal Assessment Condition Report categorizes values less than 0.1 as “good.” Other categories include “fair”



Photo by Todd Selig

(0.1 to 0.5 mg-N/L), and “poor” (greater than 0.5 mg-N/L). Using this categorization, recent dissolved inorganic nitrogen concentrations at Adams Point vary between the “good” and “fair” categories.

At the Oyster River and Upper Piscataqua River Stations, dissolved inorganic nitrogen concentrations significantly decreased (Table 8.1). This pattern may be attributed to the shorter time series at these stations, which began collecting data between 2002 and 2007. For example, the data for Upper Piscataqua River (Figure 8.2) indicate elevated concentrations during a time period that overlaps with the periods of high values for Adams Point and Lamprey River (between 2007 and 2013).

The time series for the Hampton River Station only goes back to 2018, but the data from this site indicate that dissolved inorganic nitrogen concentrations straddle the “good” and “fair” threshold (Table 8.1). The Hampton River Station has the second lowest levels of nitrogen across the seven stations listed.

Since 2016, median annual total nitrogen values at Adams Point ranged from 0.27 mg-N/L to 0.37 mg-N/L over the sample season (Table 8.2). A total nitrogen concentration greater than 0.5 mg-N/L was only measured in three sampling months since 2016. For reference, the EPA National Coastal Assessment Condition Report categorizes values less than 0.31 mg-N/L as “low,” values between 0.31 and 0.48 mg-N/L as “moderate,” and values between 0.48 and 0.68 mg-N/L as “high.”^{31,32}

Table 8.2 shows that most values over the past five years fall in the “moderate” category, according to the National Coastal Assessment Condition Report, with the Squamscott River Station standing out as having higher concentrations. It is possible that these high values could come down, however, given the 2020 upgrade of the Town of Exeter Wastewater Treatment Facility.

Relationships between nitrogen concentrations and ecosystem health response vary from estuary to estuary. Currently, researchers are addressing this issue in order to clarify these relationships for our waters.

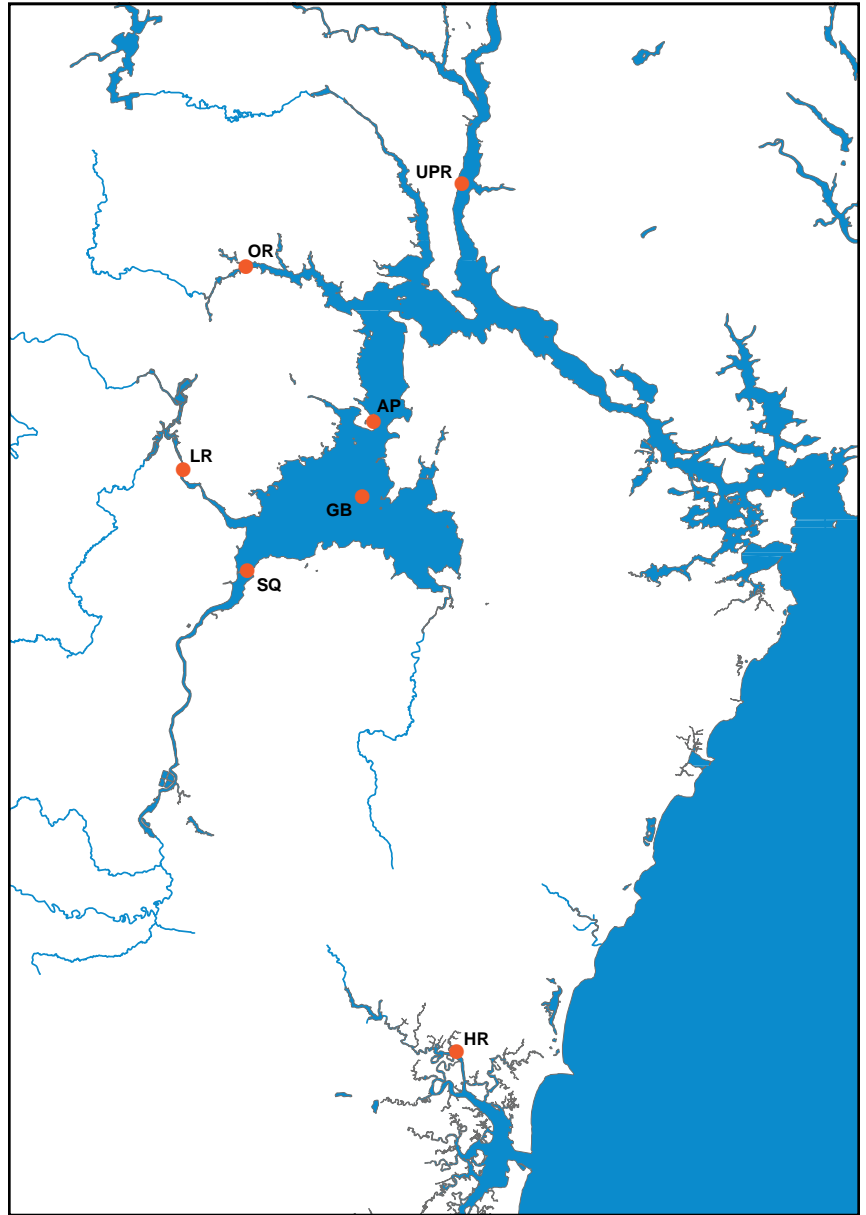


Figure 8.1: Monitoring stations for nutrient concentrations including Adams Point (AP), Great Bay (GB), Lamprey River (LR), Oyster River (OR), Squamscott River (SR), Upper Piscataqua River (UPR), and Hampton River (HR).
Data source: Jackson Estuarine Lab, UNH

Acknowledgments and Credit

Anna Mikulis (UNH) and Kalle Matso (PREP), with contributions from Easton White and Jody Potter (UNH).

Extended Report

The Extended Report includes information on other nutrients, such as phosphorus concentrations.

Nutrient Concentrations

Dissolved Inorganic Nitrogen

Location	Monitoring Period	Significant change in dissolved inorganic nitrogen concentration?	Range of Median Values 2016 – 2021 (mg-N/L)
Adams Point	1974 – 2021	No	0.06 – 0.15
Great Bay	2002 – 2021	No	0.06 – 0.15
Lamprey River	1992 – 2021	No	0.12 – 0.21
Oyster River	2005 – 2021	Yes ↓	0.13 – 0.20
Squamscott River	2002 – 2021	No	0.19 – 0.42
Upper Piscataqua River	2007 – 2021	Yes ↓	0.14 – 0.20
Hampton River	2018 – 2021	No	0.09 – 0.12*

*Range of Median Values for Hampton River include data from 2018-2021

Table 8.1. Dissolved inorganic nitrogen trends and median values at six stations in the Great Bay Estuary and one station in the Hampton-Seabrook Estuary.

Data source: Jackson Estuarine Laboratory, UNH

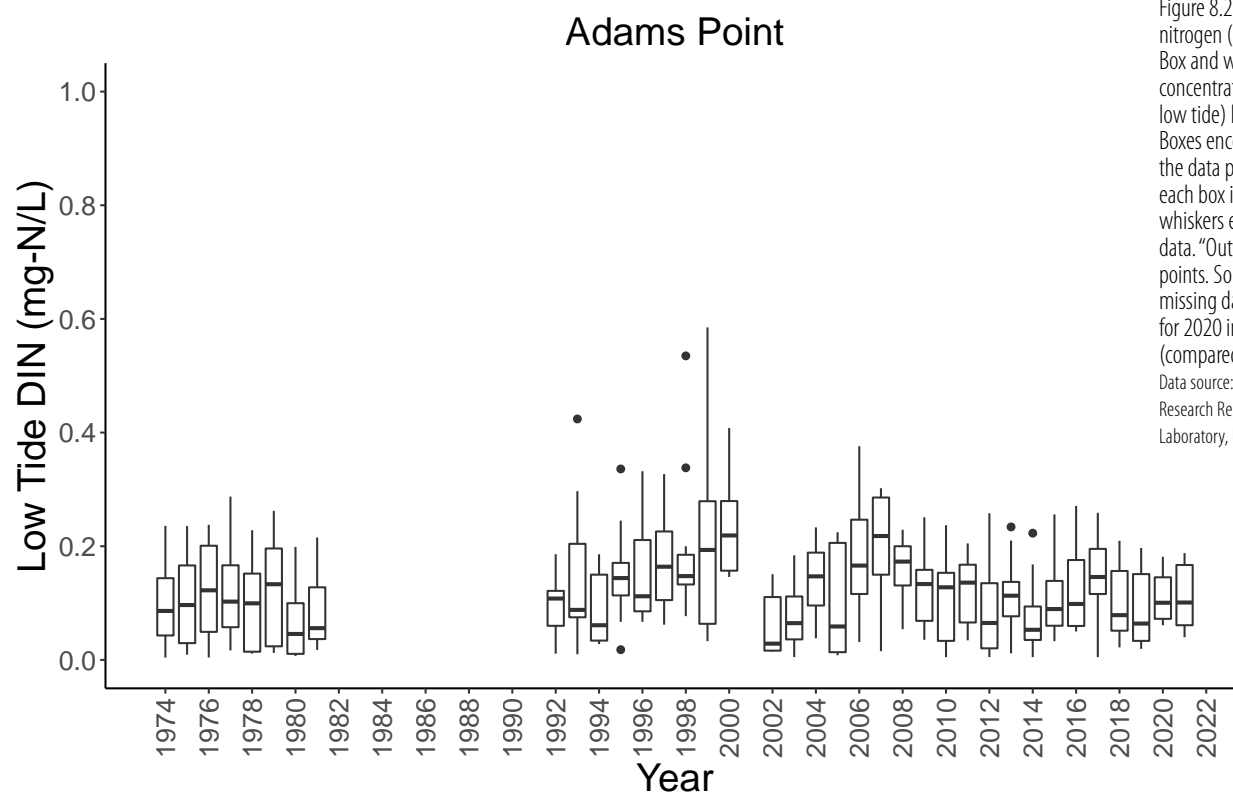


Figure 8.2: Dissolved inorganic nitrogen (DIN) at Adams Point. Box and whisker plots show DIN concentrations (collected monthly at low tide) between 1974 and 2021. Boxes encompass the middle 50% of the data points. The horizontal line in each box is the median and the vertical whiskers encompass the remaining data. "Outliers" are shown as individual points. Some years are omitted due to missing data. The box and whisker plot for 2020 includes only six DIN values (compared to nine for other years). Data source: Great Bay National Estuarine Research Reserve and the Jackson Estuarine Laboratory, UNH

Total Nitrogen

Location	Monitoring Period	Significant change in total nitrogen concentration?	Range of Median Values 2016 – 2021
Adams Point	2004 – 2021	Yes ↓	0.27 – 0.37
Great Bay	2004 – 2021	No	0.29 – 0.52
Lamprey River	2004 – 2021	No	0.39 – 0.63
Oyster River	2006 – 2021	No	0.43 – 0.60
Squamscott River	2005 – 2021	Yes ↑	0.63 – 1.04
Upper Piscataqua River	2009 – 2021	No	0.37 – 0.48
Hampton River	2018 – 2021	No	0.38 – 0.47*

*Range of Median Values for Hampton River include data from 2018–2021

Table 8.2. Total nitrogen trends and median values at six stations in the Great Bay Estuary and one station in the Hampton-Seabrook Estuary.

Data source: Jackson Estuarine Laboratory, UNH

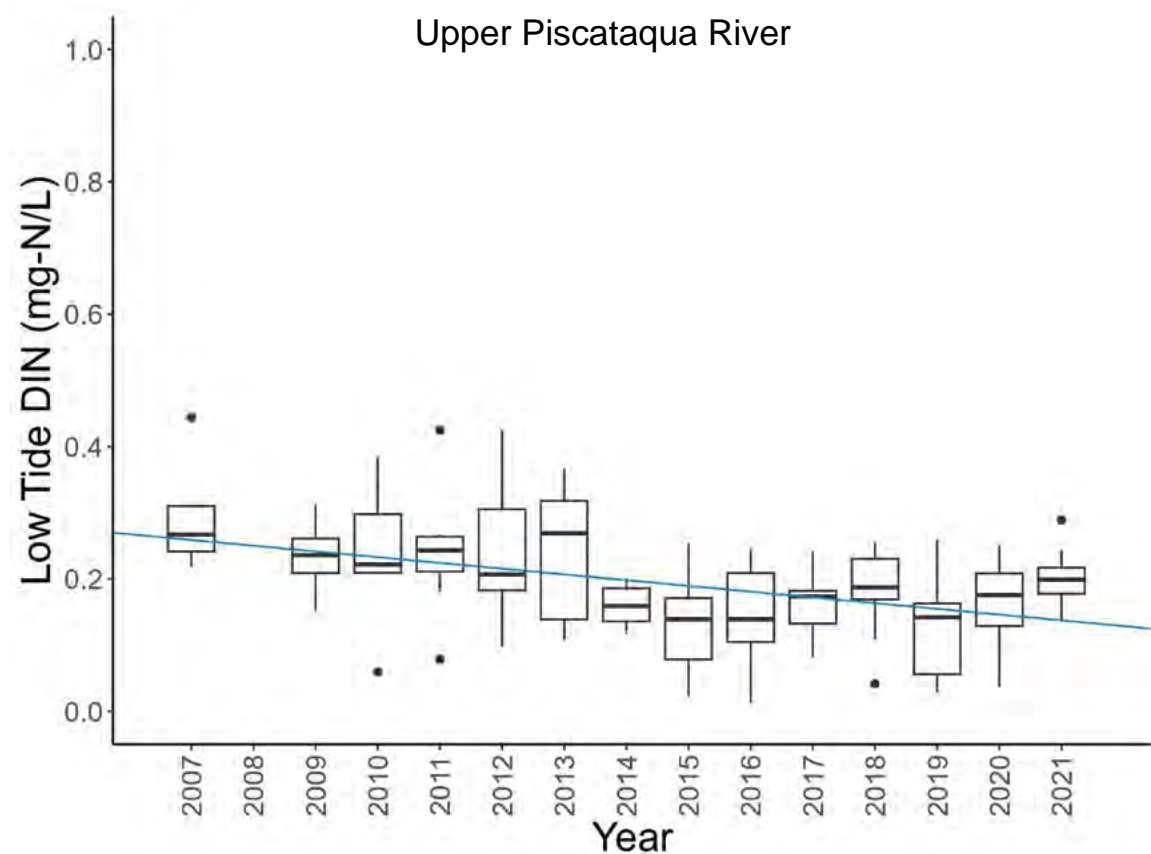


Figure 8.3: Dissolved inorganic nitrogen (DIN) at the Upper Piscataqua Station indicates a downward trend based on data collected monthly at low tide between 2007 and 2021 and shown here as box and whisker plots. Boxes encompass the middle 50% of the data points. The horizontal line in each box is the median and the vertical whiskers encompass the remaining data. "Outliers" are shown as individual points. Some years are omitted due to missing data. Blue line represents significant linear regression through annual median values.

Data source: Great Bay National Estuarine Research Reserve and the Jackson Estuarine Laboratory, UNH

Dissolved Oxygen



How often does dissolved oxygen in the Great Bay and Hampton-Seabrook Estuaries fall below 5 mg/L?

Most of the time, dissolved oxygen levels remain well above 5 mg/L in the bays and open waters located at the center of the Great Bay and in Portsmouth Harbor. However, low dissolved oxygen events do occur in the Upper Piscataqua River, all the Great Bay Estuary tidal rivers, and the Hampton River in the Hampton-Seabrook Estuary. In 2021, most low dissolved oxygen events in the tidal rivers lasted between two and four hours. If these events remain sporadic and of short duration, negative impacts on aquatic organisms will likely be limited.

Goal

No measurements below 5 mg/L for dissolved oxygen concentration.



Photo by Jerry Monkman

Why We Track This Indicator

Fish and many other organisms need dissolved oxygen in the water to survive. Dissolved oxygen levels can decrease due to various factors, including rapid changes in wind, temperature, and salinity, as well as prolonged periods of dense cloud cover. Dissolved oxygen levels can also decrease as a consequence of nutrient inputs. When nutrient loading is too high, phytoplankton and seaweed can bloom and then die, after which bacteria and other decomposers use oxygen to break down the dead organic matter.

Explanation

There were no statistically significant trends for dissolved oxygen levels in either the Great Bay (from 2005 to 2021) or Hampton-Seabrook Estuaries (from 2017 to 2021). For the Great Bay Estuary, in general, the overall trend seems to be for fewer summer days with instances of dissolved oxygen dropping below 5 mg/L than in the previous report (see Figure 9.1). For example, in the Oyster River, since 2006, the number of low dissolved oxygen days has gradually fallen. In the Squamscott River, since peaking in 2017, conditions also seem to be improving. Though less consistent, Lamprey River low dissolved oxygen days seemed to peak in 2015 and have been gradually decreasing since then.

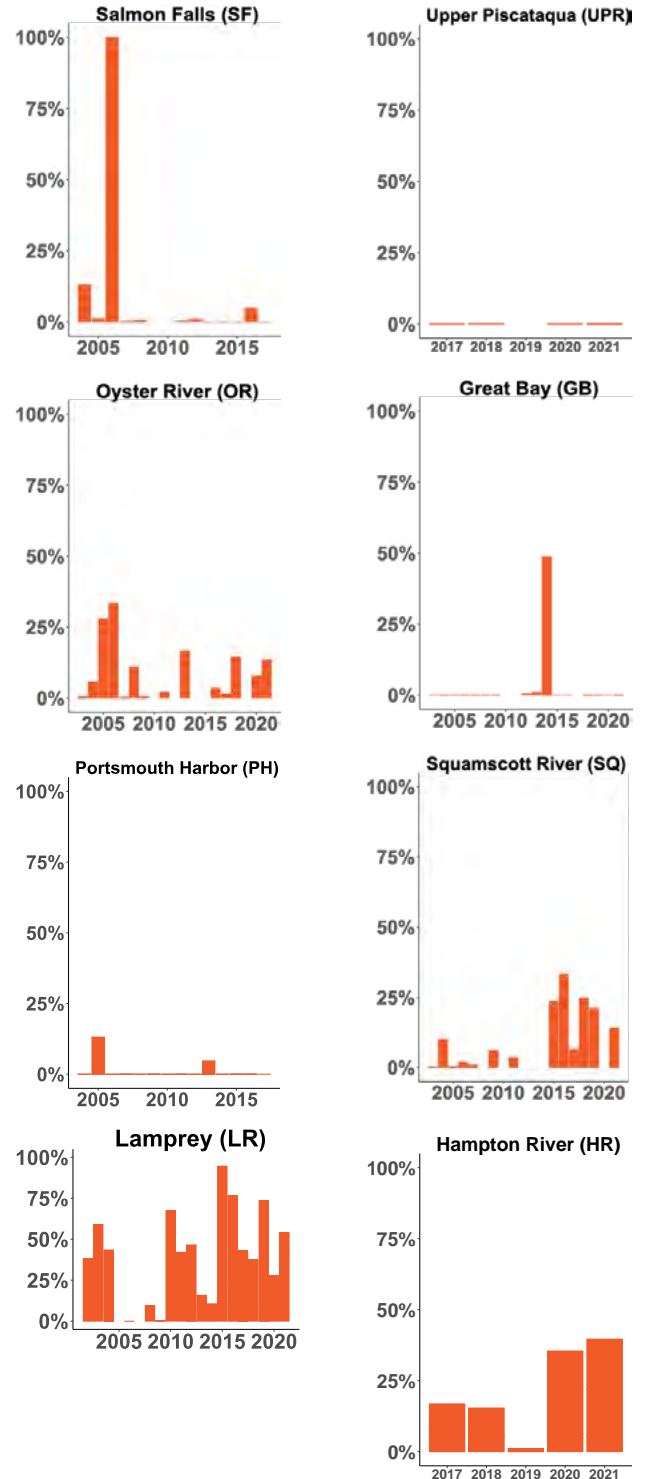
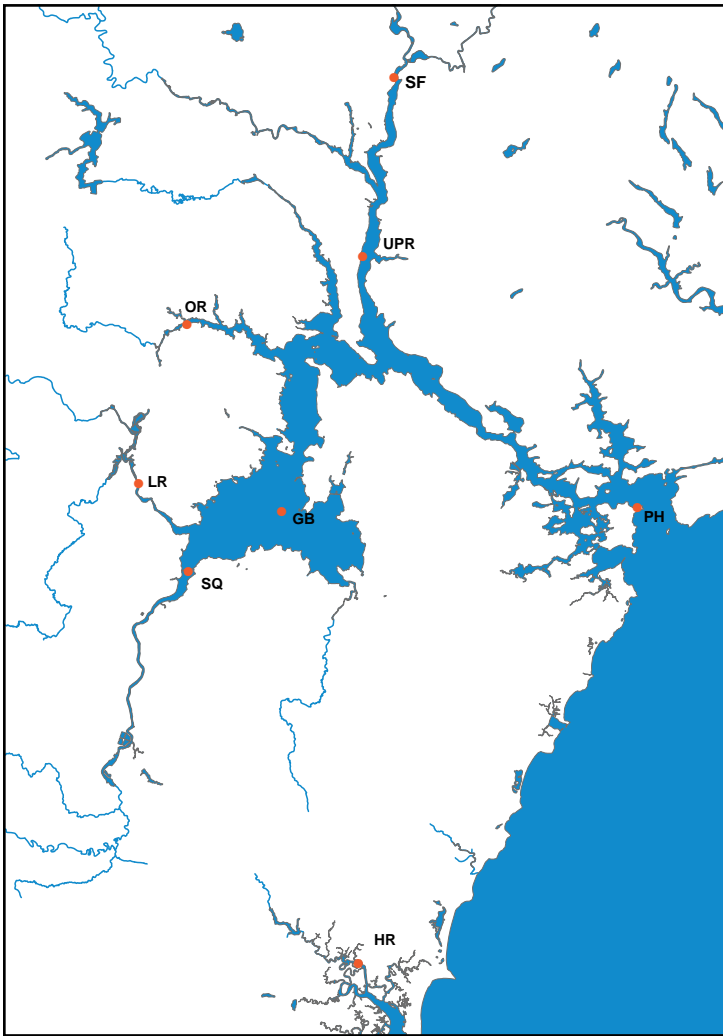
The exception to this overall trend is the Hampton River Station in the Hampton-Seabrook Estuary, where data have been collected since 2017, and in both 2020 and 2021, there were more low dissolved oxygen days than in the previous three years.

Recently, both the Great Bay and the Upper Piscataqua River Stations remain consistently above the 5 mg/L threshold.

Another important dimension to this indicator is the duration of low dissolved oxygen events. Most recently, in the Great Bay Estuary, low dissolved oxygen events have occurred infrequently and have not lasted longer than five hours. Data indicate that the Lamprey, Oyster and Squamscott Stations have the highest number of low dissolved oxygen days in this estuary. Considering sensor dissolved oxygen data from June through September, 2021, the majority of hourly measurements in all three rivers are above 5 mg/L, but there are low dissolved oxygen events for multiple hours (Figures 9.2–9.4).

The insets for these time series show how many hours the dissolved oxygen was less than 5 mg/L for the lowest day on record. In the Oyster River (Figure 9.2), this day occurred on July 2, 2021, and the data show that the low dissolved oxygen event lasted for a total of eight hours. In the Squamscott River (Figure 9.3), the lowest dissolved oxygen day occurred on August 20, 2021, with two low dissolved oxygen events within the 24-hour window, each lasting about four hours.

Previous reports have noted that the Lamprey River seems to have particular dissolved oxygen problems because the tributary is less vertically mixed than other tributaries, leading to low oxygen conditions on the bottom. Given the 2017 upgrade to the Newmarket Wastewater Treatment Facility, observers hoped that there would be fewer low dissolved oxygen events; this does, in fact, seem to be happening although the trend is not statistically significant (Figure 9.1).



In August of 2015, the Lamprey River experienced a low dissolved oxygen event that lasted seven days. In contrast, the longest lasting low dissolved oxygen event in 2021 was approximately 23 hours (Figure 9.4). This pattern of shorter periods of low dissolved oxygen could signal higher water quality. However, due to the occurrence of some low dissolved oxygen events, the average dissolved oxygen values over some period of time needs to be monitored. For example, in a 2009 Chesapeake Bay report, the recommendation was to set a 7-day average at 4 mg/L.³³ Experiments have shown that juvenile fishes experience increased mortality and decreased growth after as few as 8 hours of low dissolved oxygen situations.³⁴ The impact is worse when coupled with other stressors, such as low pH.

Data for Hampton River from 2021 are concerning because of the frequency of low dissolved oxygen events (Figure 9.5). Studies indicate that frequent low dissolved oxygen events can slowly build up stress in aquatic organisms, particularly for larval or juvenile fishes.³⁵

Acknowledgments and Credit

Easton R. White (UNH) and Wilton Burns (UNH) with contributions from Kalle Matso (PREP), Lara Martin (UNH), and Miguel Leon (UNH).

Figure 9.1: Number of summer days — the period when low dissolved oxygen (DO) events most commonly occur — when DO falls below 5 mg/L at eight sites in both the Great Bay and Hampton-Seabrook Estuaries. Data source: Jackson Estuarine Lab, UNH

Dissolved Oxygen

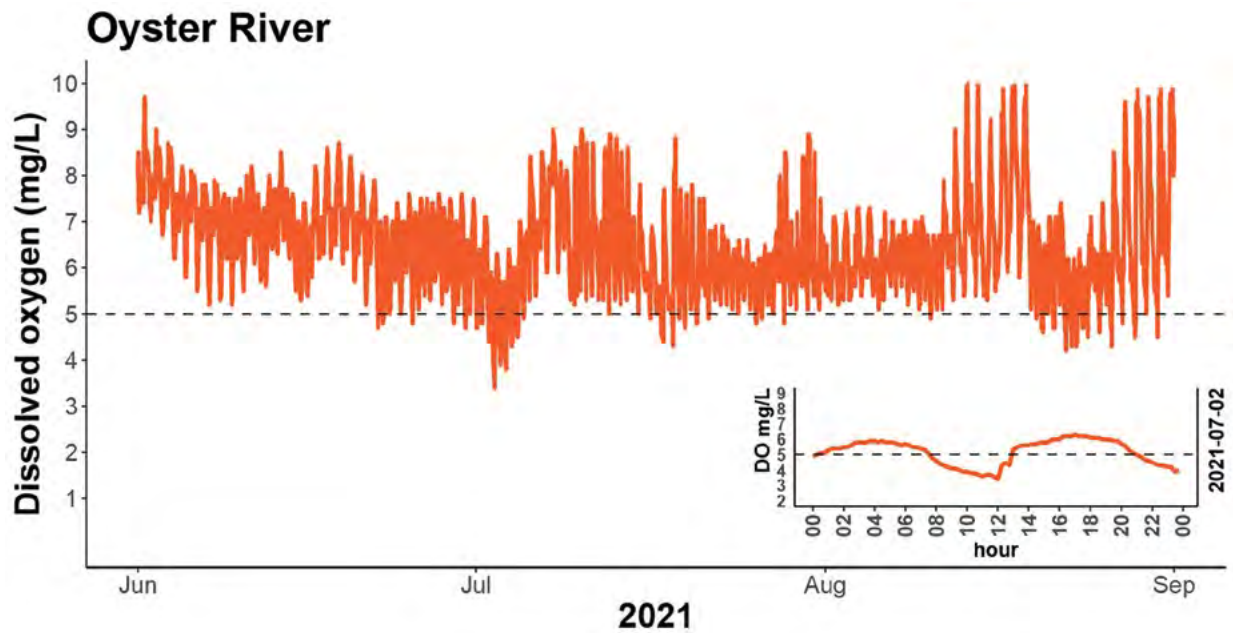


Figure 9.2: Dissolved oxygen measured every 15 minutes between June and September 2021 at Oyster River Station in the Great Bay Estuary. The smaller inset graph shows a 24-hour period on the lowest dissolved oxygen day of the Oyster River record: July 2, 2021. Data source: Jackson Estuarine Lab, UNH

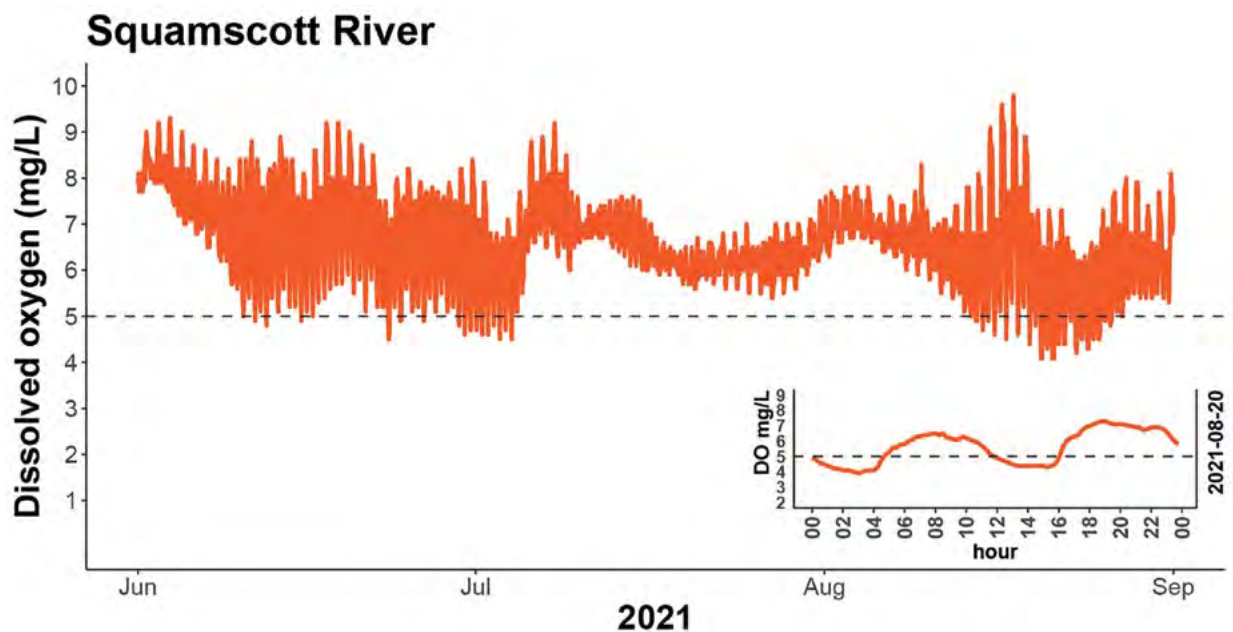


Figure 9.3: Dissolved oxygen measured every 15 minutes between June and September 2021 at the Squamscott River Station in the Great Bay Estuary. The smaller inset graph shows a 24-hour period on the lowest dissolved oxygen day of the Squamscott River record: August 20, 2021. Data source: Jackson Estuarine Lab, UNH

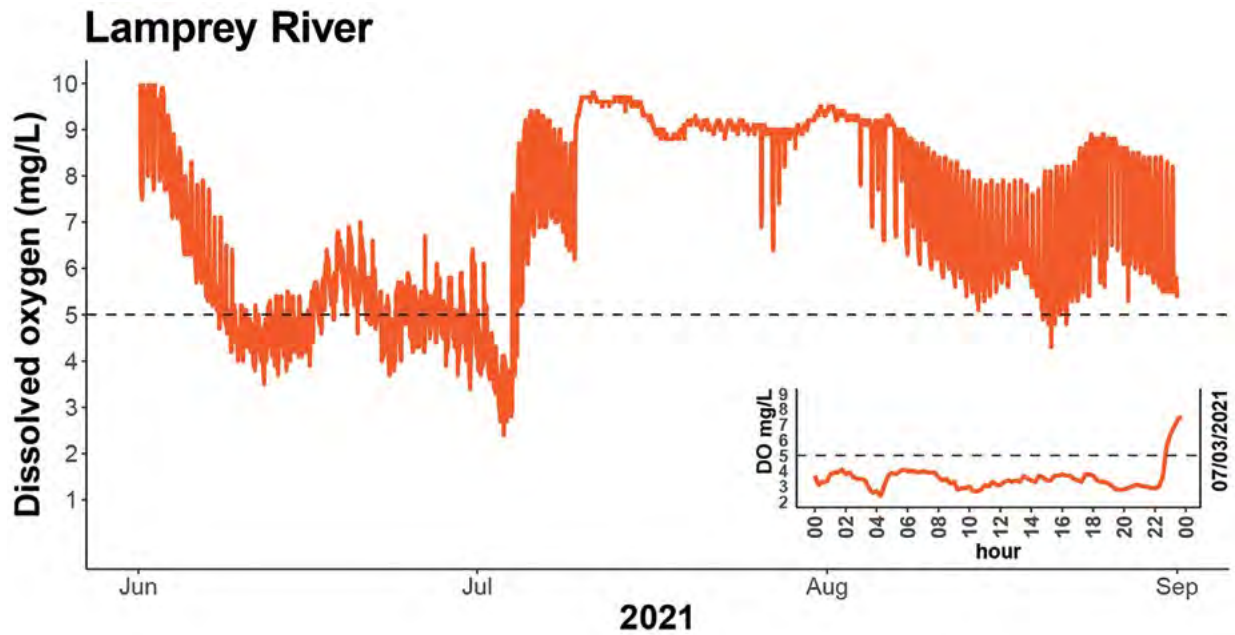


Figure 9.4: Dissolved oxygen measured every 15 minutes between June and September 2021 at the Lamprey River Station in the Great Bay Estuary. The smaller inset graph shows a 24-hour period on the lowest dissolved oxygen day of the Lamprey River record: July 3, 2021. Data source: Jackson Estuarine Lab, UNH

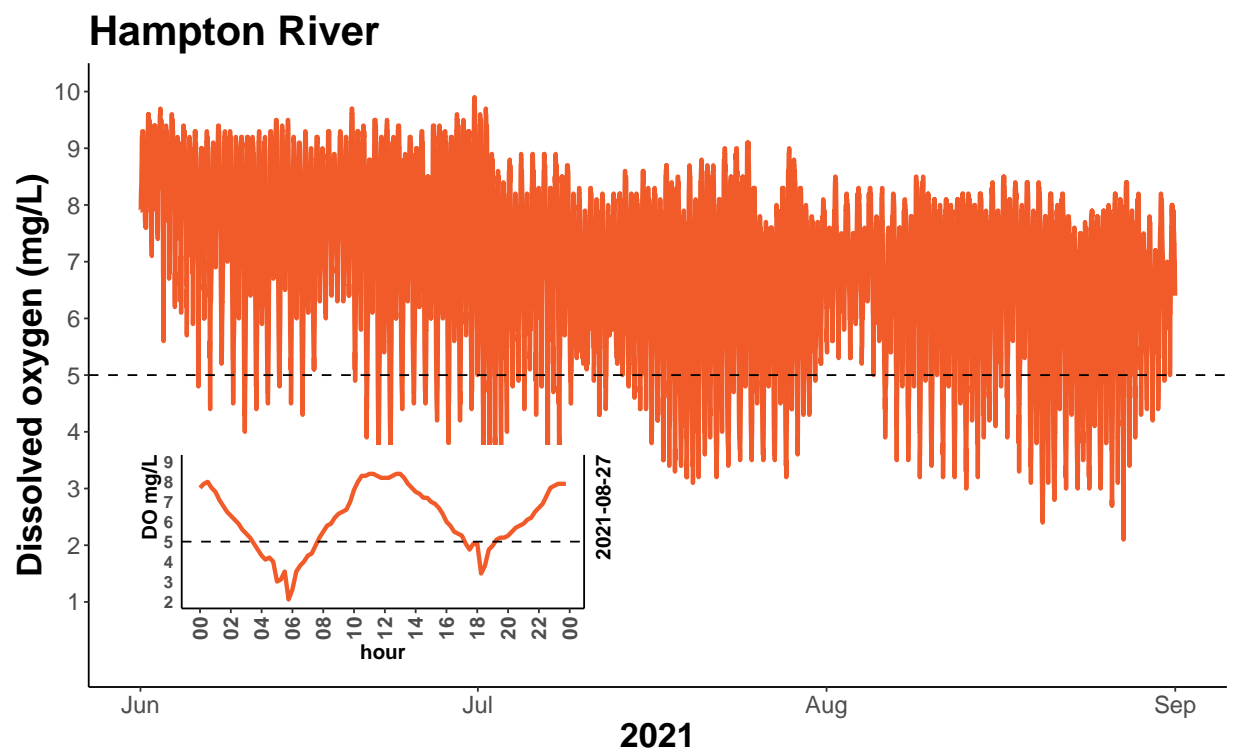


Figure 9.5: Dissolved oxygen measured every 15 minutes between June and September 2021 at the Hampton River Station in the Hampton-Seabrook Estuary. The smaller inset graph shows a 24-hour period on the lowest dissolved oxygen day of the Hampton River record: August 27, 2021. Data source: Jackson Estuarine Lab, UNH

Seaweed



What are the dominant seaweeds that grow in the Great Bay Estuary? Are some seaweeds better for the ecosystem than others? How is seaweed abundance for different species changing over time?

Since 2013, green seaweeds at a majority of the intertidal monitoring sites in the Great Bay Estuary decreased, while there were no clear patterns for red seaweeds. A new subtidal monitoring effort, started in 2018, indicates that while red and green nuisance species still compete with eelgrass, especially in the southern and western portions of the Great Bay, the proportion of eelgrass is increasing.

Goal

No increasing trends for nuisance seaweeds.

Why We Track This Indicator

Many seaweeds, like brown intertidal “rockweed,” provide important ecosystem services, such as habitat for many organisms, including juvenile oysters (see “Oysters”). However, eutrophication (i.e., excess nutrients loaded into our estuaries) can spur growth of nuisance seaweeds (usually red and green seaweeds) that in turn can block light and smother eelgrass. Too much of these unwanted seaweeds, like red *Gracilaria* or green *Ulva*, can also impact other desirable habitats such as oyster reefs. Because there is little or no eelgrass in the Hampton-Seabrook Estuary, seaweed is not actively monitored.

Explanation

Intertidal

In a healthy estuary, seaweeds are in balance with other estuarine life and are not a cause for concern. For example, attached brown seaweeds, like the image at the bottom, form important habitat and support overall productivity in the Great Bay Estuary. However, international shipping has allowed seaweeds to hitchhike from distant coasts to our estuaries and proliferate. In the Great Bay, south of Adams Point, we are seeing high abundances of these seaweeds competing with eelgrass.

Overall, data from eight stations in the Great Bay Estuary (Figure 10.1) suggest that red and green seaweeds expanded between 1980 and 2013 and since then, have decreased. The average cover of red and green seaweeds combined was generally less than 20% at Little Bay and Piscataqua River sites (Figure 10.2), and about twice as abundant in the Great Bay (Figure 10.2).

Nuisance red *Gracilaria* and green *Ulva* species composed nearly all the cover in intertidal areas. Both species can survive as drift or attached seaweed. Over the seven-year study period, only Depot Road and Adams Point had more than four years of data available for statistical analysis. Both red and green seaweeds declined significantly at the Depot Road site along the southern shore of Great Bay, but only greens were found to decline at Adams Point on the north shore of the Bay (Figure 10.3).



Clouds of nuisance green seaweed compete with eelgrass blades for light in the Great Bay near Newmarket, NH. Summer, 2022. Photo by Amanda Giacchetti.



Invasive red seaweed floats above eelgrass in the Piscataqua River, Eliot, ME. Photo by Kalle Matso.

Subtidal

The intertidal transects established earlier in the Great Bay Estuary were extended in 2018 into the subtidal regions to examine seaweed beds and directly assess eelgrass-seaweed competition (Figure 10.4). The attached browns that dominated some intertidal areas were mostly absent from subtidal sites. Despite high variability in the abundance of drift seaweeds from year-to-year, some trends are evident. The highest seaweed abundance (dominated by *Gracilaria* and *Ulva*) and lowest eelgrass abundance was at the Depot Road location, whereas eelgrass was most dominant at the Sunset Hill Farm site (lower East Great Bay) for all three years of sampling (Figure 10.4). Eelgrass cover was stable or increased at three of four sites.

Acknowledgments and Credits

David Burdick (UNH), with contributions from Gregg Moore (UNH), Art Mathieson (UNH), Andrew Payne (UNH), Chris Peter (GBNERR/NHFG), Lara Martin (UNH), Natalie White (UNH), Elizabeth Cianciola (UNH), Grant McKown (UNH), and a host of UNH students. We appreciate the assistance of volunteers organized by the Coastal Research Volunteers.

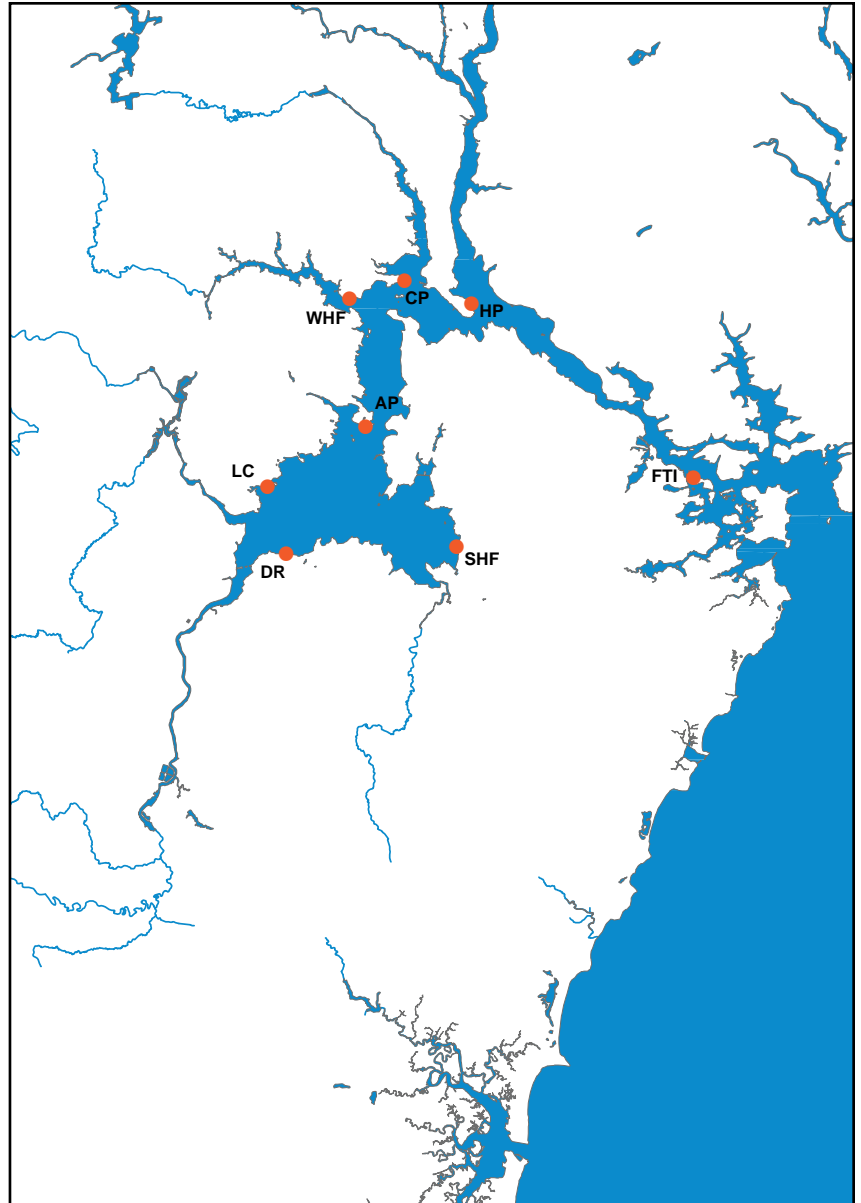


Figure 10.1: Seaweed monitoring sites in the Great Bay Estuary, which include intertidal and subtidal locations: Adams Point (AP), Sunset Hill Farm (SHF), Depot Road (DR), Lubberland Creek (LC). Sites in Little Bay and Portsmouth Harbor are intertidal only: Wagon Hill (WHF), Cedar Point (CP), Hilton Point (HP), and Four Tree Island (FTI).

Data source: Jackson Estuarine Laboratory, UNH



Aerial image of seaweed (reddish vegetation) patches within eelgrass beds in Portsmouth Harbor. Photo by Michael Routhier, UNH.

Seaweed

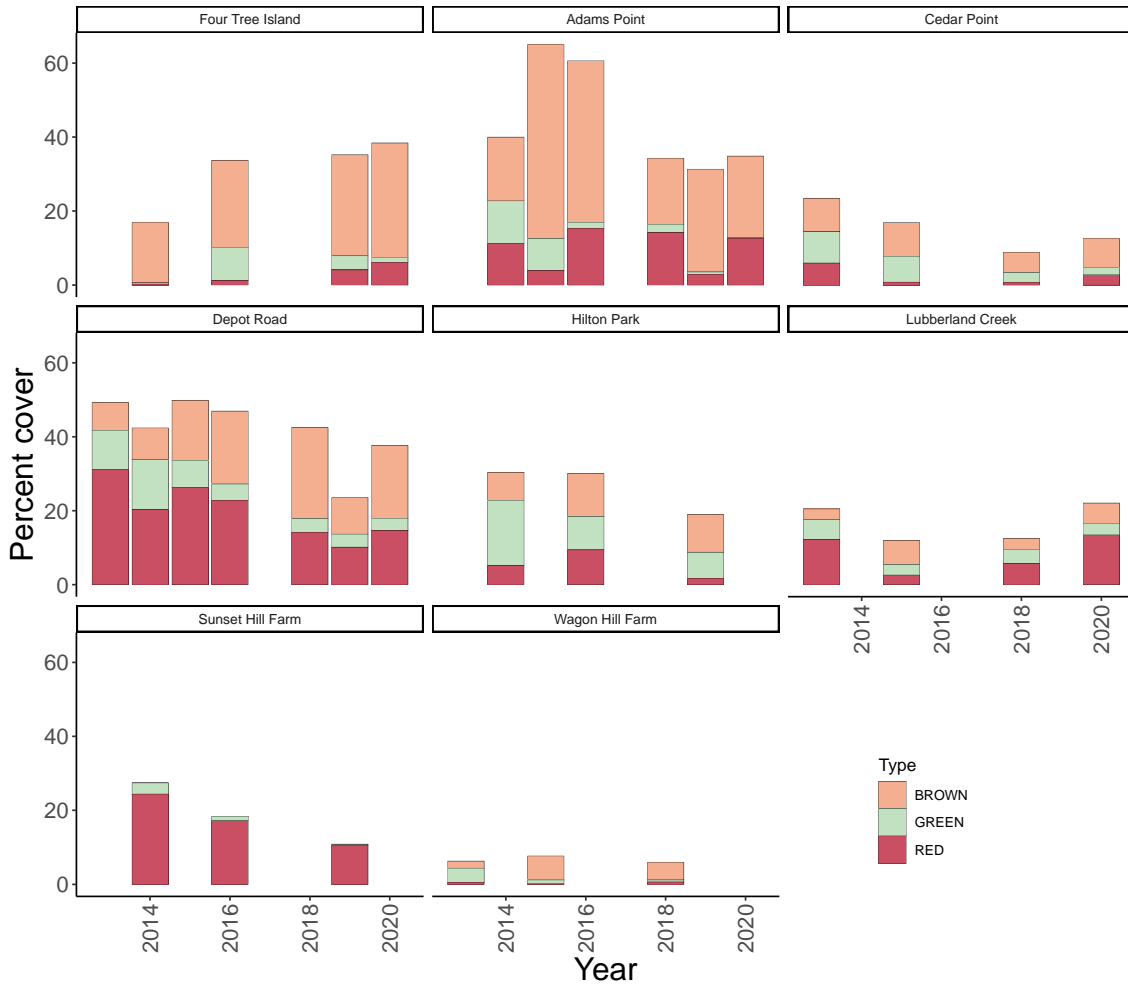


Figure 10.2: Abundance of intertidal green, red, and brown seaweeds assessed by percentage cover and averaged for three transects at depths of 0.5 to 2.5 m relative to mean low water in the Little Bay and Piscataqua River sites (Four Tree Island, Hilton Park, Cedar Point, Wagon Hill Farm) and Great Bay sites (Adams Point, Lubberland Creek, Depot Road, Sunset Hill Farm).

Data source: Jackson Estuarine Laboratory, UNH

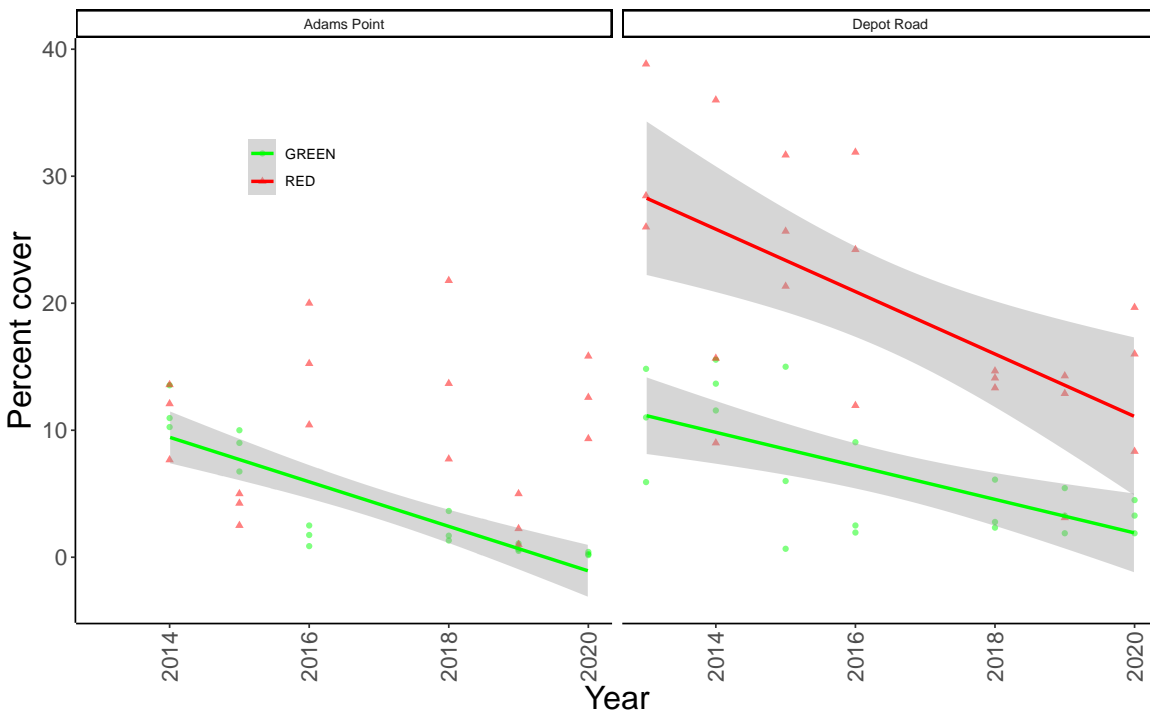


Figure 10.3: Linear regression showing red and green seaweed cover over time at Adams Point and Depot Road survey sites with best fit lines shown where change was statistically significant.

Data source: Jackson Estuarine Laboratory, UNH

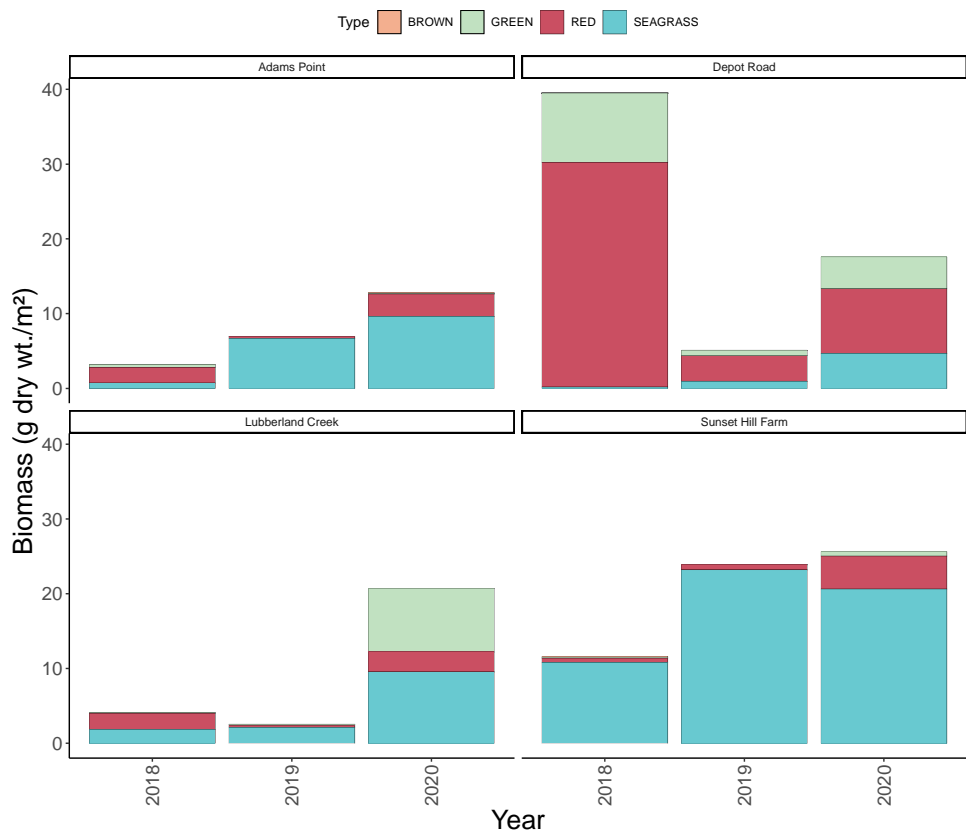


Figure 10.4: Abundance of drift seaweeds and rooted eelgrass using biomass estimates from summer sampling at four subtidal locations with three transect stations (12 stations total) in the Great Bay. Data source: Jackson Estuarine Laboratory, UNH



Eelgrass



How many acres of eelgrass are present in the Great Bay Estuary and how has eelgrass cover changed over time? Has the total amount of eelgrass — measured as biomass — changed over time?

The Great Bay Estuary (including Kittery, ME to Odiome State Park in Rye, NH) had 1,654 acres of eelgrass in 2021, slightly less than the 1,678 acres reported in 2019³⁶ (Figure 11.2). This is 43% below the peak in 1996 (2,900 acres) and 40% below the coverage in 1981 (2,752 acres), the first year that data were collected for the entire area. It is noteworthy that acreage in the Portsmouth Harbor region has been increasing steadily since 2014. Biomass, a measure of eelgrass health, at sites in Great Bay and Portsmouth Harbor are currently 214 g/m² and 139 g/m², respectively. These levels are much lower than the peaks, which were 454 g/m² for Great Bay in 1993³⁷ and 506 g/m² for Portsmouth Harbor in the late 1980s³⁸. This means that, since peaking several decades ago, biomass decreased by 53% in Great Bay and 73% at Portsmouth Harbor. Given the importance of eelgrass to the estuarine ecosystem, efforts to improve eelgrass health continue to be a high priority. Whereas factors that are impossible to control — such as increasing water temperature — are also impacting eelgrass, land conservation, and better stormwater management to reduce nutrient and sediment loading to the Great Bay Estuary are effective actions we can take to improve eelgrass habitat.

Goal

Increase eelgrass distribution to 2,900 acres in the Great Bay Estuary. Goals related to the health of eelgrass (e.g., biomass) are in development. Note that eelgrass is not and has never been abundant in the Hampton-Seabrook Estuary and so this goal does not apply there.

Why We Track This Indicator

Eelgrass (*Zostera marina*) leaves slow the flow of water, encouraging suspended materials to settle, thereby promoting water clarity. Eelgrass roots stabilize sediments and both the roots and leaves take up nutrients from sediments and the water while providing habitat for fish, shellfish, and other small invertebrates, which in turn support other wildlife such as wading birds. Finally, eelgrass is sensitive to pollution — especially nutrients and sediments — and often indicates the status of an estuary's water quality.

Explanation

To assess eelgrass, we map the number of acres of habitat and then determine how much eelgrass is growing in those habitats, because eelgrass meadows can become less dense and have less biomass (weight of plant material per area) when they are struggling. When eelgrass biomass decreases, beneficial functions, such as habitat for fish and shellfish, wave dampening, etc., also decrease. Based on 2021 data, the total acreage of eelgrass (1,654 acres) in the Great Bay Estuary has not changed notably since 2017 (Figure 11.1, Figure 11.2). The biomass of eelgrass at the deepest SeagrassNet monitoring site in the Great Bay shows overall improvement from 2019 to 2021 before a decrease in 2022. Eelgrass at the deepest site in Portsmouth Harbor decreased between 2019 and 2021 before increasing in 2022, finishing with little net change when compared to 2019 (Figure 11.3).

Total acreage of eelgrass in 2021 represents losses in some parts of the Great Bay Estuary and gains in others. For example, roughly 100 acres of eelgrass were lost in the Great Bay since 2019, especially in shallow regions of the southern portion of the Great Bay. On the other hand, there were considerable gains in acres of eelgrass in the Portsmouth Harbor and Rye coastal areas, with the highest acreage of eelgrass near Odiome Point since we began regular monitoring in 1981. In 2021, Portsmouth Harbor had 114 acres, up from 60 acres in 2010 (Figure 11.4).

These data tell a complex yet common story of eelgrass that occurs in many estuaries from North Carolina to Prince Edward Island, Canada. Eelgrass is a plant sensitive to several stressors including wasting disease, temperature, habitat disturbance, and predation. Most commonly, excessive nutrients and sediments contribute to eelgrass decline. Nutrients, such as nitrogen, spur the growth of seaweed, epiphytes (algae growing on eelgrass leaves), and phytoplankton, which then outcompete eelgrass for light. Suspended sediments, too, block light from eelgrass, which needs much more light than most algal competitors. The "Total Suspended Solids" and "Phytoplankton" sections

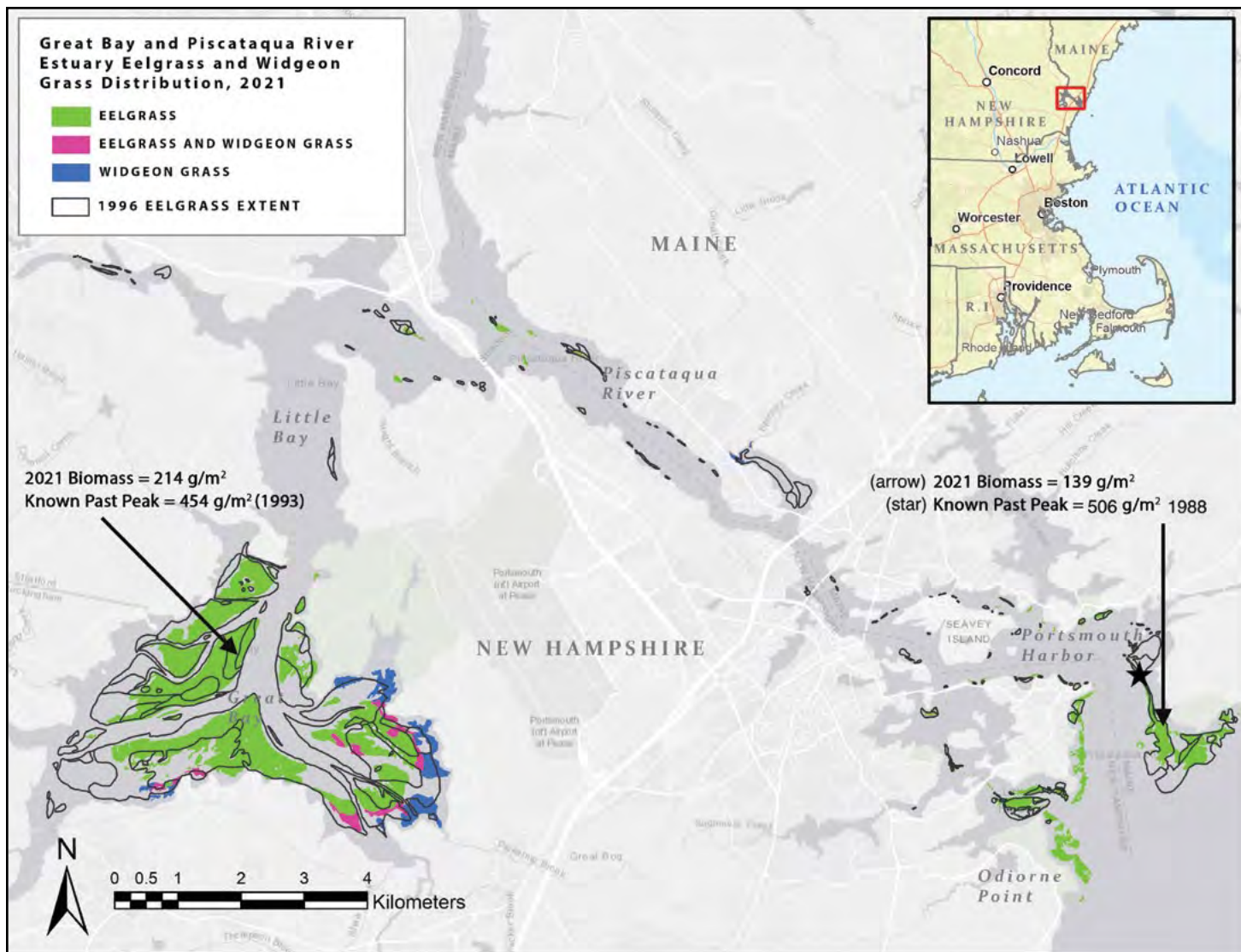


Figure 11.1: Seagrass distribution in the Great Bay Estuary in 2021, with biomass values for two sites. Black outlined polygons show the extent of eelgrass in 1996. Data source: Michael Routhier, Ray Grizzle and Krystin Ward, UNH. 1996 data from Fred Short, UNH



Eelgrass

review data indicating increasing trends in these light-blocking constituents over time.

Eelgrass is also sensitive to warming waters, a phenomenon that is occurring all along the US East Coast. This can create a “habitat pinch,” where shallow waters can have good water clarity but are too warm, and the deeper waters are cooler but difficult for eelgrass because not enough light gets to the seafloor.

The relative role of different stressors on eelgrass in the Great Bay Estuary is a topic of ongoing research. The overall trend of eelgrass acres is inversely related to nitrogen loading and precipitation (Figure 11.2), at least through 2010, but does not necessarily indicate a cause-and-effect relationship. Nitrogen loading and precipitation track each other closely, because much more nitrogen enters the system when it rains, both from non-point and point sources. The same can be said for sediments and colored dissolved organic matter; large rain events wash material from the landscape into the tributaries and estuaries. Also, strong winds can stir up existing sediments, which also blocks light from reaching eelgrass. In rare cases, the salinity of the Great Bay Estuary can be greatly reduced, as happened during the Mother’s Day Storm of 2006 (Figure 11.2). These conditions, along with the erosive force of extreme freshwater flow events, can cause significant stress to eelgrass habitats, which prefer salinity levels to be 15 ppt or higher. While the 2006 storm coincides with a notable decrease in the number of acres of eelgrass, Figure 11.2 also suggests that a downward trend in eelgrass acreage was underway before this storm.

Since the Mother’s Day storm in 2006, the number of eelgrass acres in the estuary has remained relatively flat (Figure 11.2) even as nitrogen load continues to decrease and despite some years with low precipitation. On the other hand, over the same time period, eelgrass acreage in Portsmouth Harbor decreased in the years following the storm and then began to increase starting in 2010 (Figure 11.4).

The difference in eelgrass trends between Portsmouth Harbor and Great Bay is not completely understood, and might be related to hydrodynamic,

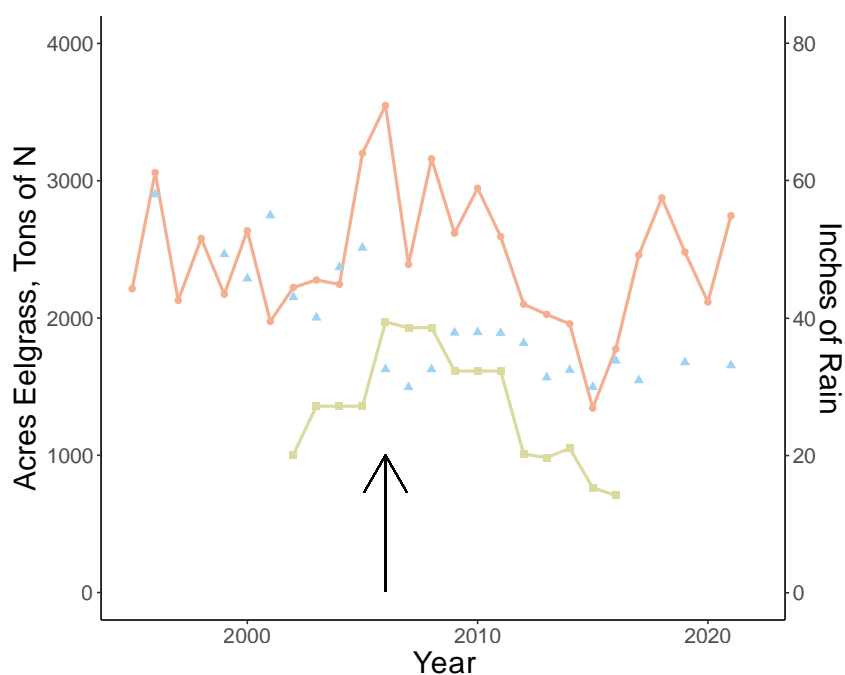


Figure 11.2: Eelgrass acres (light blue diamonds). The green line with squares indicate tons of nitrogen loading (per year). The orange line with circles represents total inches of rain. The arrow indicates the year of the Mother’s Day Storm which qualified as a 1% chance annual flood event: 1 of 3 such storms since 1935. The second such event was in 2007 and the third was in 1987. Data source: Eelgrass acres from 1996 to 2015, Fred Short (UNH); 2016 to 2019, Seth Barker; 2021, Michael Routhier, Ray Grizzle and Krystin Ward, UNH. Nitrogen loading data from the UNH Water Quality Analysis Lab, except for 1996 data point, which is from Jones 2001. Precipitation data from Greenland, NH weather station

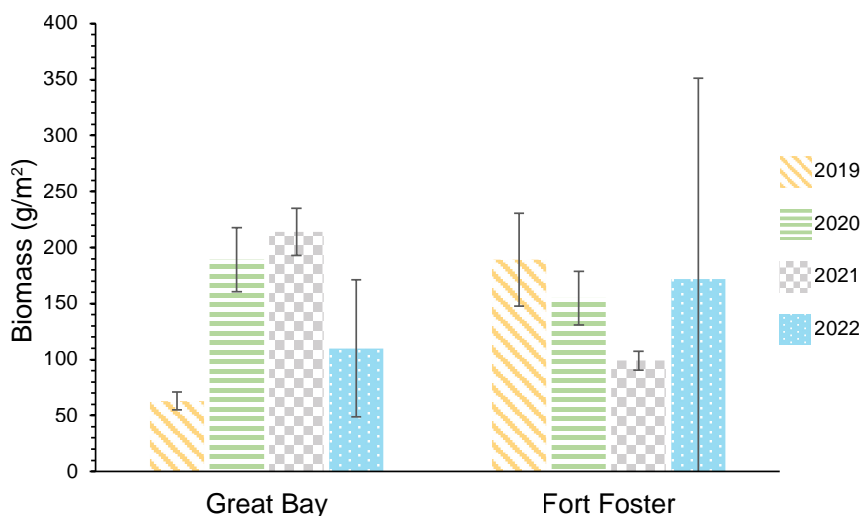


Figure 11.3: Biomass of eelgrass at deepest transect for two “SeagrassNet” monitoring stations: Great Bay and Portsmouth Harbor (Fort Foster). (See Figure 11.1 black arrows for locations on map.) Bars denote Standard Error.

Data source: Jackson Estuarine Laboratory, UNH

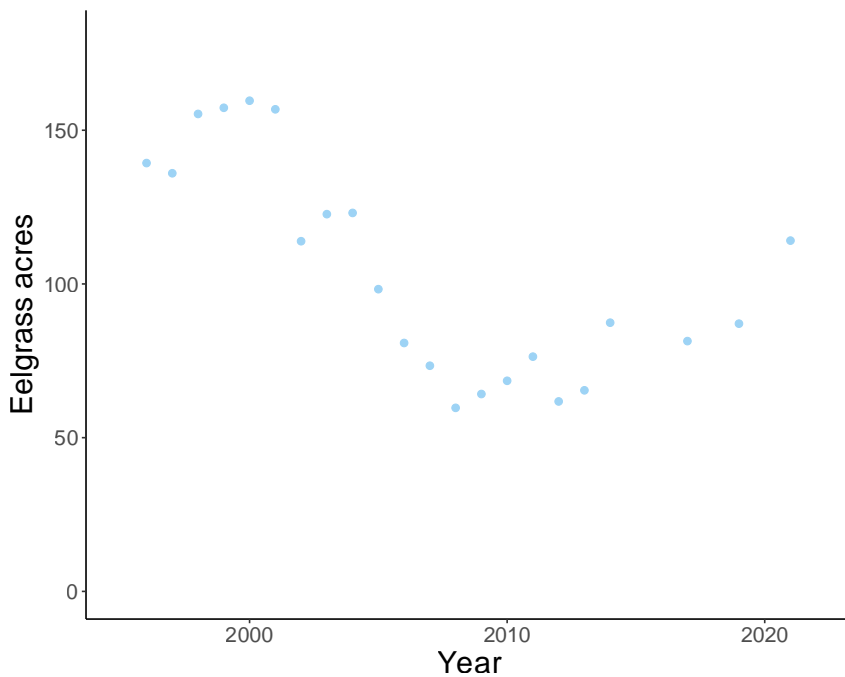


Figure 11.4: Number of acres of eelgrass in Portsmouth Harbor from 1995 to 2021.
Data source: Jackson Estuarine Laboratory, UNH

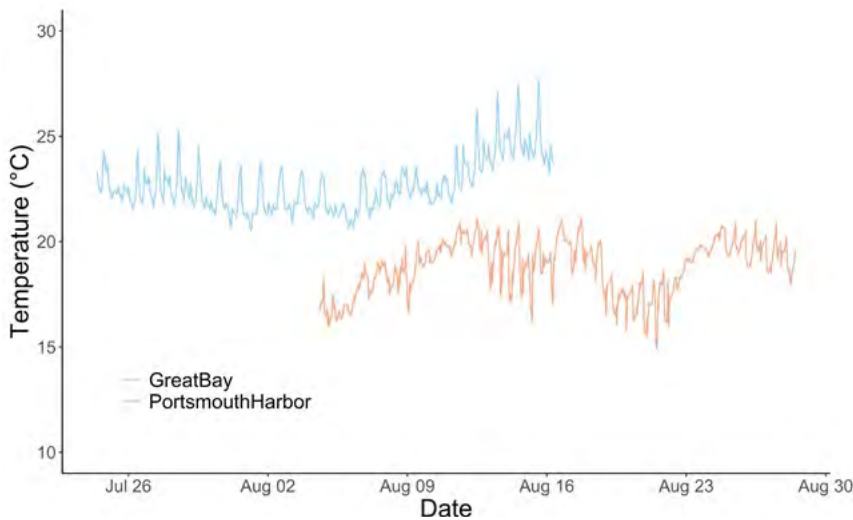


Figure 11.5: Temperature data collected by HOB0 sensors (every 10 minutes, located close to the bottom) from August 3 to August 28, 2021, at an eelgrass bed in Portsmouth Harbor (see Figure 11.1 for location) at one of the shallower locations in the Harbor and July 4 to August 16, 2021, at an eelgrass bed in the Great Bay Estuary (see Figure 11.1 for location), at one of the deeper locations.
Data source: Jackson Estuarine Laboratory, UNH

sediment, temperature, and ecological differences between the two areas. In the Great Bay, water remains “in residence” much longer; it takes 10 days for 50% of the water particles to leave the Bay. At the mouth of the Estuary, in contrast, 90% of the water particles flow to the ocean or upriver (depending on the tide) within a day. Also, the Bay is much shallower than Portsmouth Harbor. In fact, much of the Bay turns into a mudflat at low tide. Therefore, the sediments in Great Bay are fine-grained organic muds, in comparison with the coarse sands found in Portsmouth Harbor. This means that the sediments in Great Bay are more easily resuspended. Fine sediments tend to also have higher nutrient concentrations than coarser sediments and can release them slowly — years and sometimes decades later.

In addition, much of the eelgrass in Great Bay is growing in very shallow water and, therefore, is more susceptible to temperature stress (Figure 11.5). In contrast, for the Portsmouth Harbor eelgrass beds — despite the Gulf of Maine experiencing rapidly warming water — temperatures do not rise above 25°C (the threshold stress point for eelgrass)³⁹ even at the shallow eelgrass beds (Figure 11.5). Finally, the two areas may host different types and proportions of fauna that can exert top-down effects on eelgrass or eelgrass habitat.

Acknowledgments and Credit

Kalle Matso and Trevor Mattera (PREP), with contributions from Michael Routhier (UNH), Ray Grizzle (UNH), Krystin Ward (UNH), Tom Gregory (UNH), Amanda Giacchetti (UNH), Lara Martin (UNH), and David Burdick (JEL/SMSOE/UNH).

Extended Report

A new seagrass and seaweed monitoring program was started in 2021, tracking seagrass and seaweed abundance at 25 sites throughout the Great Bay Estuary. See the Extended Report for results from the first year.

Phytoplankton



How are phytoplankton concentrations changing over time?

Stations in Great Bay indicate an increase in chlorophyll-a (a proxy for phytoplankton) over time, peaking around 2010 through 2015, with levels dropping off in recent years. Other stations indicate either no trend or decreasing chlorophyll-a concentrations. Chlorophyll-a concentrations in Hampton River in recent years (2020 – 2021) are mostly at levels that indicate “good” water quality. Phytoplankton levels should be considered together with total suspended solids, because the two components combine to impact how much light gets to the bottom of our estuaries (see “Total Suspended Solids” and “Light”).

Goal

No increasing trends in phytoplankton abundance.

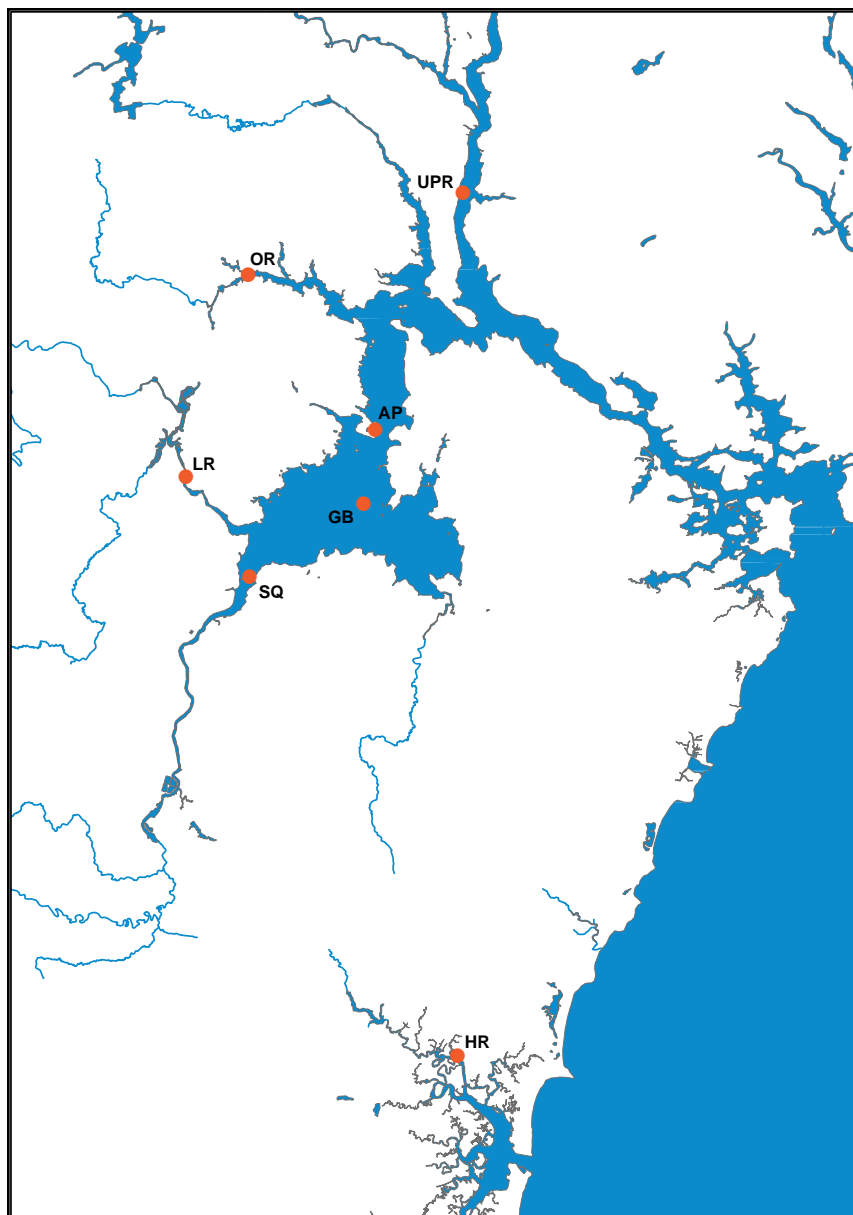


Figure 12.1: Monitoring stations for phytoplankton including Adams Point (AP), Great Bay (GB), Lamprey River (LR), Oyster River (OR), Squamscott River (SQ), Upper Piscataqua River (UPR), and Hampton River (HR)
Data source: Jackson Estuarine Lab, UNH

Why We Track This Indicator

Phytoplankton population dynamics are significant indicators of marine ecosystem health and marine food web structure. These single-cell algae impact water clarity, compete with eelgrass and seaweeds for available light and nutrients, and support biomass production in commercial fisheries. Additionally, when large populations of phytoplankton die, their decomposition decreases the dissolved oxygen available for fishes and benthic invertebrates, a problem that does occasionally occur in the tributaries that feed into both the Great Bay and Hampton-Seabrook Estuaries (see “Dissolved Oxygen”).

Explanation

Extracted chlorophyll-a measurements were compared among six locations in the Great Bay Estuary (Figure 12.1). Both the Adams Point and Great Bay Stations (Figure 12.2; Table 12.1) indicate statistically significant increasing trends while the Squamscott River (Figure 12.3) and Oyster River Stations indicate statistically decreasing trends (Table 12.1). These differences could be due to when these various time series began. For example, only the Adams Point Station includes data from the late 1980s and early 1990s, a period when chlorophyll-a levels were low. The Upper Piscataqua River Station time series only extends back to 2007

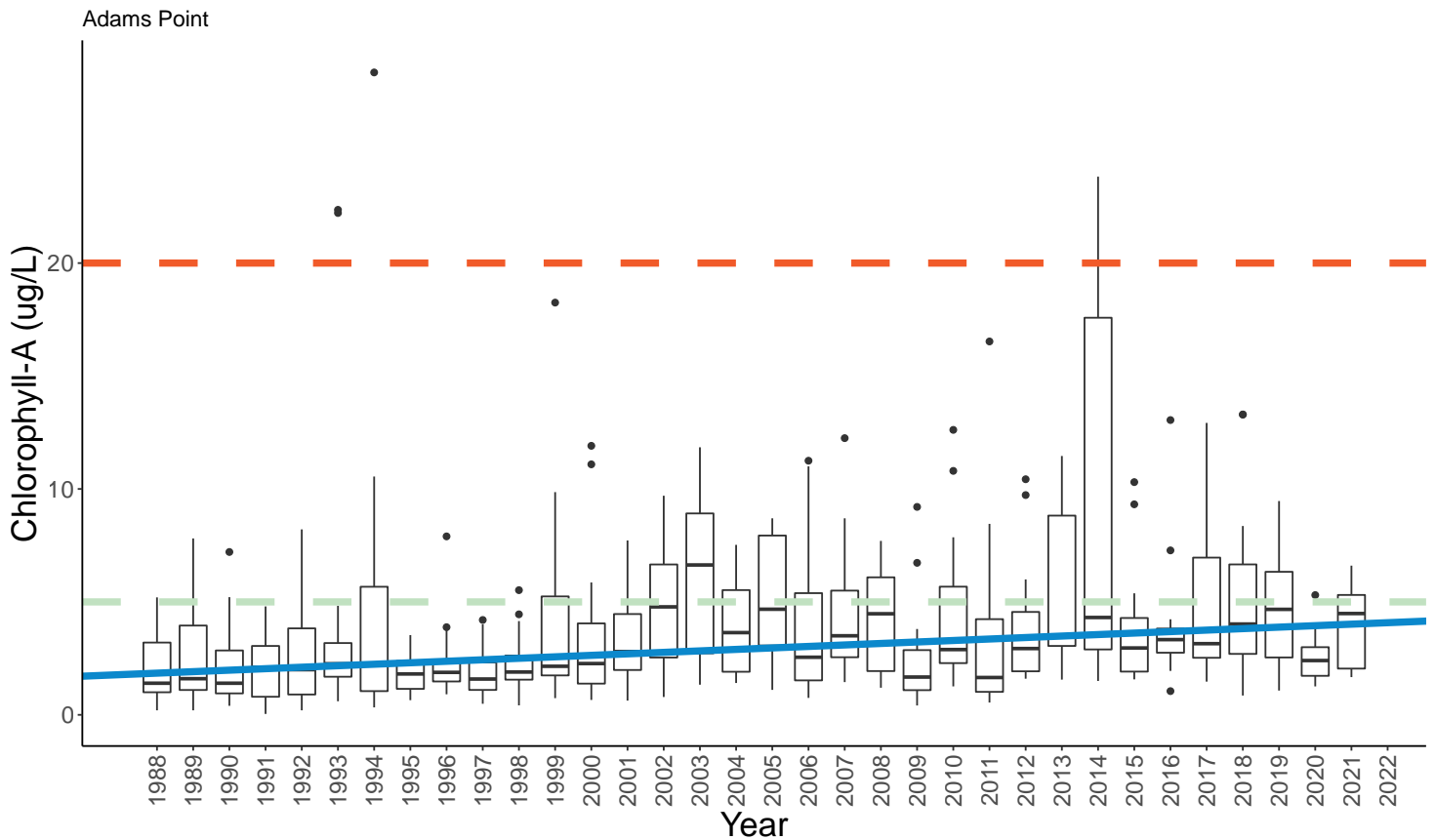


Figure 12.2: Box and whisker plot of chlorophyll-a data at the Adams Point Station (year-round, both low and high tide) from 1988 to 2021. Boxes encompass the middle 50% of the data points. The horizontal line in each box is the median and the vertical whiskers encompass the remaining data. “Outliers” are shown as individual points. In general, measurements below the green dashed line at 5µg/L reflect better water quality. Measurements between 5 and 20µg/L are “moderate” and measurements above the red dashed line (20µg/L) indicate poorer water quality. The blue trend line indicates a statistically significant increase over time.

Data source: Jackson Estuarine Laboratory, UNH



Photo by Jerry Monkman

Location	Significant change in chlorophyll-a concentration?	Dates
Adams Point	Yes ↑	1988 – 2021
Great Bay	Yes ↑	2002 – 2021
Lamprey River	No	1992 – 2021
Oyster River	Yes ↓	2002 – 2021
Squamscott River	Yes ↓	2001 – 2021
Upper Piscataqua River	No	2007 – 2021
Hampton River	No	2018 – 2021

Table 12.1. Summary of analysis of annual change in chlorophyll-a concentrations.

Data source: Jackson Estuarine Laboratory, UNH

Phytoplankton

and there have been no detectable trends (Figure 12.4). Similarly, the time series for the Hampton River Station began very recently (2018) and does not exhibit a clear trend (Figure 12.5).

At all stations investigated, chlorophyll-a concentration ranged from less than 1 $\mu\text{g/L}$ to approximately 40 $\mu\text{g/L}$ and there were significant trends in chlorophyll-a at four of the seven stations (Table 12.1). The longest time series is for Adams Point and illustrates the pattern of low levels at the beginning of the record (1988 through 2002) with higher levels over the last two decades (Figure 12.2). Currently, this station shows a statistically significant increasing trend.

Chlorophyll-a concentrations are regularly used to assess an estuary's "eutrophication" status: that is, whether the estuary contains excess nutrients. There are no current thresholds specific to our estuaries, but general thresholds do exist for coastal regions of the United States.⁴⁰ For the Northeast, chlorophyll-a levels less than 5 $\mu\text{g/L}$ are categorized as "low" with regard to eutrophic status, concentrations between 5 and 20 $\mu\text{g/L}$ are "moderate," and concentrations above 20 $\mu\text{g/L}$ are considered "high." In general, looking at Figures 12.1 through 12.4, most measurements fall in either the "low" or "moderate" category (encompassing from 0 to 20 $\mu\text{g/L}$) with some, but infrequent, measurements that are "high." It is encouraging that the vast majority of measurements are less than 10 $\mu\text{g/L}$ in the most recent years.

Across all locations, chlorophyll-a concentrations were seasonally variable, with a primary peak in the spring (Figure 12.6). Although chlorophyll-a should continue to be tracked, efforts should be made to characterize the dominant phytoplankton communities in estuarine waters consistently over time. This would provide essential information regarding the health of our estuaries, as well as their potential to nutritionally support important fisheries such as oyster aquaculture.

Acknowledgments and Credit

Elizabeth Harvey (UNH), with contributions from Kalle Matso (PREP), Lara Martin (UNH), and Tom Gregory (UNH).

Extended Report

Another analysis of chlorophyll-a shows how both minimum and maximum levels at Adams Point have statistically increased since 1988.

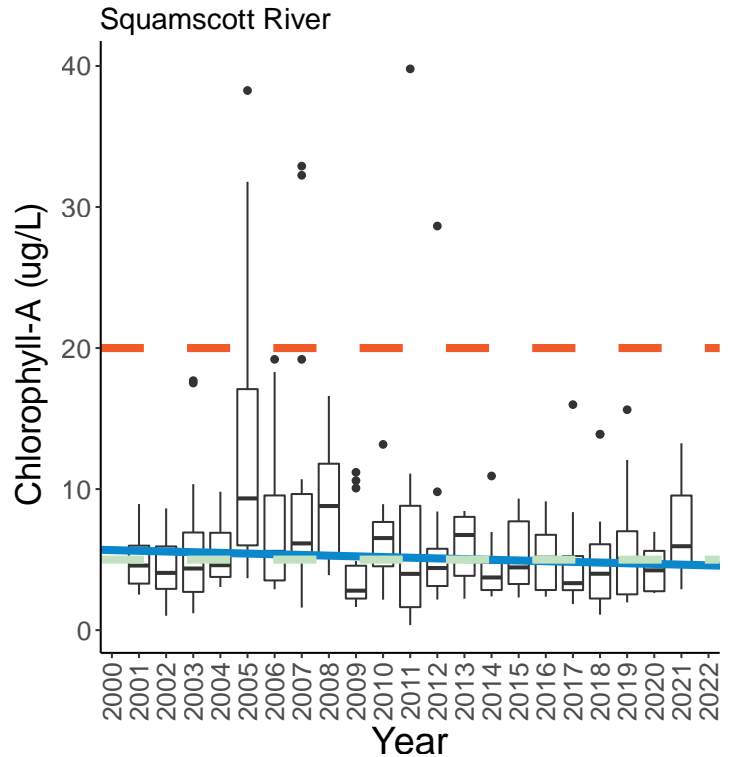


Figure 12.3: Box and whisker plot of chlorophyll-a data at the Squamscott River Station (low tide only) from 2001 to 2021. Boxes encompass the middle 50% of the data points. The horizontal line in each box is the median and the vertical whiskers encompass the remaining data. "Outliers" are shown as individual points. In general, measurements below the green dashed line at 5 $\mu\text{g/L}$ reflect better water quality. Measurements between 5 and 20 $\mu\text{g/L}$ are "moderate" and measurements above the red dashed line (20 $\mu\text{g/L}$) indicate poorer water quality. The blue trend line indicates a statistically significant decrease over time. Data source: Jackson Estuarine Laboratory, UNH



Photo by Jerry Monkman

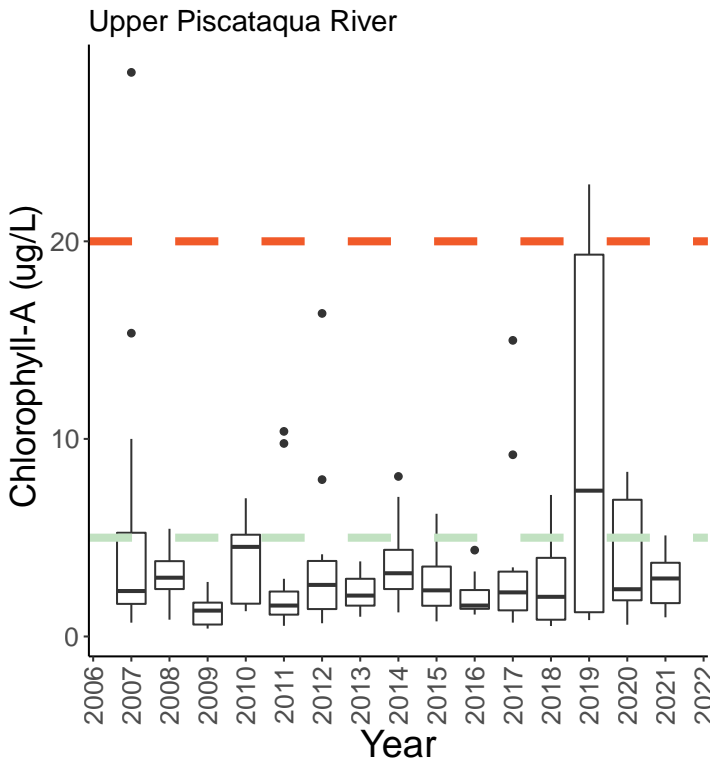


Figure 12.4: Box and whisker plot of chlorophyll-a data at the Upper Piscataqua River Station (low tide only) from 2007-2021. Boxes encompass the middle 50% of the data points. The horizontal line in each box is the median and the vertical whiskers encompass the remaining data. "Outliers" are shown as individual points. In general, measurements below the green dashed line at 5µg/L reflect better water quality. Measurements between 5 and 20µg/L are "moderate" and measurements above the red dashed line (20µg/L) indicate poorer water quality. There was no statistical trend.

Data source: Jackson Estuarine Laboratory, UNH

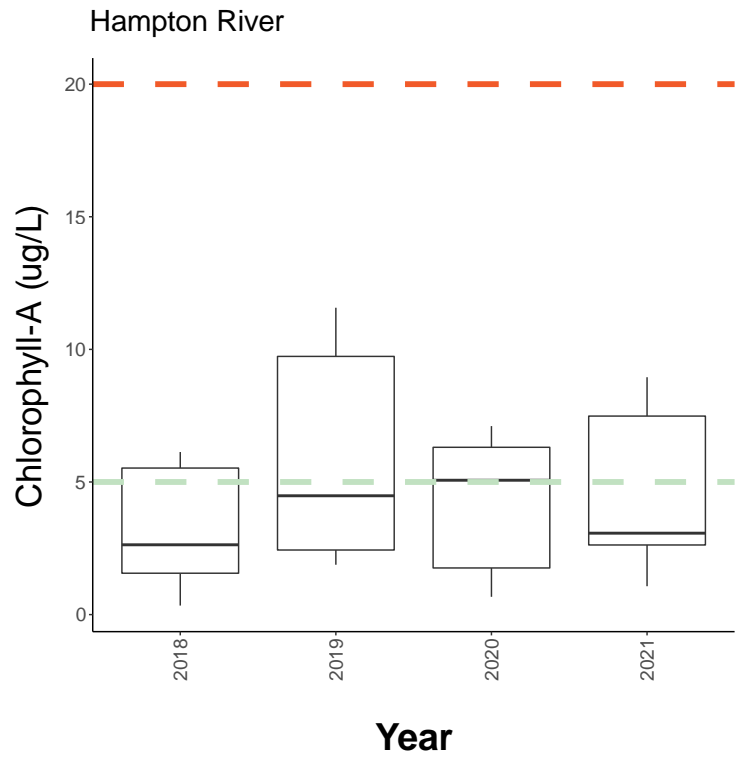
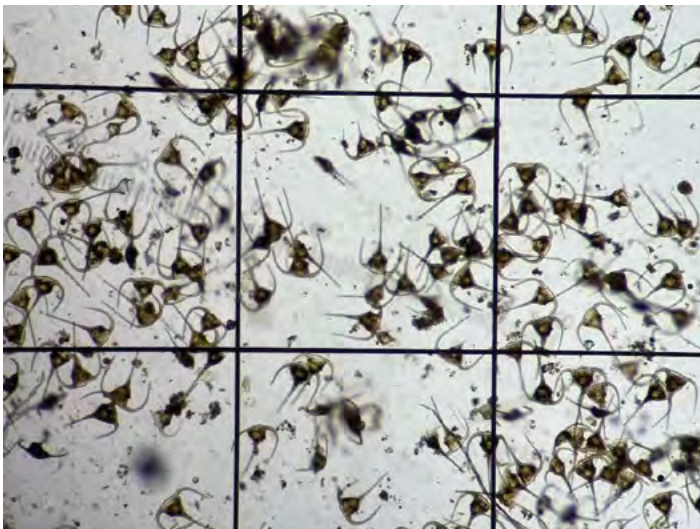


Figure 12.5: Box and whisker plot of chlorophyll-a data at the Hampton River Station (low tide only) from 2018 to 2021. Boxes encompass the middle 50% of the data points. The horizontal line in each box is the median and the vertical whiskers encompass the remaining data. "Outliers" are shown as individual points. In general, measurements below the green dashed line at 5µg/L reflect better water quality. Measurements between 5 and 20µg/L are "moderate" and measurements above the red dashed line (20µg/L) indicate poorer water quality. There was no statistical trend.

Data source: Jackson Estuarine Laboratory, UNH



Cells of *Ceratium longipes* from water sampled in April of 2023 off the coast of New Castle, NH. Photo by Eric Schroeder, Shellfish Program Volunteer.

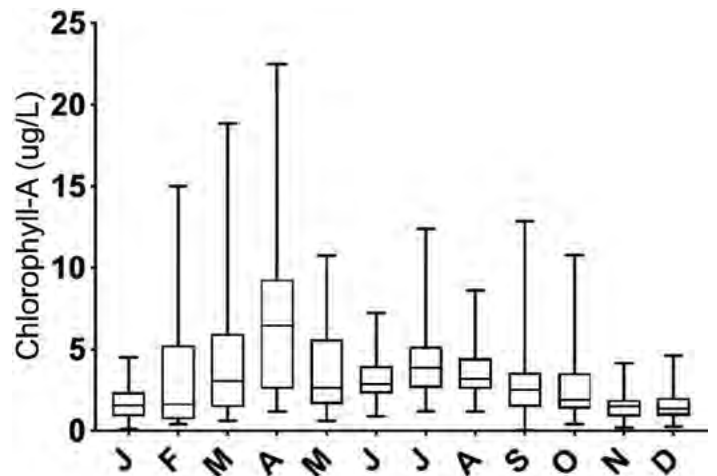
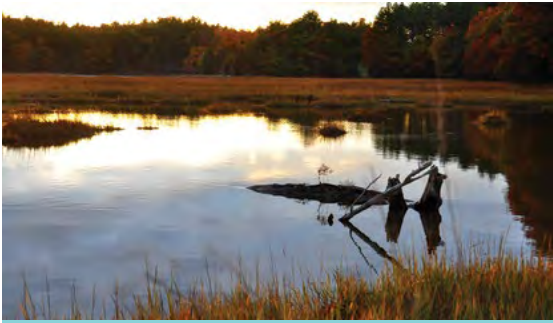


Figure 12.6: Monthly mean of chlorophyll-a concentration at the Adams Point Station (both low and high tide samples). This dataset runs from 1998 – 2020. The line within each box is the mean across all years examined, and whiskers encompass the minimum and maximum values.

Data source: Jackson Estuarine Laboratory, UNH

Total Suspended Solids



How have total suspended solids in both estuaries changed over time?

Total Suspended Solids (TSS) at Adams Point had a statistically significant increasing trend since monitoring began in 1989 across both high and low tide sampling. At the Great Bay Station, TSS concentrations had no temporal trend, remaining consistent since 2002. At low tide, both the Adams Point and Great Bay Stations had decreasing levels over 2019, 2020, and 2021. At the Hampton River Station in 2021, total suspended solids concentrations were at medium levels: higher than some Great Bay Estuary stations but lower than others. The level of suspended solids in an estuary, and thus the clarity of its waters, varies with the tides, rainfall, regional development, an increase or decrease in shoreline vegetative buffers, and a host of other factors.

Goal

No increasing trends for total suspended solids.

Why We Track This Indicator

Total suspended solids are particles suspended in the water column measured as the dry weight of particles filtered from a known volume of water. They can consist of phytoplankton or pieces of plant matter, but most total suspended solids are generally made up of inorganic particles, such as sediment. Sources of suspended solids include erosion from streambanks, salt marshes, and the upland portion of the watershed. Surface water inflows, stormwater runoff, and wastewater treatment effluent all can deliver total suspended solids to estuaries. In addition to external sources of suspended solids, they can also originate from resuspension within an estuary. Increasing suspended sediments reduces water clarity and light availability for primary producers such as eelgrass, seaweeds, and phytoplankton. High total suspended solid values can also negatively impact oyster feeding and the aesthetic value of our estuaries.

Explanation

The Adams Point Station has the longest time series dating back to 1989. Since that time, total suspended solids have statistically increased, but concentrations appear to be decreasing in recent years (Figure 13.2). Median annual low measurements at Adams Point over the last three years (2019–2021) are all lower than the six preceding years. The Upper Piscataqua River Station has a similar pattern, with recent years showing a plateau in total suspended solids concentrations (Figure 13.3).

Broadly, Table 13.1 demonstrates clearly that total suspended solid concentrations have increased around the Great Bay Estuary over the past two decades, with most of the stations indicating statistically increasing trends. For the Hampton-Seabrook Estuary, data on total suspended solids has only been collected for the period 2018 through 2021. During that time, values have been comparable to the Great Bay Station, ranging between 18.3 and 23.2 mg/L (Figure 13.4).

Location	Significant change in TSS concentration?	Dates for Trends in Column to Left	Range of Median Values 2016 – 2021 (mg/L)
Adams Point	Yes ↑	1989 – 2021	15.7 – 21.6
Great Bay	Yes ↑	2002 – 2021	16.1 – 23.2
Lamprey River	Yes ↑	1992 – 2021	3.6 – 16.1
Oyster River	Yes ↑	2004 – 2021	17.6 – 36.8
Squamscott River	No	2002 – 2021	29.0 – 54.1
Upper Piscataqua River	No	2007 – 2021	12.0 – 14.2
Hampton River	No	2018 – 2021	18.9 – 22.1

Table 13.1: Total suspended solids (TSS) trends and median values at six stations in the Great Bay Estuary and one station in the Hampton-Seabrook Estuary. Trends and values reflect low tide sampling only.

Data source: Jackson Estuarine Laboratory, UNH

At the Great Bay Station, since 2002, suspended solids have remained relatively stable, with a low tide median concentration of 17.1 mg/L for the entire record. The observed statistical increase in suspended solids at the Great Bay Station is likely driven by the eight measurements that exceed 50 mg/L since 2015. Despite the increasing trend, the median concentration decreased in 2021 to 18.3 mg/L (Figure 13.5). The median concentration in 2021 exceeded that of Adams Point (17.9 mg/L).

For context, consider that values over 15 mg/L are often cited as being very challenging for the health of eelgrass.⁴¹ When concentrations are regularly above 15 mg/L, light is blocked and eelgrass cannot photosynthesize, while seaweeds and phytoplankton continue to thrive since they have lower photosynthesis requirements. For more on total suspended solids and eelgrass, see “Light.”

High suspended solids concentrations also have the potential to harm oysters. Oyster monitoring efforts indicate that oyster reefs that are not built high enough above the estuary floor can be smothered by sediment deposits.

As is often the case with estuarine science, there is a range of conditions that are optimal for ecosystems. For example, some light scattering by total suspended solids helps phytoplankton suspended in the water column receive sufficient light to grow. On the other hand, if the water is clearer, more light reaches the bottom, which benefits eelgrass. Thus, there is a “sweet spot” that balances the light available to phytoplankton—critical food for oysters and fish—with the light for benthic primary producers like seagrass.

Chemists, ecologists, hydrologists, and oceanographers are working together to understand the connections between the source and transport of sediments in our estuaries. For example, decreases in eelgrass and oyster habitats lead to greater resuspension of sediments, but sediments may also be added to the estuary from the surface water inflows or the estuary shores. At the same time, hydrologic and hydrodynamic drivers (e.g., changing climate patterns

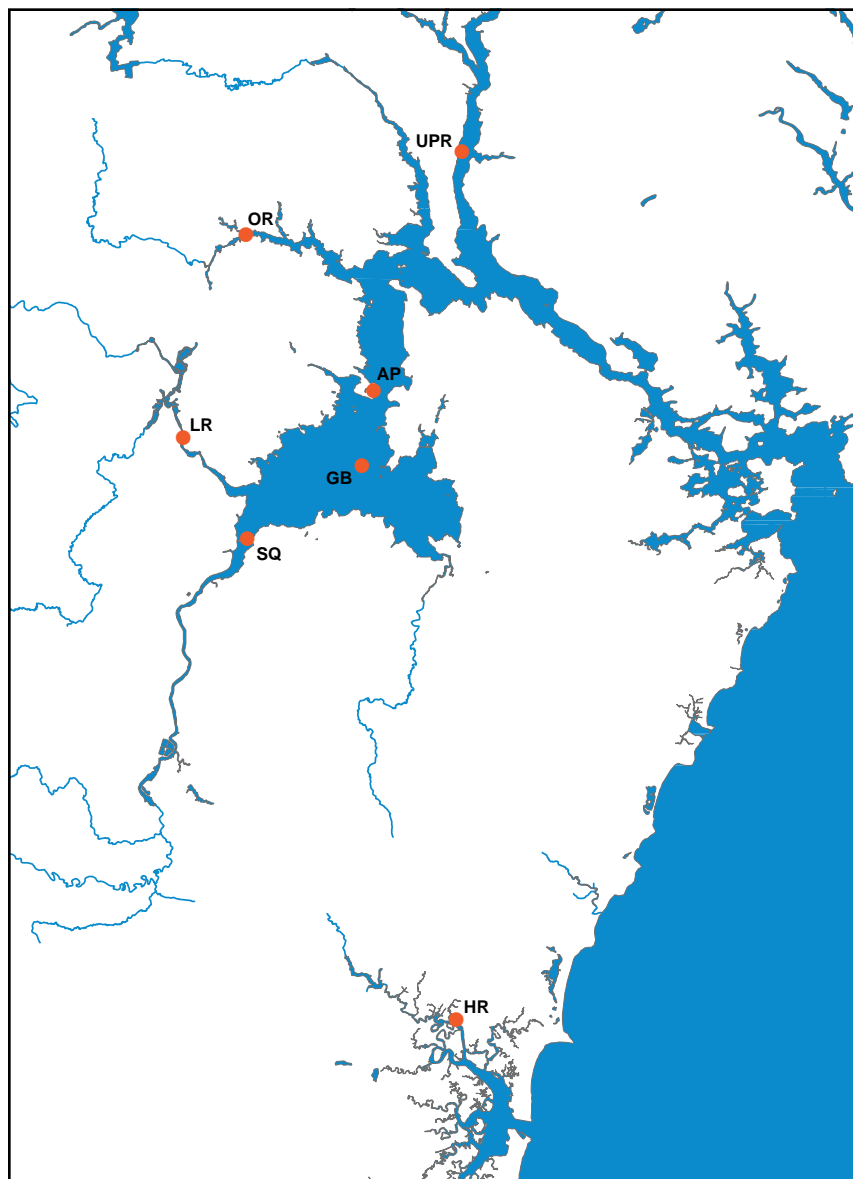


Figure 13.1: Monitoring stations for total suspended solids including Adams Point (AP), Great Bay (GB), Lamprey River (LR), Oyster River (OR), Squamscott River (SQ), Upper Piscataqua River (UPR), and Hampton River (HR).
Data source: Jackson Estuarine Lab, UNH

such as drought or record rainfall) can influence the delivery of total suspended solids from the surrounding watershed and the flushing of total suspended solids from the estuary. Finally, it is important to acknowledge that a certain amount of sediment transport from the watershed is necessary to maintain salt marsh elevations, and so is a key factor in determining salt marsh resilience to rising sea-level.

Acknowledgments and Credit

Anna Mikulis (UNH) with contributions from Miguel Leon (UNH), Kalle Matso (PREP), Easton White (UNH), Lara Martin (UNH), and Tom Gregory (UNH).

Extended Report

See the extended report for data on other stations.

Total Suspended Solids

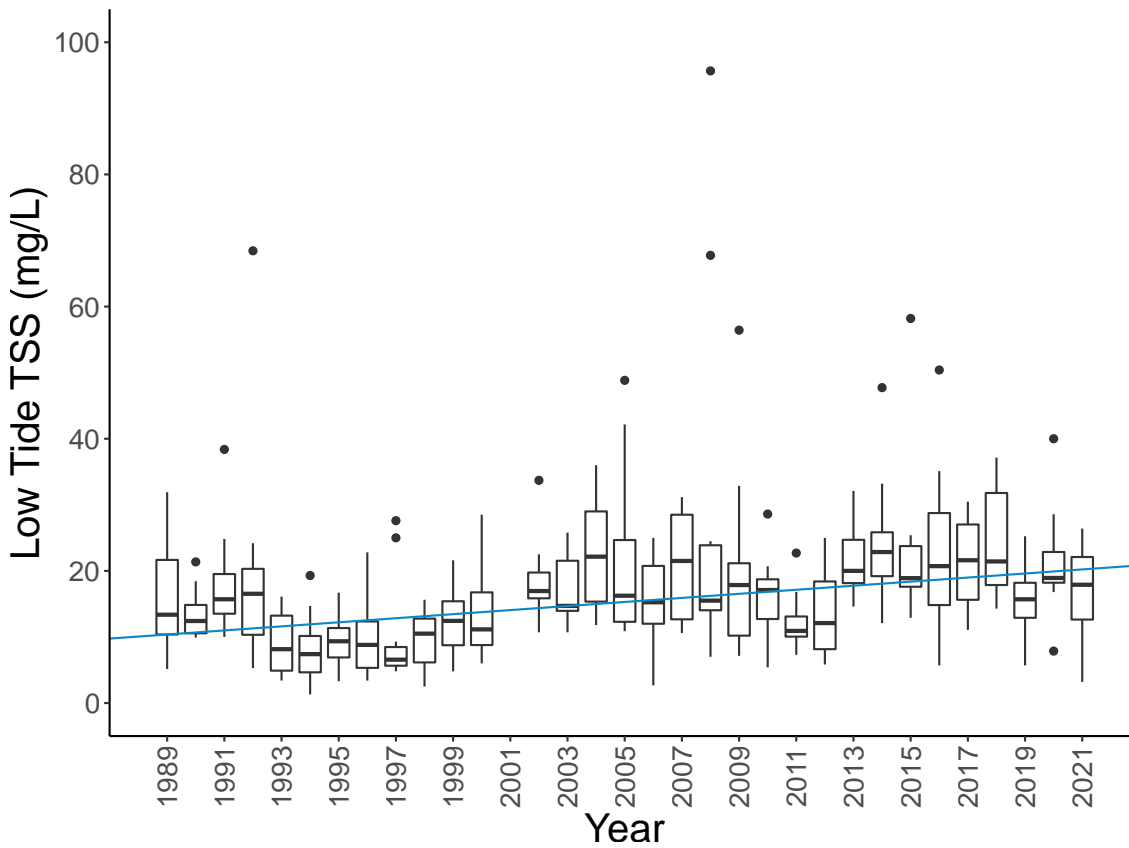


Figure 13.2: Total suspended solids (TSS) at Adams Point Station (low tide only). Boxes encompass the middle 50% of the data points. The horizontal line in each box is the median and the vertical whiskers encompass the remaining data. "Outliers" are shown as individual points. Year 2001 not included due to missing data. The linear regression represented by the blue line shows the statistically significant increasing trend in annual median TSS concentrations.
Data source: Jackson Estuarine Laboratory, UNH

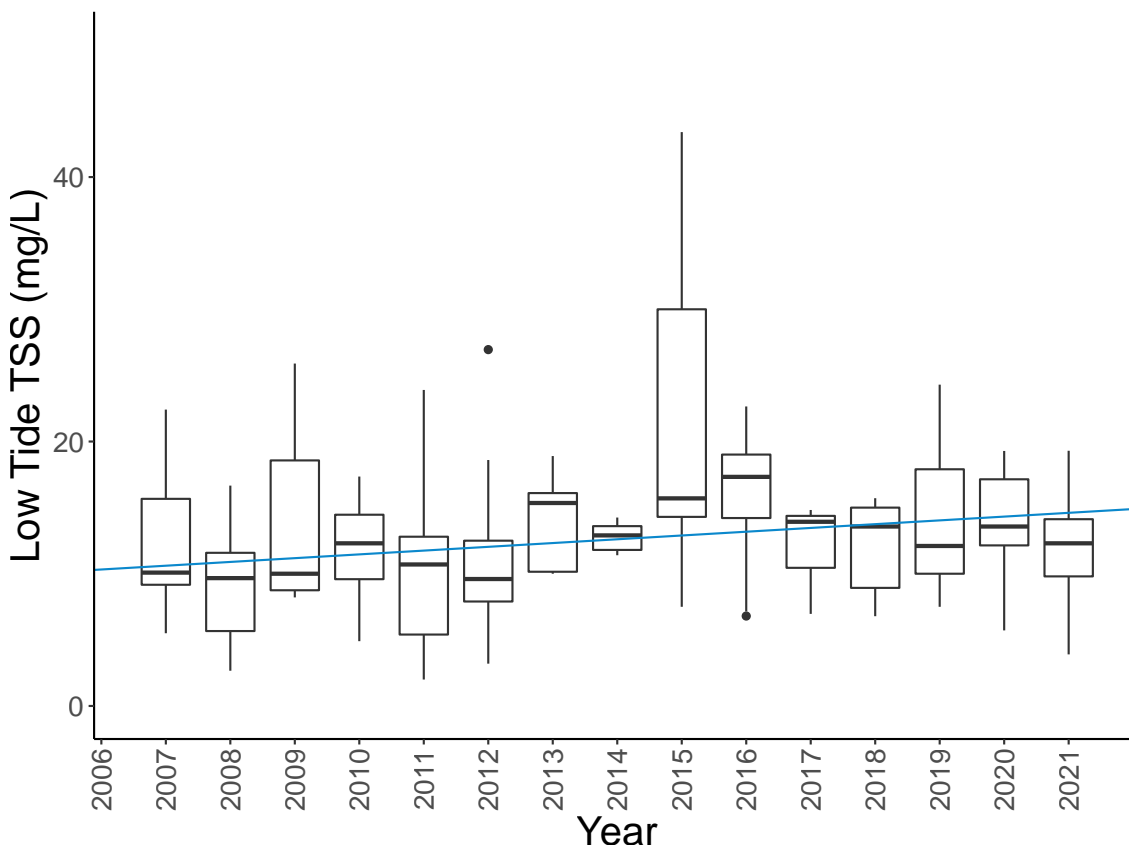


Figure 13.3: Total suspended solids (TSS) at Upper Piscataqua River Station. Boxes encompass the middle 50% of the data points. The horizontal line in each box is the median and the vertical whiskers encompass the remaining data. "Outliers" are shown as individual points. The linear regression represented by the blue line shows the statistically significant increasing trend in annual mean TSS concentrations.
Data source: Jackson Estuarine Laboratory, UNH

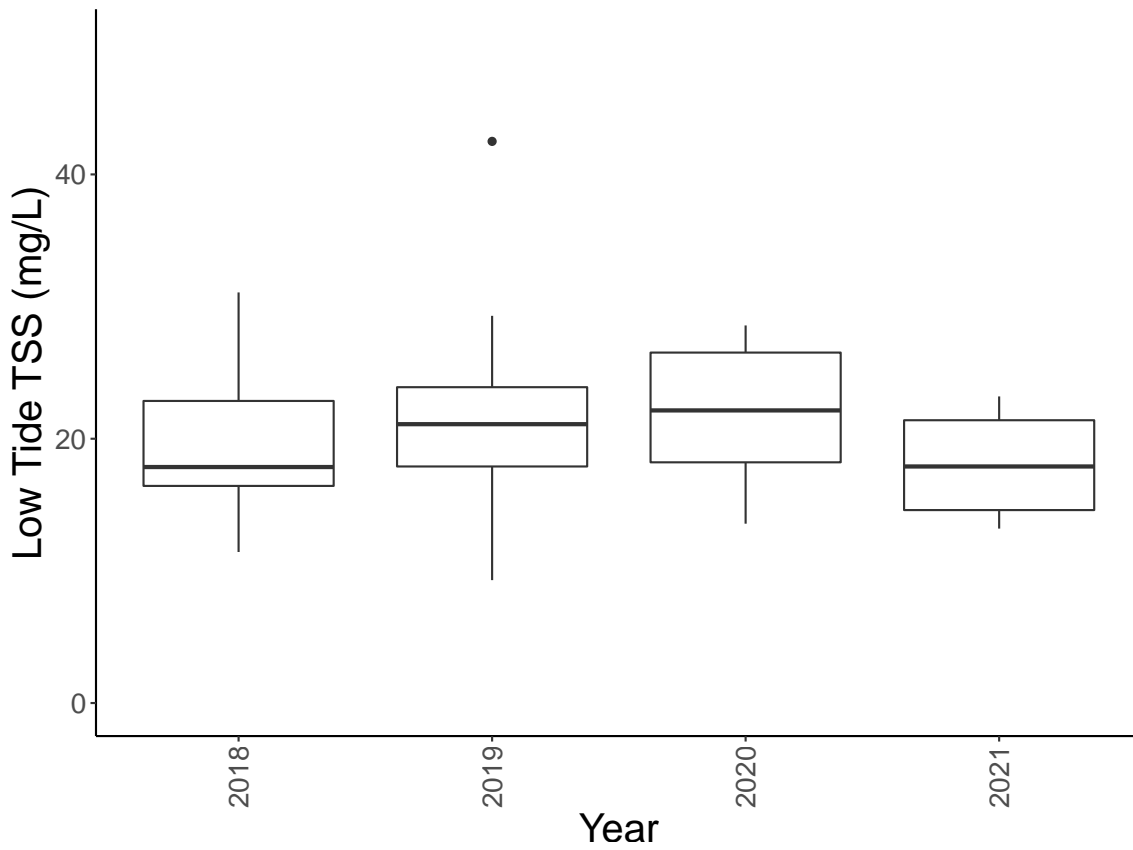


Figure 13.4: Total suspended solids (TSS) at Hampton River Station from 2018 to 2021. Boxes encompass the middle 50% of the data points. The horizontal line in each box is the median and the vertical whiskers encompass the remaining data. "Outliers" are shown as individual points. Data source: Jackson Estuarine Laboratory, UNH

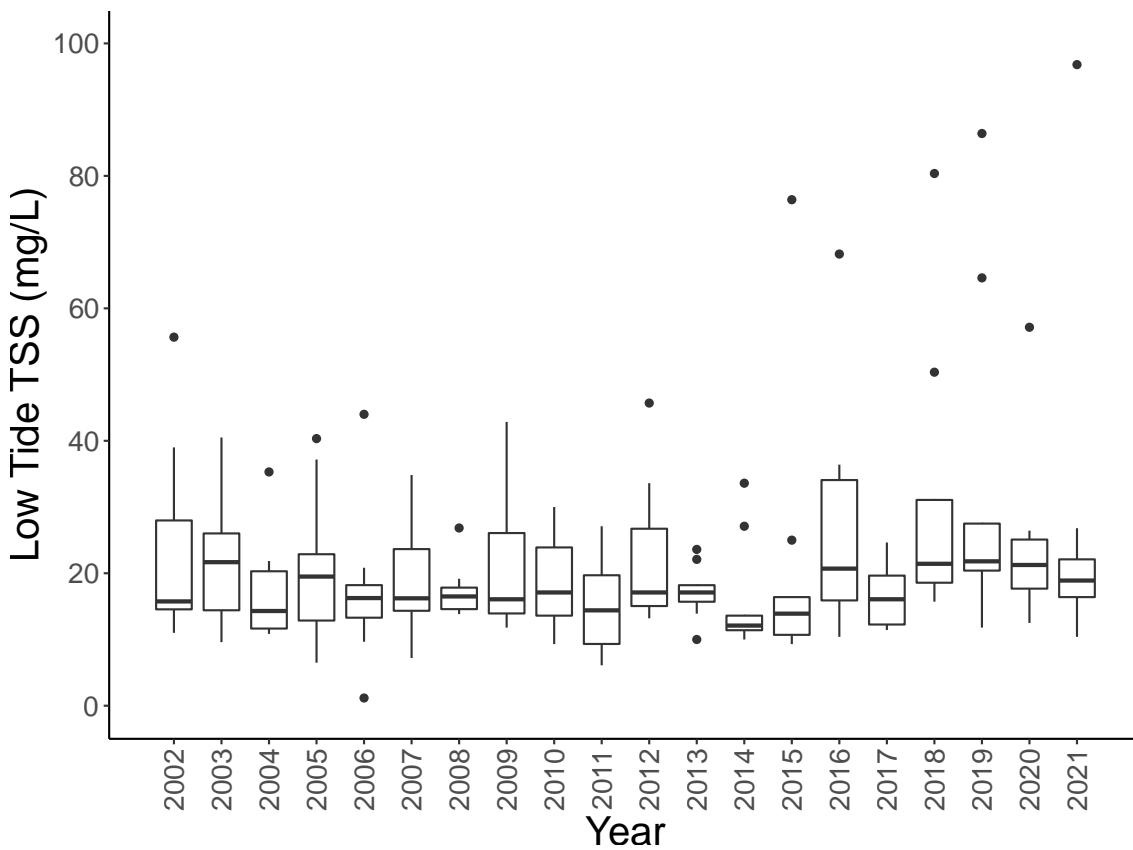


Figure 13.5: Total suspended solids (TSS) at Great Bay Station (low tide only). Boxes encompass the middle 50% of the data points. The horizontal line in each box is the median and the vertical whiskers encompass the remaining data. "Outliers" are shown as individual points. Data source: Jackson Estuarine Laboratory, UNH



What are the underwater light conditions and how have they changed over time?

As often happens in estuaries, light penetration is greater at the mouth of the Great Bay Estuary than in the upper portions of the estuary, where light frequently does not meet eelgrass requirements. At Adams Point, where data collection began in 2003, there is a statistically significant increasing trend in light attenuation (reduction) pointing to worsening light conditions. The two main constituents that attenuate light — total suspended solids and phytoplankton — have increased since 1988 at Adams Point, with total suspended solids decreasing in recent years. In the Hampton-Seabrook Estuary, light attenuation data has been collected since 2018, and values are comparable to Adams Point.

Why We Track Light

Underwater light conditions impact primary producers like eelgrass, seaweed, and phytoplankton. When the water has high concentrations of suspended material (e.g., plankton or sediments) and/or dissolved substances (e.g., colored dissolved organic matter, a.k.a. CDOM), light is “attenuated” (i.e., reduced), making survival more difficult for plants like eelgrass that need higher light levels than seaweeds and phytoplankton.

Explanation

This section focuses on the Great Bay Estuary due to the connection between light and eelgrass. Eelgrass habitat is not present in the Hampton-Seabrook Estuary, but light attenuation data has been collected there since 2018. Currently, light attenuation values at the Hampton River Station are comparable to the values in the Great Bay Estuary, described below.

It is well known that eelgrass in the Great Bay Estuary has struggled since its peak in 1996. Very often, eelgrass disappears because light conditions have degraded. This is worrisome because it could lead to an undesirable feedback loop, where less eelgrass leads to less stable sediments and reduced filtering of nutrients, which leads to worsening light conditions and the loop continues.

In the Great Bay Estuary, our longest time series of light data starts in 2003 at the Adams Point Station (Figure 14.1), and these data indicate a statistically significant increasing trend for light attenuation (Figure 14.2). “Light attenuation” or “Kd” refers to the loss of light as water gets deeper. So, low values indicate more light is penetrating deeper. There are no trends in light attenuation at other stations, possibly due to not having as many years of data. Unfortunately, none of our light attenuation data extend back to the time when eelgrass was more abundant (1996).



Eelgrass monitoring off of New Castle, NH in 2022, at approximately 17 feet of depth. The water is clearer near the coast when compared with Great Bay so eelgrass can grow at greater depths. Photo by Kalle Matso.

In 2009, the NHDES report, *Numeric Nutrient Criteria for the Great Bay Estuary* suggested a range of light attenuation values (0.5/m to 0.75/m) for the maintenance of existing eelgrass beds, depending on how deep the beds are.⁴² A peer review of this document noted that these attenuation targets could actually be too high — i.e., light attenuation needs to be less, so more light penetrates the water column — given that eelgrass loss has already occurred, and that better conditions are required for recovery as compared with “maintenance.”⁴³ For the deeper beds (~3 m) in Portsmouth Harbor, lower light attenuation (i.e., higher penetration) is necessary because the light has to travel through more water to reach the eelgrass. For the meadows in Great Bay proper, light attenuation values as high as 0.75/m were deemed acceptable because the plants are only expected to grow in water 2 m deep.

In Portsmouth Harbor, between 2004 and 2017, the median light attenuation value is 0.61/m. In the Upper Piscataqua River, between 2007 and 2020, the median value is 1.30/m. At Adams Point (Figure 14.2), between 2003 and 2021, the median light attenuation value is 1.2/m, and very few data points in recent years are below the threshold of 0.75/m. The high number of data points above 1.0/m and approaching 2.0/m suggests that light is a serious concern in terms of eelgrass recovery and perhaps even for basic maintenance of current levels.

Given the concern about light, the next step is to look at the things that can attenuate light in the Great Bay Estuary. The three main controls of light in estuaries are total suspended solids, chlorophyll-a (a proxy for phytoplankton), and colored dissolved organic matter. By looking closely at the levels of these constituents at various places in the Great Bay Estuary, managers can see what changes they will need to make to improve light conditions for eelgrass. Usually, phytoplankton is the most amenable to change through control of nutrients, even if it is not the highest attenuator of light. Colored dissolved organic matter is more difficult to manage as it is mostly derived from decomposing leaves and other plant material delivered by rivers. For these reasons, phytoplankton management thresholds are often lower for systems with higher total suspended solids values.

Adding more complications to an already complex topic, it is important to understand that light can be attenuated in other ways (Figure 14.3). “Epiphytes” — algae or plant matter that grow on other plants — often grow on the eelgrass blades, especially when grazers are not abundant or nutrients (e.g., nitrogen) are high. Also, seaweeds can grow inside, around, and on top of



Figure 14.1: Monitoring station for light at Adams Point (AP)

Data source: Jackson Estuarine Lab, UNH

eelgrass beds, blocking light and adding organic matter to the sediments. In the estuaries around Prince Edward Island, Canada, for example, scientists found that eelgrass was impacted by seaweed proliferation, fueled by nitrogen from agricultural runoff. However, light attenuation measured in the water column never changed.

Total suspended solid levels have been declining in recent years while there was no clear pattern in phytoplankton levels (see “Total Suspended Solids” and “Phytoplankton”). In 2021, a 3-year project began with the goal of better understanding the relationship between nutrients and sediments and how these constituents relate to light, eelgrass, seaweeds, phytoplankton, and epiphytes.

Acknowledgments and Credit

Kalle Matso (PREP) with contributions from Lara Martin (UNH).

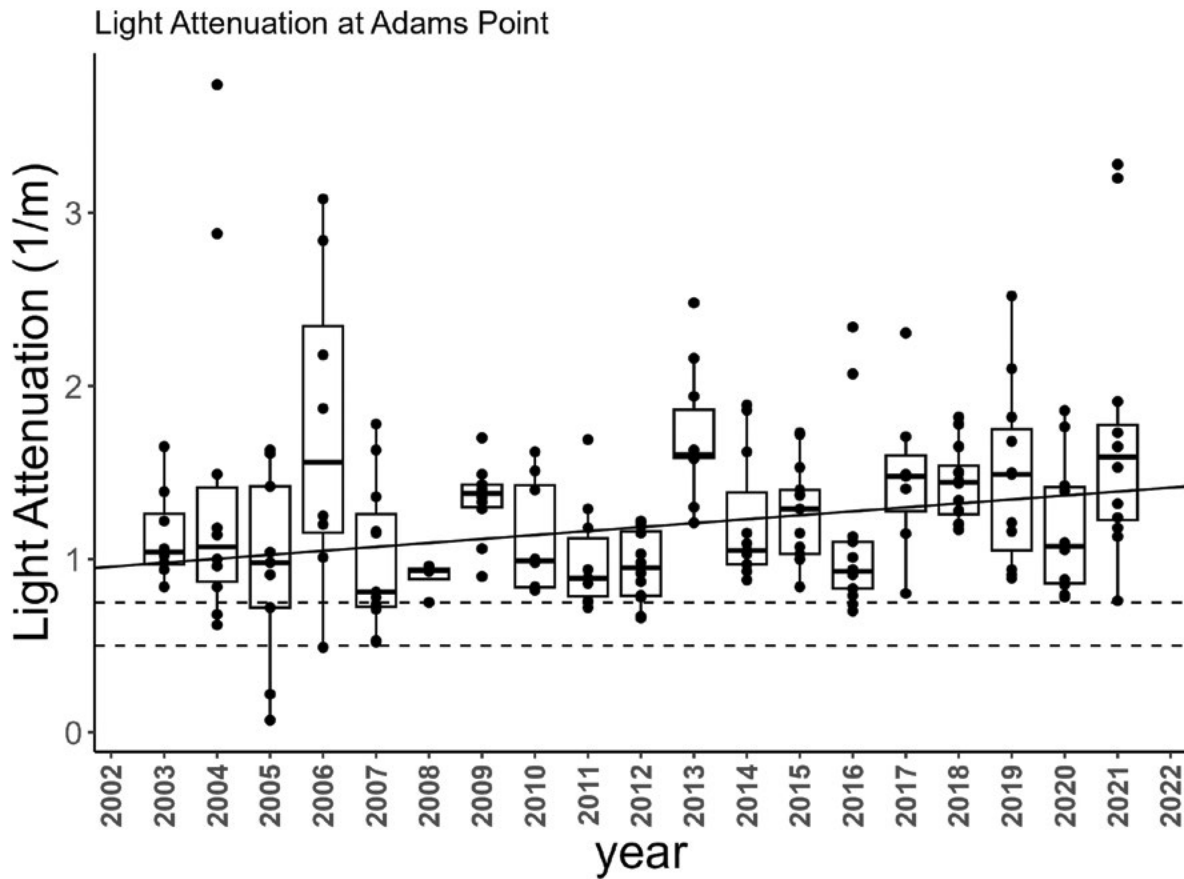


Figure 14.2: Light attenuation (K_d) data at Adams Point, 2003 through 2021. Data are log-transformed and include a mix of high and low tide samples, with all samples taken between April 1 and August 30 of the given year. Boxes encompass the middle 50% of the data points. The horizontal line in each box is the median and the vertical whiskers encompass the remaining data. "Outliers" are shown as individual points. Lines at 0.5/m and 0.75/m refer to suggested range of light attenuation values for the maintenance of existing eelgrass beds. The trend line indicates a statistically significant increasing relationship over time.

Data source: Jackson Estuarine Lab, UNH



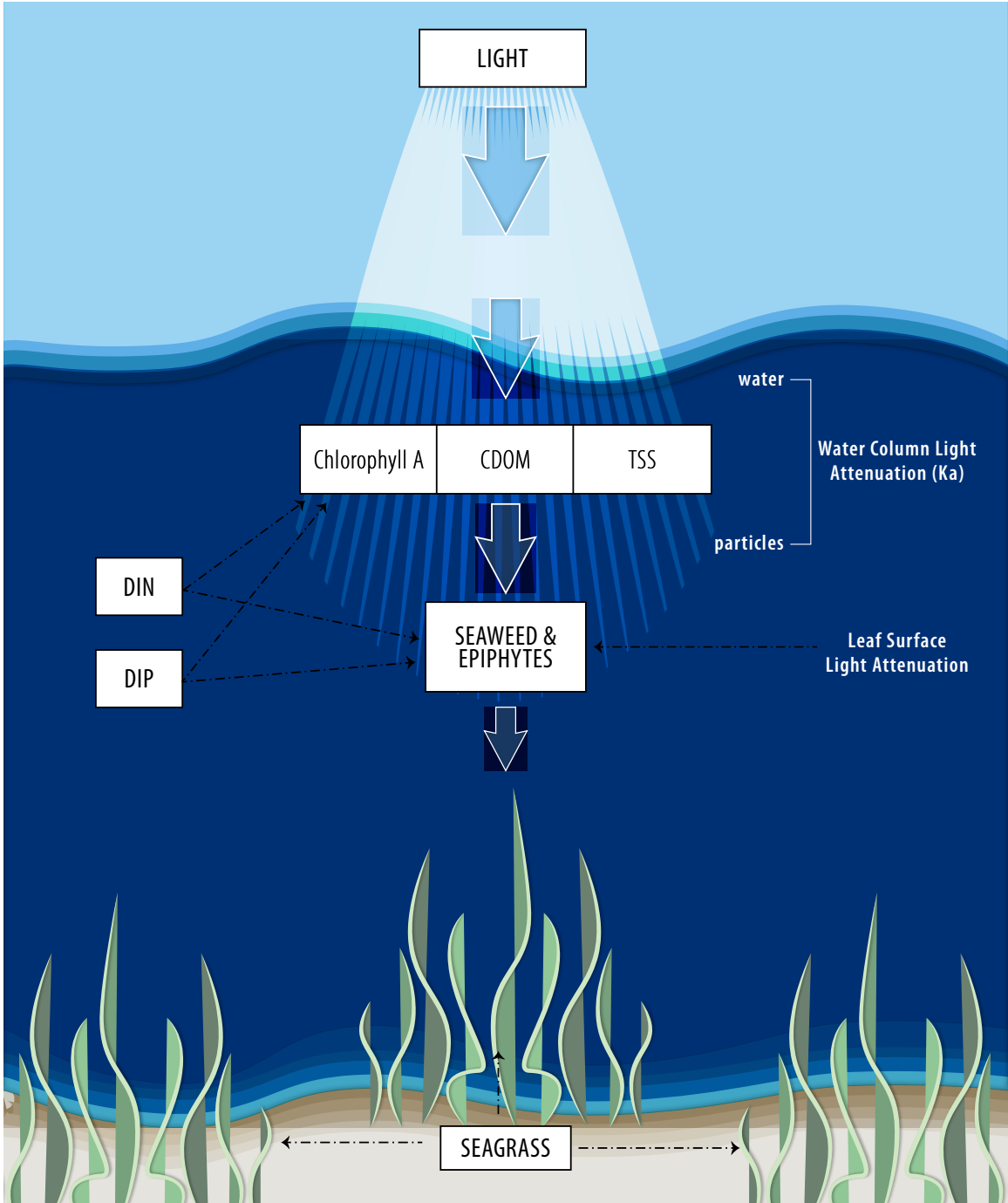


Figure 14.3: This image, adapted from the Long Island Sound Study, "Habitat Restoration Initiative," illustrates the interactive effects of nutrients and living resources on light penetration including Dissolved Inorganic Nitrogen (DIN) and Dissolved Inorganic Phosphorus (DIP), Colored Dissolved Organic Matter (CDOM), and Total Suspended Solids (TSS). Grazers include fishes and invertebrates that feed on the algae that can grow on eelgrass leaves.
 Data source: Long Island Sound Study

Bacteria



How have concentrations of bacterial indicators of fecal contamination changed over time in the Great Bay Estuary?

Tracking data from bacterial indicators suggest that ongoing management actions within the watershed have reduced levels of fecal contamination. Over the long-term (1988 to present), bacterial indicator levels have decreased estuary-wide; however, there have been no significant trends at the routinely monitored sites over the past six years. Monitoring for bacteria in the Hampton-Seabrook Estuary is currently being developed and will be included in future reports.

Goal

No increasing trends for fecal coliforms, enterococci or *Escherichia coli* bacteria.



Why We Track This Indicator

Activities such as shellfish harvesting and swimming depend on safe water quality, which is tracked by measuring concentrations of bacterial indicators of fecal contamination. These water quality indicators are affected by point and non-point pollution, human (sewage) and non-human (animal) sources of pollution, environmental conditions, and climate change. Tracking these indicator organisms allows for evaluation of water quality relative to potential risks for human illness.

Explanation

Long-term data for tracking baseline (dry weather) trends in fecal indicator bacteria are only available for two currently monitored sites, Adams Point and the Lamprey River (Figure 15.1). At both sites, the long-term trends for enterococci, fecal coliforms, and *E. coli* have decreased since the last report, issued in 2018. This can be attributed, in part, to improved stormwater infrastructure and wastewater treatment at all facilities in the watershed. There was a significantly decreasing trend in the annual average concentration data



(1988 – 2021) of fecal coliforms at Adams Point (Figure 15.2). Enterococci concentrations in the Lamprey River have significantly decreased from 1990 – 2021 (Figure 15.3).

The monitoring protocol is set up to assess baseline conditions and so it avoids wet weather, known to cause elevated contamination levels in the Great Bay Estuary.⁴⁴ However, since our region is forecast to receive more extreme precipitation events, these data do not reflect typical conditions, but rather, dry conditions.

State standard concentrations are included for each graph in Figures 15.2 and 15.3 as a reference, though the analysis procedures used for these data are slightly different than those required for assessing water quality classifications. Recent (2016 – 2021) levels of fecal coliforms at Adams Point (less than 5 colony forming units/100 mL) and enterococci levels in the Lamprey River (less than or equal to 24 colony forming units/100 mL) have, on average, remained below these reference concentrations, indicating acceptable quality. Generally, fecal indicator bacteria are present at elevated levels in estuarine tributaries that include urban centers at the head-of-tide, where there are more non-point sources, making the origin of pollution difficult to pinpoint. Head-of-tide urban centers may also have wastewater treatment facility discharges and significant impervious surfaces that cause runoff and increased stormwater-related contamination.

Excessive fecal indicator bacteria levels can be managed in various ways, informed by additional laboratory tests — microbial source tracking — that can identify the sources of the contaminating bacteria (e.g., humans, dogs, wildlife). This tracking tool can help managers identify a specific source so that the problem can be effectively addressed (e.g., replacement of a failed septic tank, education to manage pet waste). An ongoing study in the Lamprey River is using this tool to inform how best to ensure that river water quality is safe for recreational uses.⁴⁵

Other bacteria of public health concern include *Vibrio* and some other naturally occurring bacterial species that are not a result of fecal pollution. The dramatic increasing trend in illnesses over the past 15 years, including gastroenteritis and wound infections, caused by *Vibrio* species in the Northeast⁴⁶ is a regionally significant concern as coastal waters continue to warm.⁴⁷ *Vibrio parahaemolyticus* populations are increasing in the Northeast and in the Great Bay Estuary,⁴⁸ however, there have been only rare illnesses to date from exposure to New Hampshire coastal waters and shellfish.

Acknowledgments and Credit

Stephen Jones (NH Sea Grant/UNH).

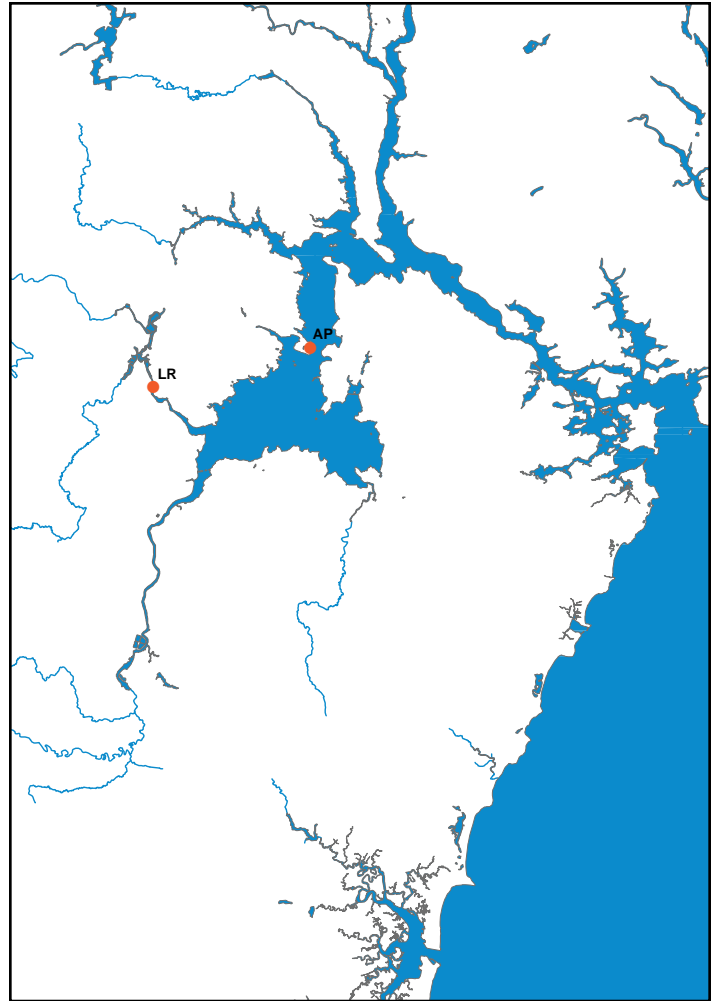


Figure 15.1: Monitoring stations for bacteria at Adams Point (AP) and Lamprey River (LR)
Data source: Jackson Estuarine Lab, UNH

Extended Report

Ongoing monitoring for *Vibrio* species has resulted in relatively long-term (2007 to present) databases for levels of *V. parahaemolyticus*, *V. vulnificus* and *V. cholerae* in oysters, water, plankton and sediments of the Great Bay Estuary. In addition, ongoing studies show what types of fecal-borne bacteria sources are present in the Lamprey River and in other coastal watersheds. See the Extended Report for summaries of both types of studies.

Bacteria

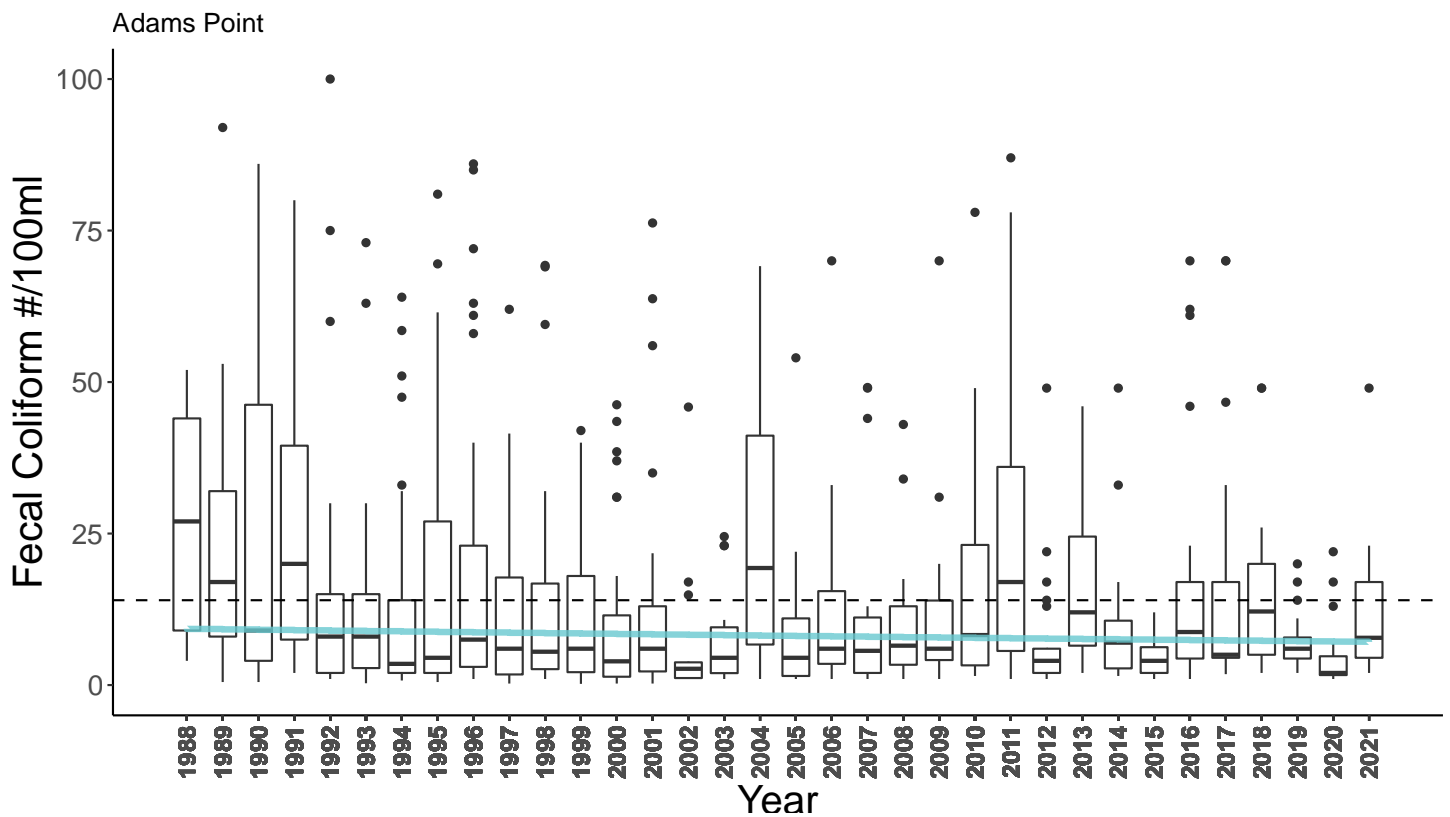
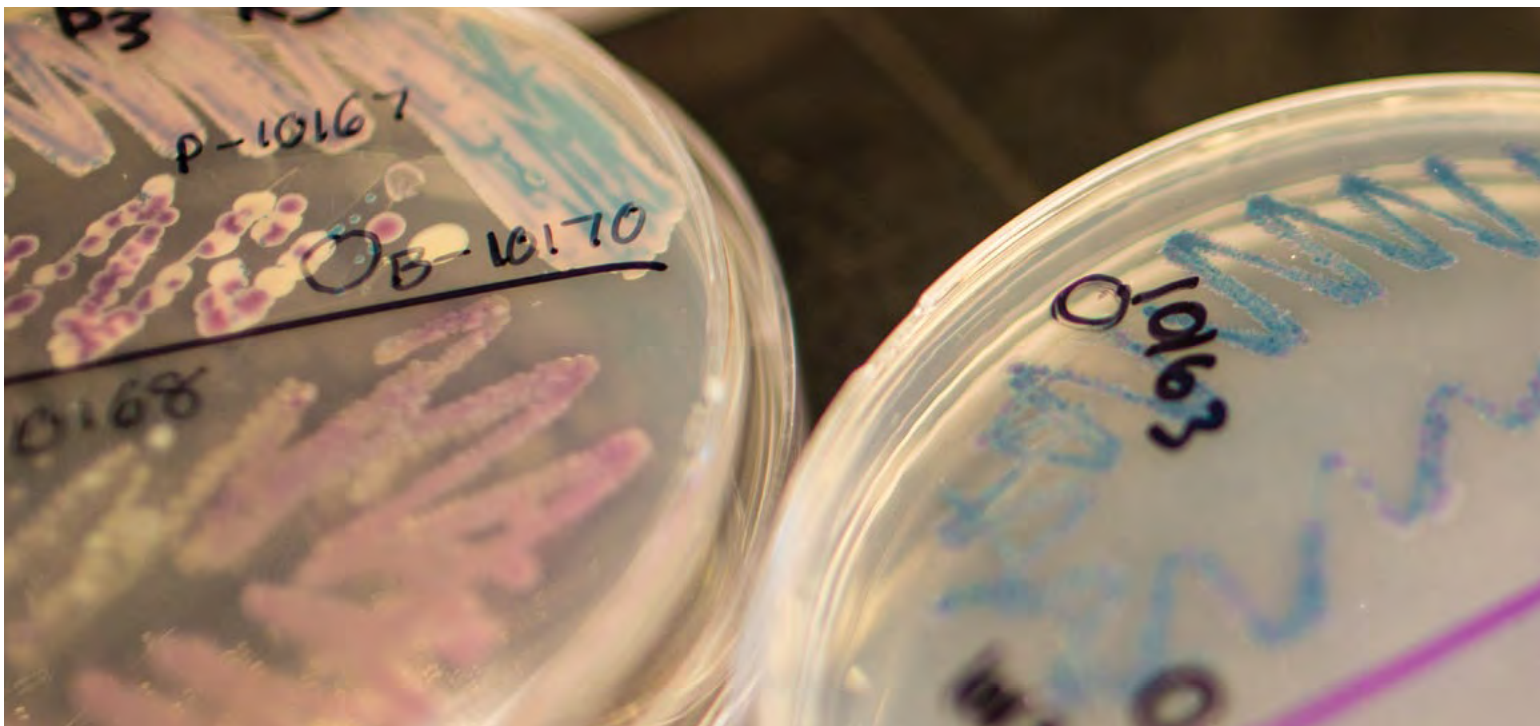


Figure 15.2: Long-term trends for monthly fecal coliform concentrations at Adams Point grouped by year. The dashed line shows the New Hampshire State standard for fecal coliforms (14/100 mL). Boxes encompass the middle 50% of the data points. The horizontal line in each box is the median and the vertical whiskers encompass the remaining data. "Outliers" are shown as individual points. The solid blue line indicates a statistically significant trend. The fecal coliform indicator, the standard for shellfish regulation, is used at this location due to the prevalence of shellfish harvesting in the area. Typically, nine samples are taken per year, from April through December.

Data source: Jackson Estuarine Laboratory, UNH



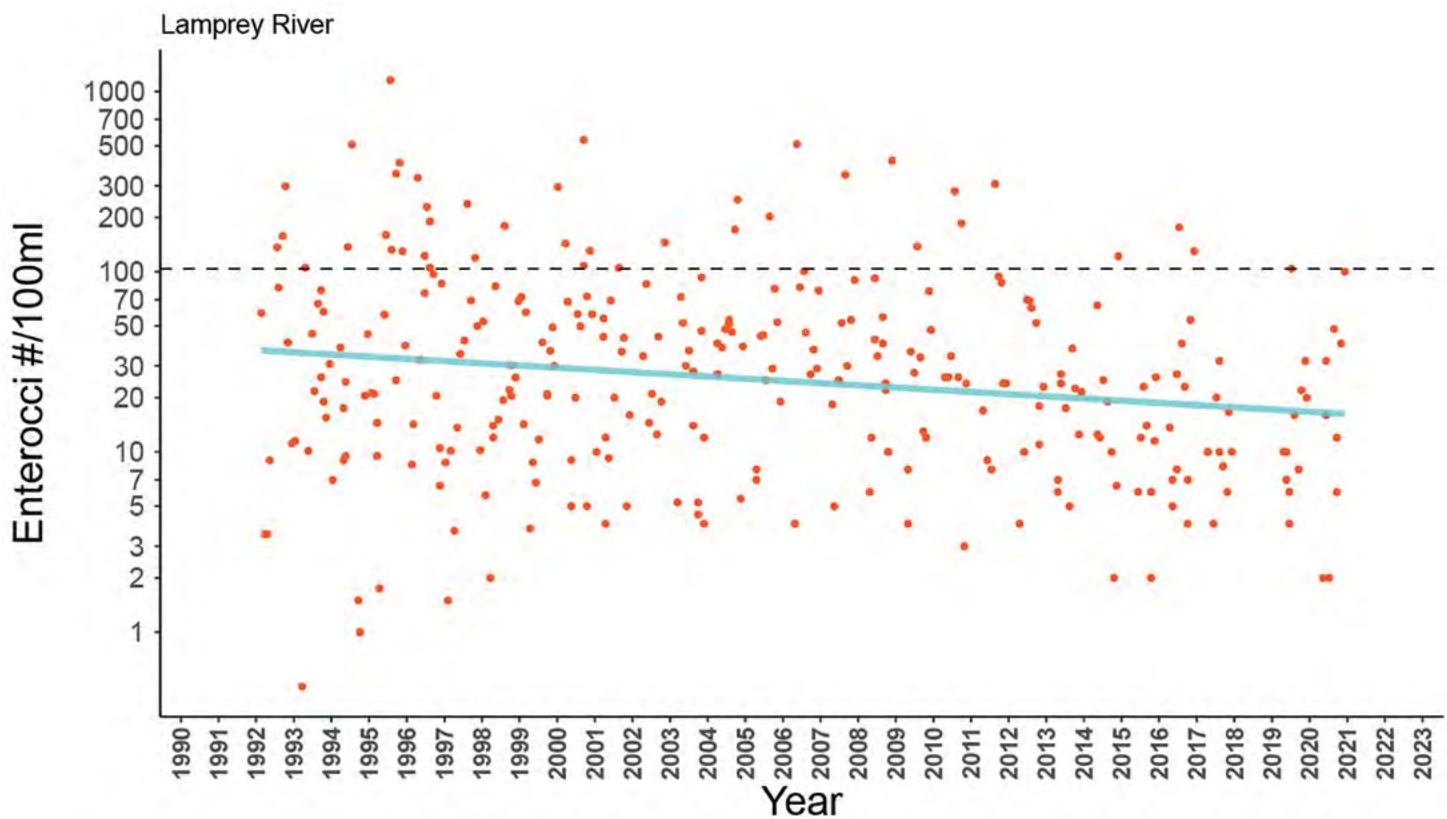


Figure 15.3: Long-term trends for monthly enterococci concentrations at the Lamprey River plotted on a log-scale, grouped by year. The dashed line shows the New Hampshire State standard for enterococci (104/100 mL). The blue line indicates a statistically significant trend. The enterococci indicator, the standard for marine recreation, is used at this location due to the prevalence of boaters, stand-up paddlers, etc. on the Lamprey River. Typically, nine samples are taken per year, from April through December.

Data source: Jackson Estuarine Laboratory, UNH



Shellfish Harvest Opportunities



What percentage of our estuaries are open for shellfish harvesting and how has this changed over time?

The percentage of possible acre-days when shellfish beds are open has been on a statistically significant, gradual upward trend from 2006 to 2021. Factors driving the upward trend in harvest opportunities in our estuaries include wastewater treatment facility upgrades, the opening of new harvest areas in Little Bay and the Oyster River due to expanded testing programs, better understanding of pollution dispersion by tidal currents, and improved management of risk related to potential boat sewage contamination. Increased harvest opportunities coincide with decreasing bacteria concentrations (see “Bacteria”), underscoring the effectiveness of management efforts.

Goal

Improve water quality and identify and mitigate pollution sources so that additional estuarine areas meet water quality standards for bacteria and for shellfish harvesting.

Why We Track This Indicator

Shellfish beds are closed — either temporarily or indefinitely — to commercial and recreational harvesting due to high amounts of bacteria or other pollutants in the water, as often occurs after heavy rainfall or accidental discharge of improperly treated sewage. Closures also occur for precautionary reasons related to wastewater treatment facilities. Therefore, the amount of time that shellfish beds are open for harvest can be used as an indicator of water quality as it relates to human health.

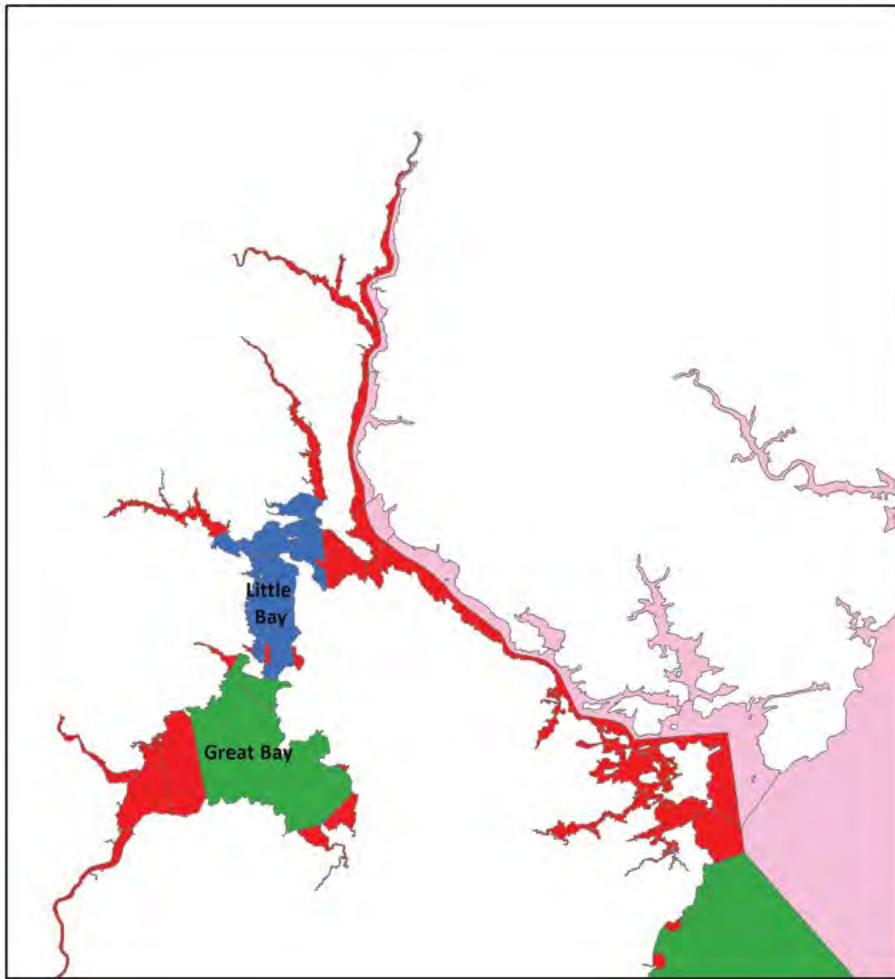
Explanation

Figure 16.1 indicates open and closed areas of the Great Bay and Hampton-Seabrook Estuaries for shellfish harvesting in 2021. The percentage of possible acre-days (i.e., the number of open acres multiplied by the number of days those acres were open for harvest) in 2021 was 82% for the Great Bay Estuary and 55% for the Hampton-Seabrook Estuary (Figure 16.2).

Shellfish areas often are closed as a safety measure, especially after heavy rainfall, because significant rain events often lead to increased pollution. In addition, operational problems, either at wastewater treatment facilities or in the sewer infrastructure, can lead to closures because of improper discharge of treated sewage. To re-open a shellfish area in these instances, New Hampshire Shellfish Program staff analyze water samples to ensure the number of fecal coliform bacteria meet established safety standards (see “Bacteria”). Samples of shellfish tissue also are analyzed for certain types of pollution events.

Less often, areas are closed due to the occurrence of harmful algae blooms, commonly known as “red tide.” Since 2000, red tides have been responsible for multiple day closures in nine different years. In some years, red tides may have occurred at times when the beds were already closed for conservation purposes; in those cases, they are not recorded as contributing to more closures.

Much of the Great Bay Estuary and Hampton-Seabrook Estuary data reflects the interannual variability of weather, with wet years leading to more numerous temporary harvest closures. The large number of closures in 2016 in the Hampton-Seabrook Estuary was the result of a significant discharge of raw sewage from a broken 14-inch sewer pipe under a salt marsh in the Town of Hampton. The long-term trend of gradual improvements since 2000 might reflect improved data collection and pollution source management by New Hampshire Department of Environmental Services, U.S. Environmental Protection Agency, and seacoast municipalities. Such efforts include programs to identify and eliminate illicit discharges, upgrade or build new wastewater treatment facilities, reduce wet-weather “combined sewer overflows” by expanding and upgrading sewer collection lines and pump-station capacity, and develop a more detailed understanding of individual wastewater treatment facility operations, effluent quality, and distribution patterns of pollutants in the receiving waters.

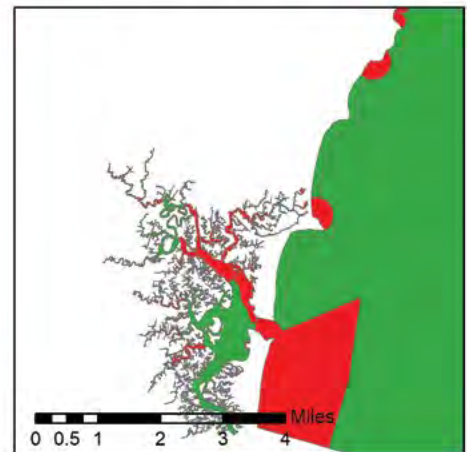


Recreational Shellfish Harvest Categories



For areas shaded in blue, harvest is allowed Saturdays only, 9:00am to sunset.

Temporary closures for heavy rain, red tide and other issues are implemented as needed in blue and green areas.



Maps Prepared May 2022

Figure 16.1: Map showing recreational shellfish harvest categories for both the Great Bay and Hampton-Seabrook Estuaries. Data source: NH Department of Environmental Services, Shellfish Program



Photo by Jerry Monkman

Shellfish Harvest Opportunities

The amount of area designated as conditionally approved — open but subject to temporary closures due to water quality issues — has remained relatively steady at around 5,300 acres in recent years (Figure 16.3). The drop in acres during 2014–2017 was based on results of the December 2012 Portsmouth Wastewater Treatment Facility Dye Study, which examined how the former treatment facility affected water quality in the estuary.⁴⁹ The earlier version of the facility employed a relatively simple sewage treatment process. At a total cost of over \$90 million, the new facility uses more modern sewage treatment technologies and treatment, resulting in more thoroughly treated effluent. Subsequent studies of effluent quality and seawater/shellfish microbiological indicators have allowed for some of the previous harvesting restrictions to be relaxed. In addition to the Portsmouth improvements, Exeter upgraded its wastewater treatment facility and significantly upgraded its sewage collection system — completed in 2020 at a total cost of \$53.5 million. As post-upgrade monitoring of water quality continues, shellfishing areas might be opened more frequently.

For the Hampton-Seabrook area, most of the closed areas (red areas in Figure 16.1) are safety closures due to the proximity to the outfalls for the Hampton and Seabrook Wastewater Treatment Facilities. The Town of Hampton facility relates to the red area within Hampton Harbor and the Town of Seabrook facility relates

to the area in the Atlantic Ocean, offshore of Seabrook Beach. The Seabrook facility releases its effluent 1,500 feet offshore via an underground pipe. Both facilities are modern systems that are functioning effectively with regard to effluent disinfection. However, the New Hampshire Shellfish Program maintains safety closures due to the contingency of a temporary system breakdown.

The two smaller red areas in Hampton and North Hampton are related to unexplained but occasional occurrences of very high fecal coliform bacteria, possibly caused by owners not picking up pet waste.

Maine waters, including areas of the Piscataqua River and Spruce Creek, are closed for harvest, partly due to concerns about the Portsmouth facility. The exception to this is Spinney Creek Shellfish in Eliot, Maine, which has a specialized facility for removing potential pathogens from shellfish. As ongoing studies document the positive water quality effects of the Portsmouth facility upgrade, the New Hampshire Department of Environmental Services and Maine Department of Marine Resources will reassess the public health risks and modify harvesting classifications in the areas under their jurisdictions.

Acknowledgments and Credit

Chris Nash (NH Department of Environmental Services, Shellfish Program)



Oysters in the Great Bay open up to filter phytoplankton from the water. Photo by Kalle Matso.

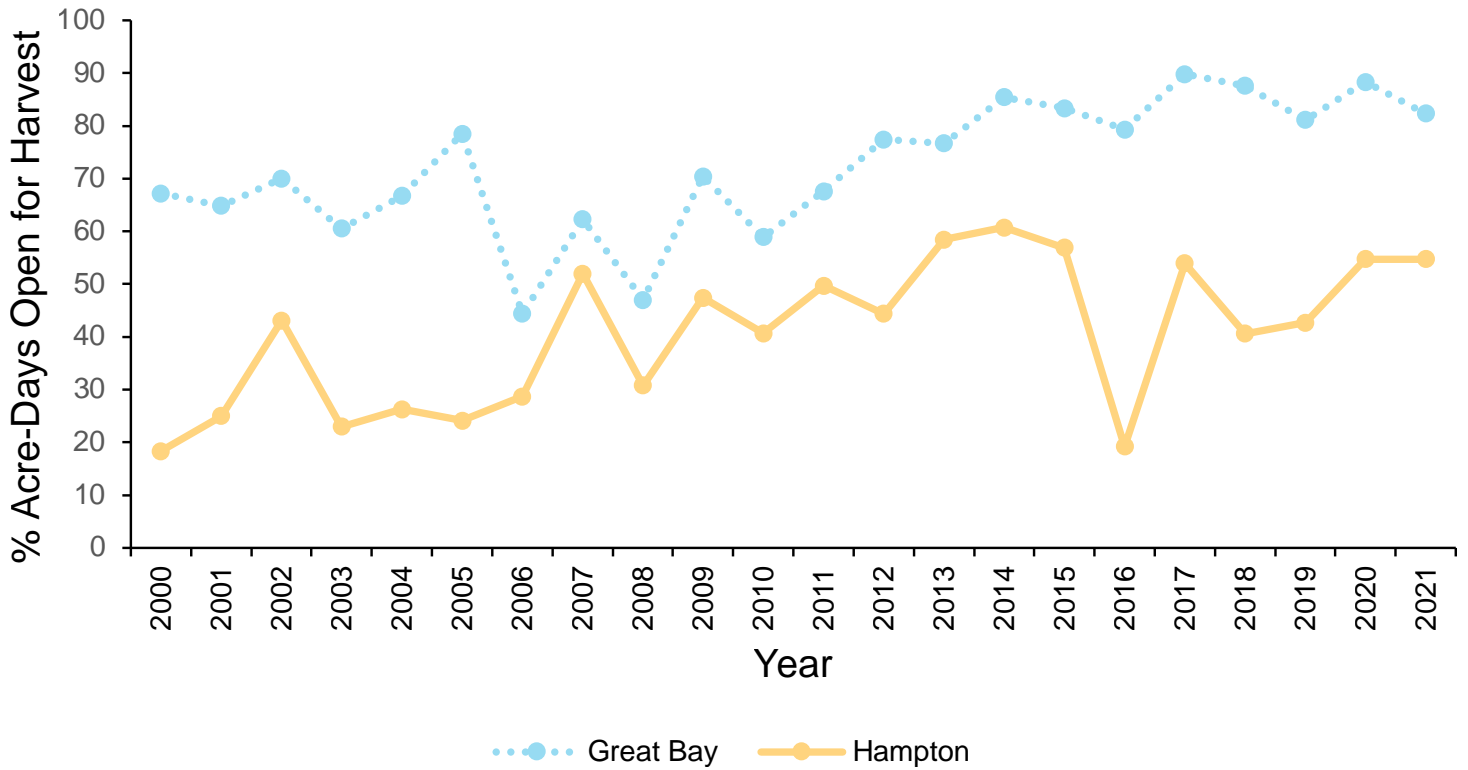


Figure 16.2: Shellfish harvest opportunities for Great Bay and Hampton-Seabrook Estuaries. Graph displays percentage maximum possible “acre-days,” which is the number of open acres multiplied by the number of days those acres were open for harvest.
 Data source: NH Department of Environmental Services, Shellfish Program

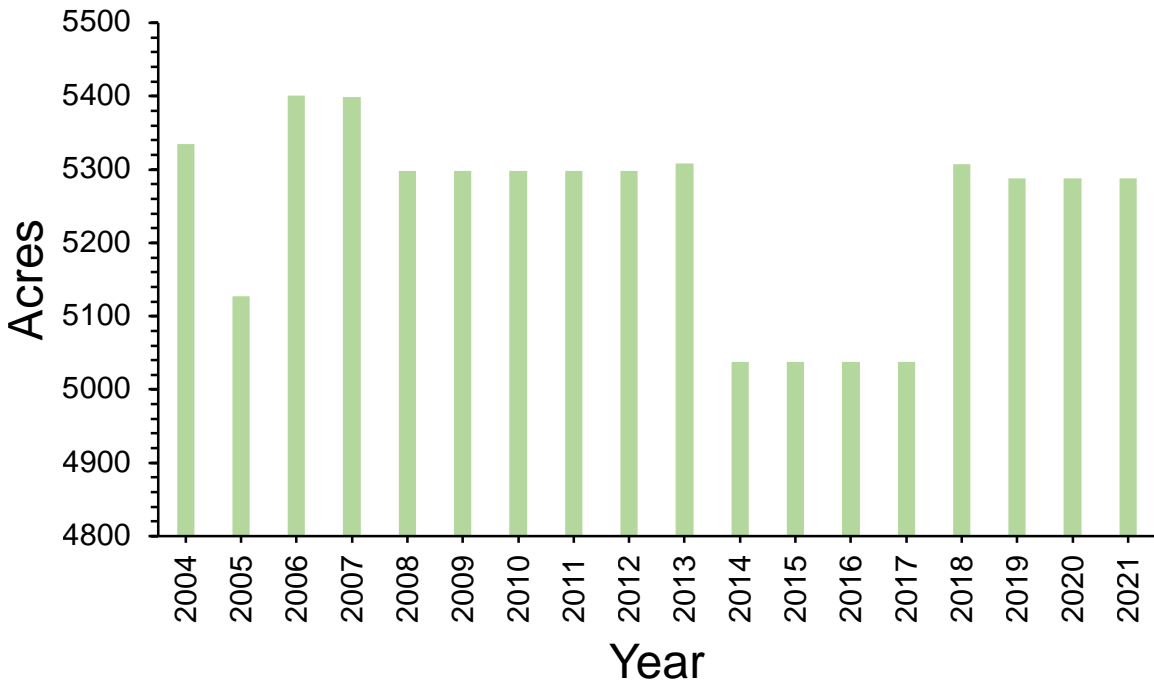


Figure 16.3: Trends in the acres of estuarine waters conditionally approved for shellfish harvest for years 2004 – 2021.
 Data source: NH Department of Environmental Services, Shellfish Program

Oysters, Oyster Restoration, and Oyster Aquaculture



OYSTERS

How many adult oysters are present on natural reefs in the Great Bay Estuary and how has the number changed over time?

The number of adult native oysters (*Crassostrea virginica*, the eastern or American oyster) decreased from >25 million in 1993 to ~1.2 million in 2000, a 95% loss (Figure 17.1). Annual sampling since 2000 had indicated <5 million were present each year until 2020 when oysters rebounded to 7.4 million on natural reefs. Additionally, oyster aquaculture has dramatically increased in the past several years and in 2021 there were nearly as many live oysters on aquaculture facilities as adult oysters on the natural reefs (see below).

Oysters Goal

Increase the abundance of adult oysters (that are greater than 80 mm in shell height) at the six regularly monitored oyster reefs in the Great Bay Estuary to 10 million by 2030. The previous goal was to reach 10 million by 2020; this was not met.

Why We Track This Indicator

Oysters support a recreational fishery and a rapidly growing aquaculture (farming) industry, and provide important ecosystem services. As filter feeders, they reduce phytoplankton biomass and other suspended particles, thereby increasing light penetration to benthic plants such as eelgrass. They also provide habitat for resident and migratory fishes and many other species. Since the early 1990s, as oyster populations in the Great Bay Estuary declined, the functions and services they provided also declined. However, substantial efforts are underway to restore oyster populations and the multiple roles they play in the estuary.

Explanation

Wild oysters mainly occur on subtidal reefs in the Great Bay Estuary but have been found in intertidal waters in recent years. The six major subtidal reefs are monitored annually providing abundant data for long-term assessments. Underwater video surveys in 2020 by UNH scientists indicated that the total area covered by live reefs was ~80 acres,⁵¹ compared to historical (1970s) estimates of “live oyster bottom” coverage ranging from 900 to 1,300 acres.⁵²

A major limitation on oyster health for the past 20 years has been disease caused by two microscopic parasitic organisms: Dermo (*Perkinsus marinus*) and MSX (*Haplosporidium nelsoni*). Both parasites are present in both wild and aquacultured oysters in the Great Bay Estuary.⁵³ Whereas MSX is in decline in the Estuary, Dermo, a warmer water parasite, has become more prevalent in the last decade, and is expected to be favored by warmer winters as climate change continues.^{54,55} In recent years, oysters have rarely grown past 115 mm in shell height. This suggests average longevity is now only 4 or 5 years rather than 10+ years as in the early 1990s, when oysters greater than 200 mm were common.

Oyster populations in the Great Bay Estuary also face challenges due to a lack of suitable substrate on which oyster larvae can settle. Oysters themselves provide hard substrate as they grow and increase in shell size, but less and less oyster habitat diminishes the available hard substrate for new recruits. This has been offset to some extent by deploying oyster and other mollusk shell — from restaurants and other sources — in key locations in the Great Bay Estuary (see “Oyster Restoration”).

Sedimentation is another stressor related to the issue of available substrate for new oysters to set. Sediments enter the estuary from run-off, eroding salt marshes and stream banks, and can be resuspended from the bottom sediments during storm events. With eelgrass and oyster habitats decreased from historic levels, sediments may be more easily resuspended following storms and high-flow periods. Oyster restoration monitoring has indicated that young reefs can be rapidly smothered by sediment in many areas.

Recreational harvesting of oysters also may be stressing the population. Although studies from other areas have shown that restricted harvesting can

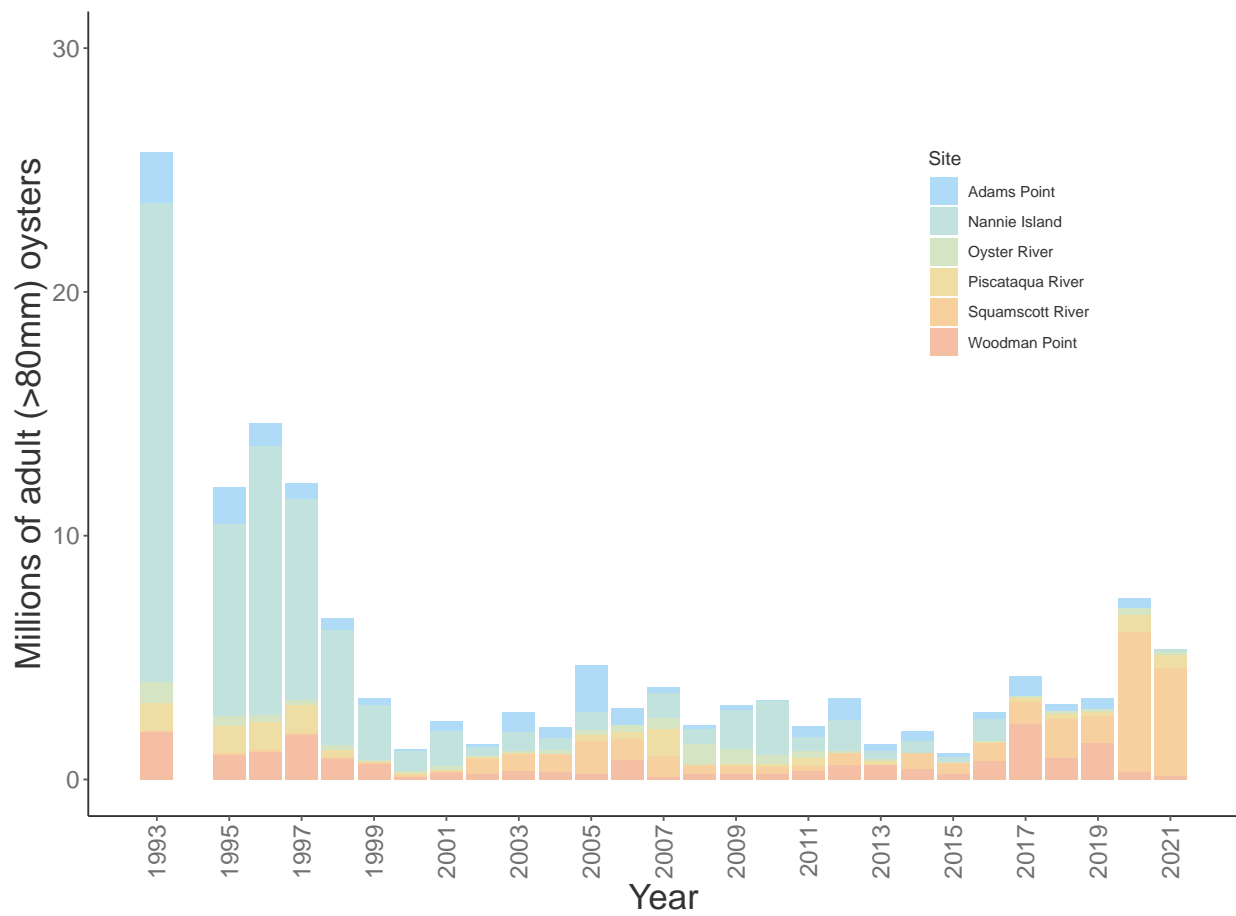


Figure 17.1: Number of adult oysters (>80 mm shell height) at the six regularly monitored natural reefs from 1993 – 2021. Data source: NH Fish and Game



Photo by Jerry Monkman

Oysters, Oyster Restoration, and Oyster Aquaculture

provide benefits through the resuspension and removal of sediment on reefs that are regularly harvested, there are no data that quantify the relationship between oyster harvest and sediment removal. In reaction to the Nannie Island oyster reef population decline (shown in Figure 17.1), the New Hampshire Fish and Game Department implemented a five-year harvest closure (2022–2026) of a 15-acre area covering a substantial portion of the Nannie Island oyster reef to encourage oyster growth and provide an opportunity for new restoration projects (Figure 17.2; see more discussion in “Oyster Restoration”).

In the past 10 or so years, eastern oysters have been documented in the intertidal zone in New Hampshire and Maine, and anecdotal evidence indicates this is a recent phenomenon likely related to climate change.⁵⁶ Rock outcrops and other hard substrata in the intertidal zone of the Great Bay Estuary are typically covered by two furoid brown seaweeds: *Ascophyllum nodosum* and *Fucus* spp., collectively called rockweed. Oysters in the intertidal zone of the Great Bay Estuary only occur under the rockweed canopy. These intertidal oysters have not been quantified, but available data indicate the total intertidal population could be as much as the subtidal reef population.

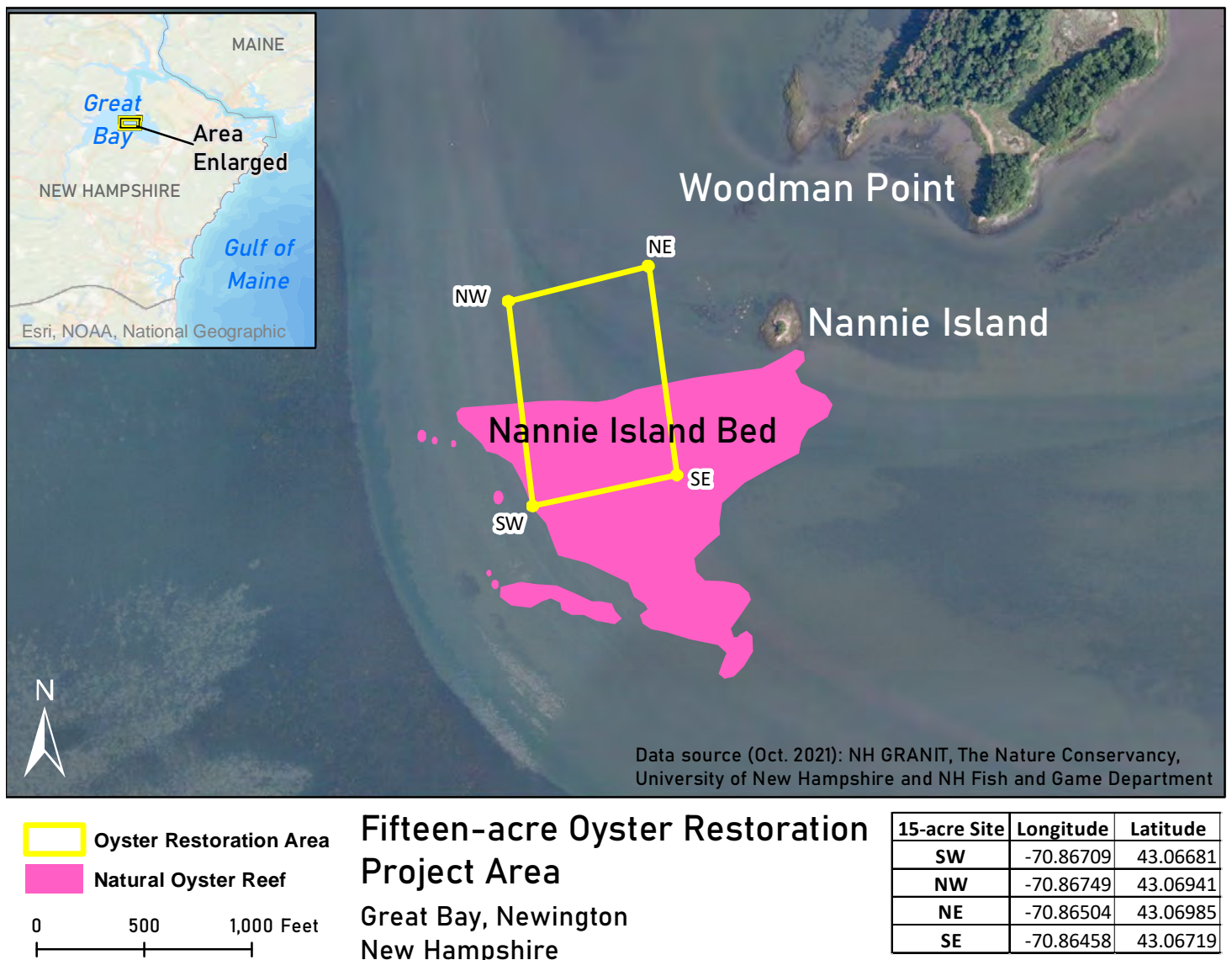


Figure 17.2: 15-acre area covering a portion of the degraded Nannie Island natural reef where shellfish harvest will be prohibited through October 31, 2026. Data source: NH GRANIT, The Nature Conservancy, University of New Hampshire, and NH Fish and Game Department



OYSTER RESTORATION

How many acres of oyster reef restoration projects have been initiated since 2000?

Although there are insufficient data to fully evaluate the PREP goal, oyster reef restoration projects totaling about 75 acres have been initiated since 2000. Sedimentation and other mortality factors hampered success at most sites, but methods have been developed recently that show good promise. Moreover, the process has become highly collaborative in recent years. Planned projects for 2023 and future years involve collaborations between New Hampshire Fish and Game Department, The Nature Conservancy, the USDA's Natural Resources Conservation Service, and the University of New Hampshire. Restoration projects are focused on the Great Bay Estuary since there is no historical record of oysters in the Hampton-Seabrook Estuary.

Oyster Restoration Goal

Restore 20 acres of oyster reef habitat by 2030. The previous goal was to be met by 2020. Although more than 20 acres of restoration were initiated, it is not clear that 20 acres of sustained habitat survived.

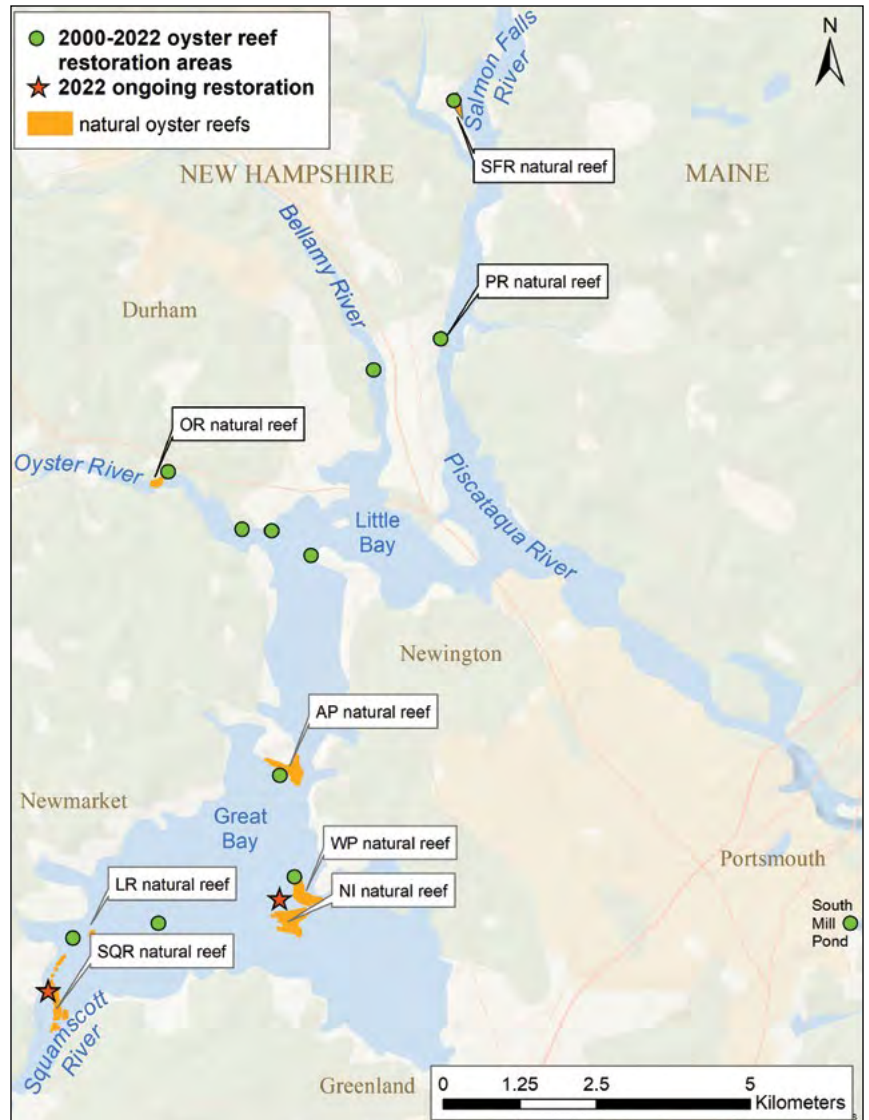


Figure 17.3: Locations of major oyster restoration projects (green dots) since 2000 and remaining natural oyster reefs (orange polygons). Note that there were multiple projects in five of the areas in the Squamscott River (SQR) and Lamprey River (LR), Adams Point (AP), and near Nannie Island (NI). Also shown are Woodman Point (WP), Oyster River (OR), and Salmon Falls River (SFR).

Data source: University of New Hampshire

Why We Track This Indicator

This indicator quantifies the results of activities aimed at restoring reefs, and it provides a metric of success at achieving two oyster-related goals (10 million oysters and 20 acres of restored reef). Historically, oyster management was mainly concerned with oysters as a recreational fishery. In recent years, the focus has been on restoring reefs that oysters naturally form rather than just numbers of oysters; this is because the reefs provide habitat for other species as well.

Oysters, Oyster Restoration, and Oyster Aquaculture

Explanation

There is no widely accepted method for determining when an oyster reef has been “restored.” Current research includes efforts to determine metrics that will allow assessment of this goal.

Between 2000 and 2021, 75 acres of oyster reef restoration projects were initiated (Figure 17.3), but the success of most projects was not quantified beyond one or two years. Recent assessments of restoration sites up to 13 years post-construction indicated most sites had a reduction in base shell cover compared to initial restored reef base, and constructed reefs located near native reefs had the highest live oyster densities.⁵⁷ However, there are insufficient data on live oyster density, recruitment to the area (new oyster larvae settling), and reef areal coverage at most sites to allow a current quantitative assessment of “restored” reefs.

Disease, lack of hard substrate, and sedimentation explain the major constraints on reef restoration. Long-term development of the constructed reef is largely dependent on two factors: the shell base remaining above the soft sediment surface so that oyster larvae can settle, and an adequate level of natural recruitment from wild oyster larvae. Unfortunately, the recent long-term assessments discussed above found substantial losses (burial and/or subsidence) of the shell base at many sites and lack of natural recruitment at most. These findings resulted in two new design criteria for most projects since ~2018.

First, reef restoration sites are positioned as close as possible to a natural reef, since recent research showed that recruitment decreased significantly as distance from a native natural reef increased.⁵⁸ Second, reef bases are designed to consist of multiple

Oyster Aquaculture

Although oyster aquaculture is usually thought of in terms of economic metrics and currently there are no management goals, this activity is directly related to oyster abundance and oyster restoration goals.

Shellfish aquaculture (primarily eastern oysters) in New Hampshire has grown from six acres in 2010 (two businesses) to 80.4 acres in 2021 (16 businesses; Figure 17.4). The average annual oyster harvest was 581,749 for the past five years (2017 to 2021), a dramatic increase from 2012–2016 when the average harvest was 129,045 oysters. Nearly a million oysters were harvested from New Hampshire’s oyster farms in 2021, including ~30% sold for use on oyster restoration sites (see “Oyster Restoration”). Oyster aquaculture in New Hampshire is an economically and ecologically important industry that is rapidly growing.

In 2021, there were ~7 million oysters (20–100 mm shell height) on 74 acres of licensed aquaculture sites in Little Bay — roughly the same number as the ~7.4 million adult (greater than 80 mm) oysters on natural reefs in 2020. Although not directly comparable, the numbers clearly indicate that the total population of farmed oysters (all size classes) is similar

to that for adult oysters on natural reefs in recent years. Additionally, if farmed oysters and wild oysters were counted in the context of the aforementioned goal of 10 million adult oysters in the Great Bay Estuary by 2030, then that goal may have been met in 2021.

Four key facts explain how farmed oysters are important to PREP’s goal of more abundant wild oysters. First, farmed oysters in New Hampshire are from “seed” (juvenile oysters) produced by brood stock maintained in hatcheries, mostly in Maine. In other words, they are not from wild New Hampshire or Maine oysters. The brood stock oysters in most cases have been selected for fast growth and disease tolerance. Recent data have indicated that farmed oysters >3 years old have less disease and they generally are larger in size than wild oysters of similar age. Second, although there are important differences, oysters on farms do provide water filtration. Third, oyster farms also provide habitat for a wide range of organisms. Recent research in the Great Bay Estuary found that farm gear supported invertebrate and macroalgal communities similar to adjacent eelgrass and oyster reef habitats.^{59,60} Fourth, the larvae produced by oysters on farms can disperse away from the farm sites and may produce recruits for wild reefs.

mounds of mollusk shell projecting less than 0.5 m above the sediment surface and arranged randomly across as much of the restoration site as funds will allow (typically ~25% coverage).

Acknowledgments and Credit

Ray Grizzle (UNH), Krystin Ward (UNH), and Robert Atwood (NHFG).



Restoration by Design
 Learn more about recommended approaches for restoring oysters in the Great Bay Estuary in the Restoration by Design report from the NH chapter of The Nature Conservancy, PREP, and the USDA Natural Resources Conservation Services, published in January 2021. Download the report at: scholars.unh.edu/PREP/449/

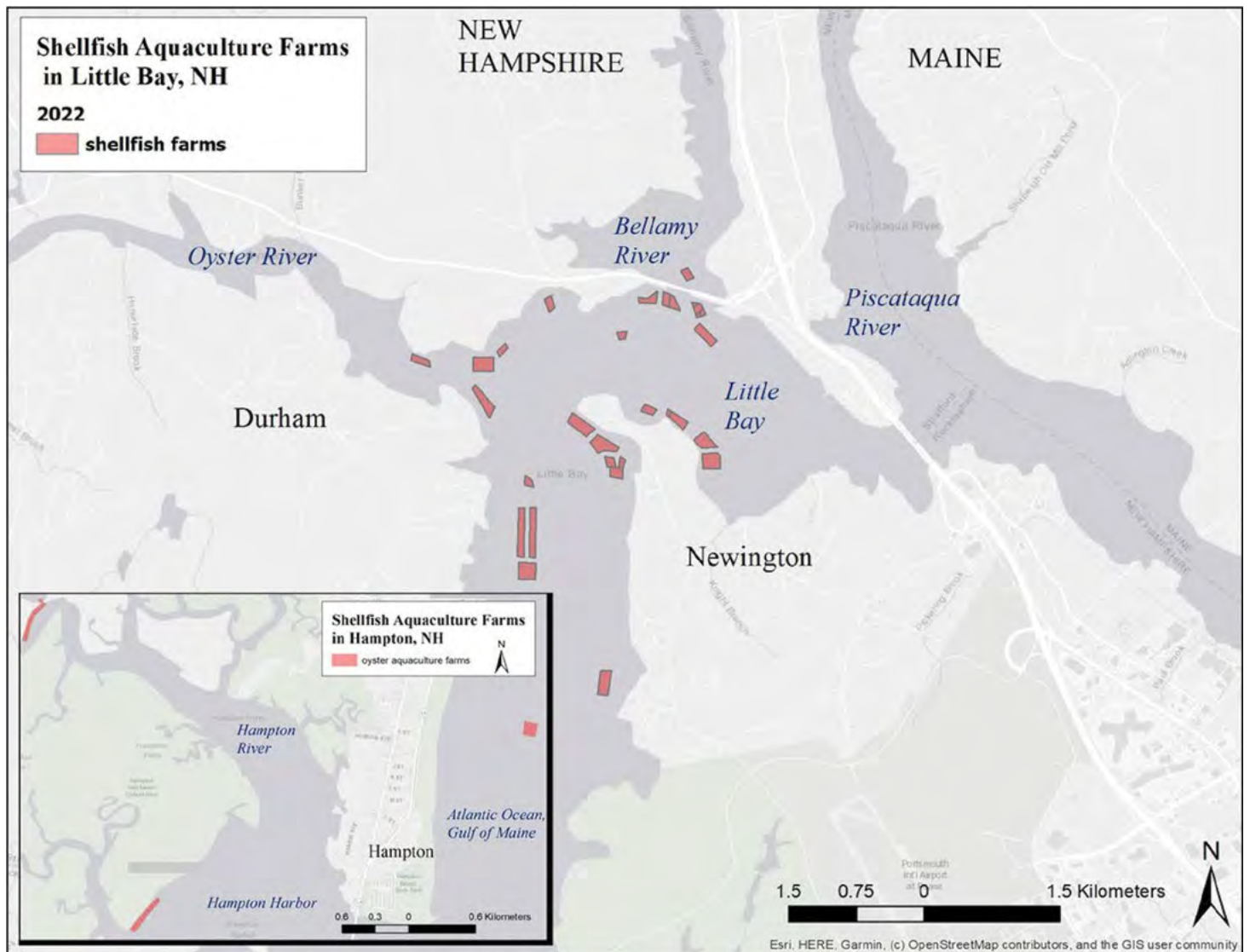


Figure 17.4: Locations and sizes (total areal coverage = 80.4 acres) of licensed shellfish (mostly oysters) farms in New Hampshire in 2022. Data source: University of New Hampshire and NH Fish and Game Department

Softshell Clams



What is the current population of adult softshell clams in Hampton-Seabrook Harbor? How has the habitat changed over time?

In 2020, the estimated population of adult softshell clams in Hampton-Seabrook Harbor was 5.1 million. Before 1998, the population size was variable, with peaks usually of more than 15 million clams. However, since 1998, the population has remained below 10 million and, most often, below 5 million.

Goal

Increase the number of adult softshell clams in the Hampton-Seabrook Estuary to 5.5 million clams.

Why We Track This Indicator

Clams consume phytoplankton and detritus to form an important link between food webs in the water column and the sediments. Clamming also provides recreational opportunities and food. Finally, softshell clam condition and abundance can offer insight into the environmental health of a system.

Explanation

In 2020, the estimated population of adult (>50 mm, or almost 2 inches, in shell length) softshell clams (*Mya arenaria*) in Hampton-Seabrook Harbor was 5.1 million, below the PREP goal of 5.5 million. Softshell clams are present in the Great Bay Estuary although recreational clamming is not as prevalent. Softshell clams are only monitored in the Hampton-Seabrook Estuary at this time. The standing stock of softshell clams at the Hampton-Seabrook Estuary clam flats (Figure 18.1) has fluctuated over the years (Figure 18.2). In some cases, the stock increases were most likely caused by the closure of the flats to harvesting. For example, the clam flats were closed to recreational harvesting from 1989 through 1993 due to a lack of sanitary surveys of the growing areas. The Common Island and Browns River flats were reopened intermittently beginning in 1994. The Confluence and Middle Ground flats were reopened in 1994 and 1998. All flats were and still are periodically closed due to coliform pollution following heavy rains and paralytic shellfish poisoning (red tide) outbreaks. Since the reopening of the flats in 1993–1997 and the resulting increase in harvesting, the standing stock of clams has generally declined. Since 2012, it has remained below the PREP goal of 5.5 million (Figure 18.2; Table 18.1).

Standing stock is estimated as the density (number per square meter) of adult clams multiplied by the acreage of the flats. As a result, standing stock is affected by changes in the density of clams as well as the acreage of the flats themselves. Clam flats are an extremely dynamic environment due to sediment erosion and accretion, both driven by storms and human activities such as dredging. PREP and partners are considering changing the metric from standing stock to density of softshell clams to avoid variability caused by changes in the acreage of the flats.

Softshell clams might also be limited by a type of contagious cancer (hemic neoplasia) that affects marine bivalves but is not dangerous to humans. The disease is transmitted directly among softshell clams through the transfer of cells called neoplastic hemocytes.^{60,61,62} There are several factors that make softshell clams more susceptible to this disease, including pollution (mainly heavy metals and hydrocarbons) and warming water temperatures.⁶³ The percentage of softshell clams infected with neoplasia increased from 2002 through 2015 and has averaged between 60% and 79% since 2015 (Figure 18.3). A review of data collected from 2002–2018 indicates that the advanced forms of neoplasia are significantly increasing in the Hampton-Seabrook Estuary.⁶⁴

Green crabs prey on softshell clams, especially newly settled individuals, reducing softshell clam population size; therefore, studies have noted a significant negative relationship between green crab abundance and density of newly settled



Photo by Jerry Monkman



Figure 18.1: Location and names of the three major softshell clam flats in Hampton-Seabrook Harbor: Confluence Flat, Common Island Flat, and Middle Ground Flat.

Data source: Normandeau Associates, with support from NextEra Energy.

softshell clams.⁶⁵ Green crab abundance in Hampton-Seabrook Harbor was highest in 1992 and 1996 and has generally declined since then (Figure 18.4). Cold winter water temperatures often limit green crab abundance. Given the trend of warming waters in our region, one concern is that green crab abundance will increase as we look towards the future, negatively impacting softshell clams.

Acknowledgments and Credit

Paul Geoghegan (Normandeau Associates) with contributions from Kalle Matso (PREP) and Trevor Mattera (PREP).



Photo by Jerry Monkman

Softshell Clams

Year	Common Island Flat	Confluence Flat	Middle Ground Flat	Total
1977	54.9	27.2	49.7	131.8
1979	54.8	26.7	53.5	135.0
1981	54	24.7	50.8	129.5
1983	52.7	26.4	49.9	129.0
1984	50	21.7	47.9	119.6
1995	45.7	26.4	47.3	119.4
2002	36.9	23.4	57.8	118.1
2013	32.3	21.9	48.7	102.9
2016	25.3	21.9	31.8	79.0
2021	25.3	21.9	29.5	76.7

Table 18.1. Acres of the major clam flats used in this report: Common Island Flat, Confluence Flat, and Middle Ground Flat. Data source: Normandeau Associates, with support from NextEra Energy

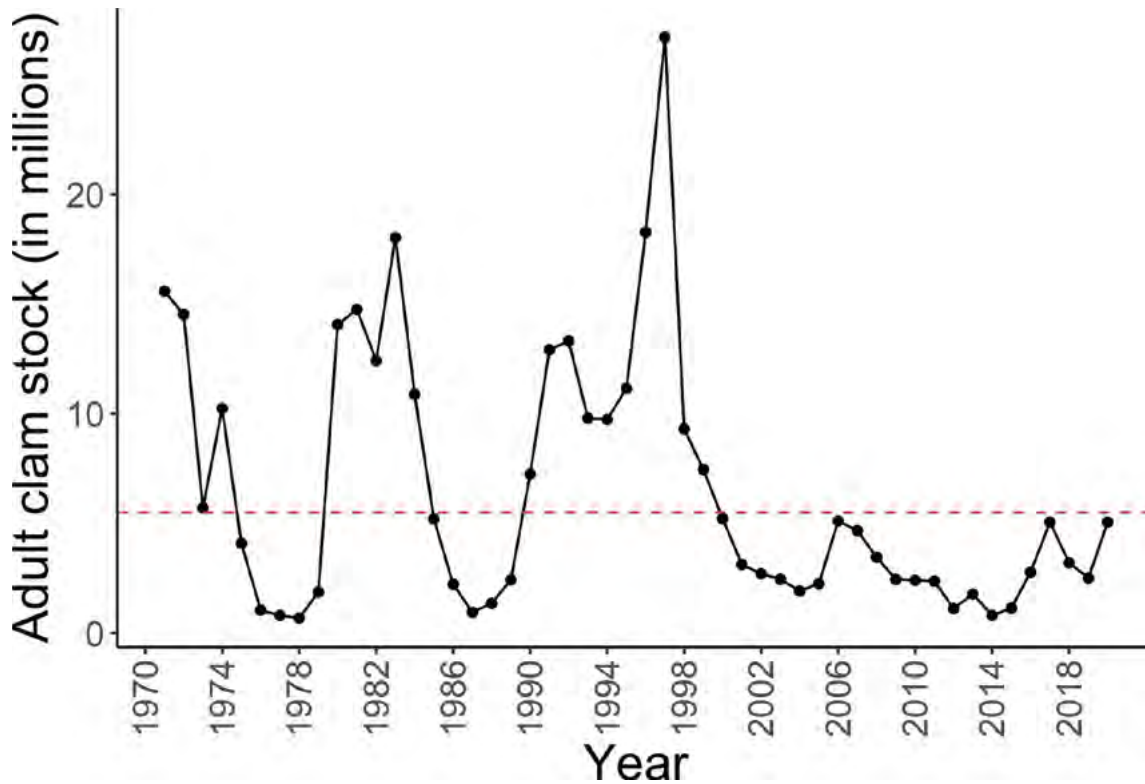


Figure 18.2: Standing stock of adult softshell clams in Hampton-Seabrook Harbor. Red dashed line indicates PREP goal of 5.5 million clams. Data source: Normandeau Associates, with support from NextEra Energy

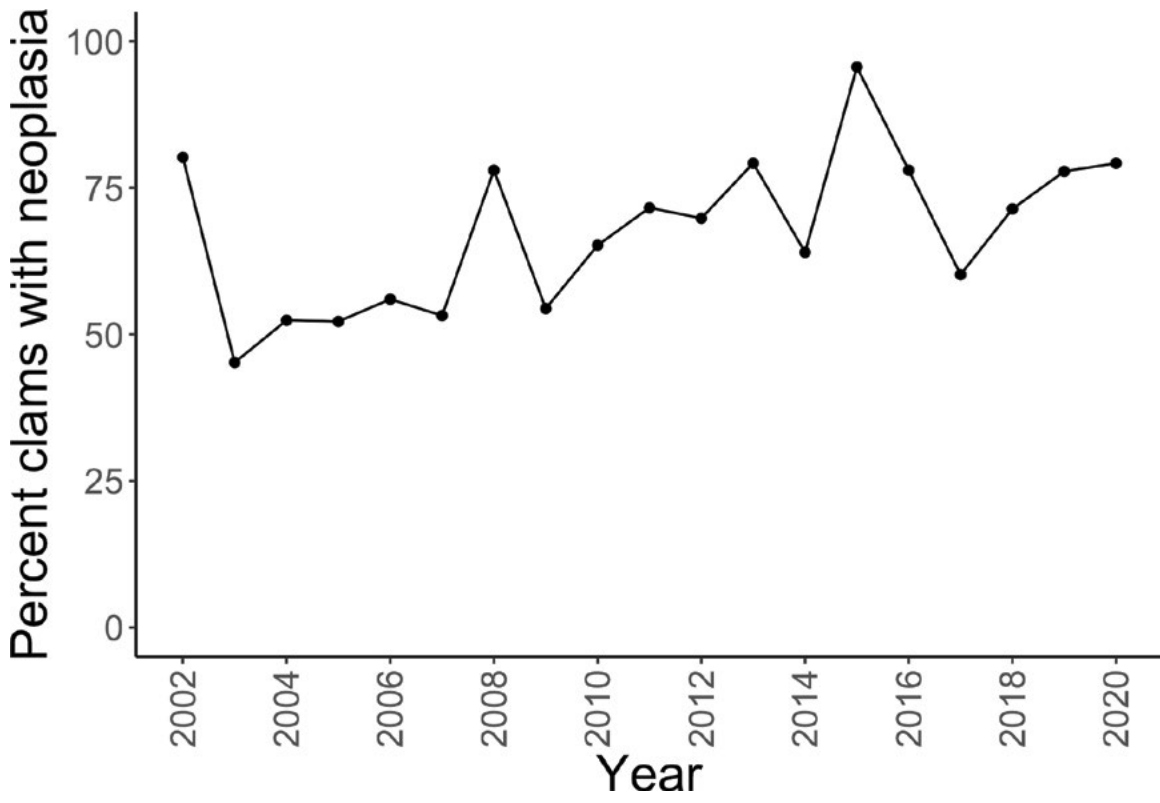


Figure 18.3: Percent of softshell clams with any amount of neoplasia in Hampton-Seabrook Harbor. Data source: Normandeau Associates, with support from NextEra Energy

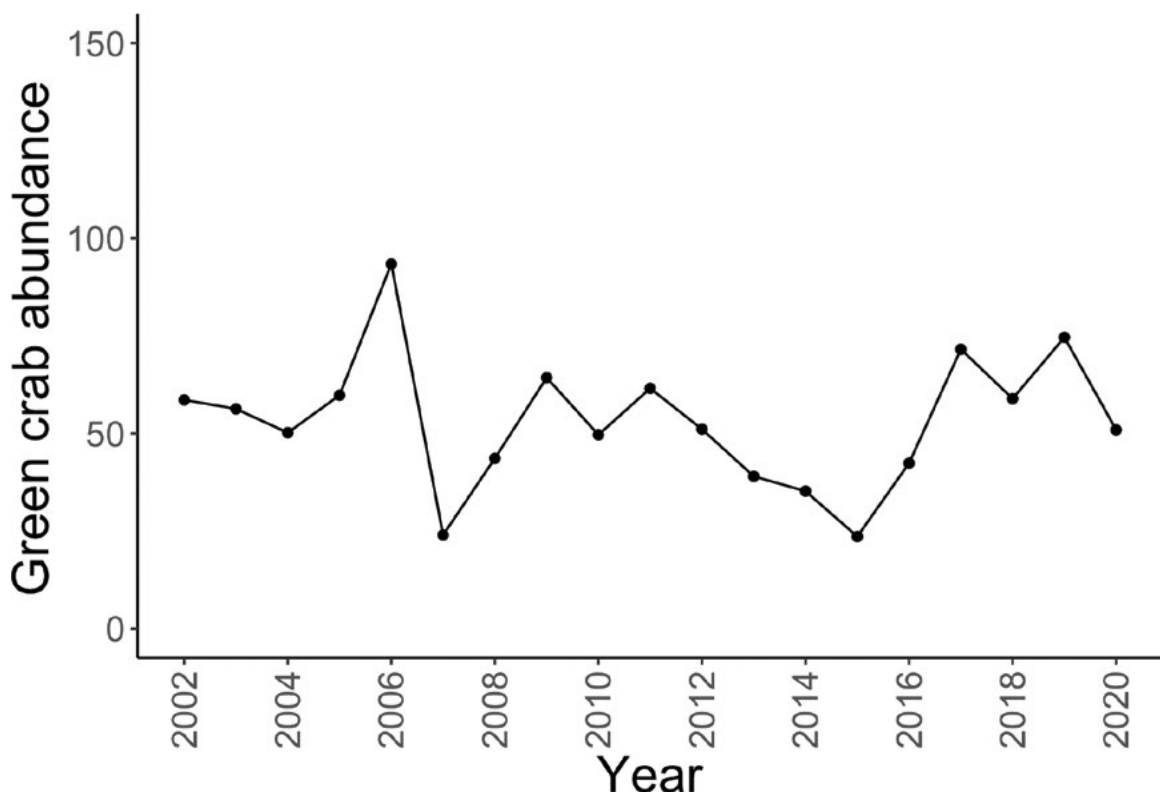


Figure 18.4: Green crab abundance in Hampton-Seabrook Harbor as measured by CPUE (catch per unit effort). Green crabs are caught in baited traps, twice a month year-round with the exception of February and March. Data source: Normandeau Associates with support from NextEra Energy

Beach Advisories



How many times did beach advisory days occur on public tidal beaches in the Piscataqua Region Watershed due to bacterial pollution, and have beach advisory days changed over time?

Across the Piscataqua Region's 16 public tidal beaches in New Hampshire and one public tidal beach in Maine, beach advisory days occurred more than the PREP goal of 1% of beach-days from 2017 to 2021. There was a significant increase in New Hampshire beach advisory days since 2003.

Goal

Less than 1% of beach days over the summer season are affected by advisories due to bacteria pollution.



Why We Track This Indicator

Beach advisories measure the health and safety of the region's popular recreational areas and serve as an indicator of overall water quality. More specifically, this indicator reflects issues related to fecal pollution from humans, livestock, pets, or wildlife. Related indicators include "Bacteria," which looks at similar indicating bacteria, but at different sites, and only during dry-weather periods. Also, this report features the indicator, "Shellfish Harvest Opportunities;" New Hampshire's Shellfish Program uses a combination of bacteria concentrations, rainy weather monitoring, and assessment of harmful algal blooms to open or close certain areas to shellfish harvesting.

Explanation

The Piscataqua Region Watershed is home to 16 public tidal beaches in New Hampshire, as well as Fort Foster in Kittery, Maine. Since 2003, between one and 18 advisories have been issued per year across these beaches due to elevated counts of enterococci — a type of bacteria in our guts that aid in digestion and are used as an indicator of fecal bacteria. Sun Valley Beach, one of the sixteen New Hampshire beaches, is the only beach that never had an advisory. Maine's Fort Foster has had between one and four advisories issued per year since 2003 (Figure 19.1).

Advisories between 2003 and 2021 have affected 306 of 31,822 summer beach days (1.0%) between Memorial Day and Labor Day (Figure 19.2). Within the last five summers (2017 – 2021), there have been 162 affected summer beach days out of 8,449 total (1.9% of beach-days). In 2021, New Hampshire saw the highest number of beach advisories and the highest number of beach advisory days since 2003, with 18 advisories affecting seven beaches for a total of 52 days (3.1% of total beach-days). At Fort Foster, there have been no beach advisories since 2016. The highest number of advisories Fort Foster has seen (four) was back in 2009.

Most advisories reported in 2020 and 2021 impacted North Hampton State Beach and New Castle Town Beach. These two beaches are historically known for having issues with elevated enterococci levels. Together, they have accounted for nearly half of all posted beach advisories since 2003, having a combined total of 51 advisories out of 110.

The number and duration of advisories varies from year to year depending on different environmental conditions, especially due to excessive rainfall events and other severe weather. Such events can facilitate stormwater runoff, which can transport fecal matter into coastal waters. Unfortunately, due to the increase in number of beach advisories between 2017 and 2021, New Hampshire tidal beaches in the region did not continue to meet PREP's goal of beach advisories affecting fewer than 1% of summer beach-days.

Acknowledgments and Credit

Amanda Giacchetti (UNH) with contributions from Abigail Lyon (PREP).

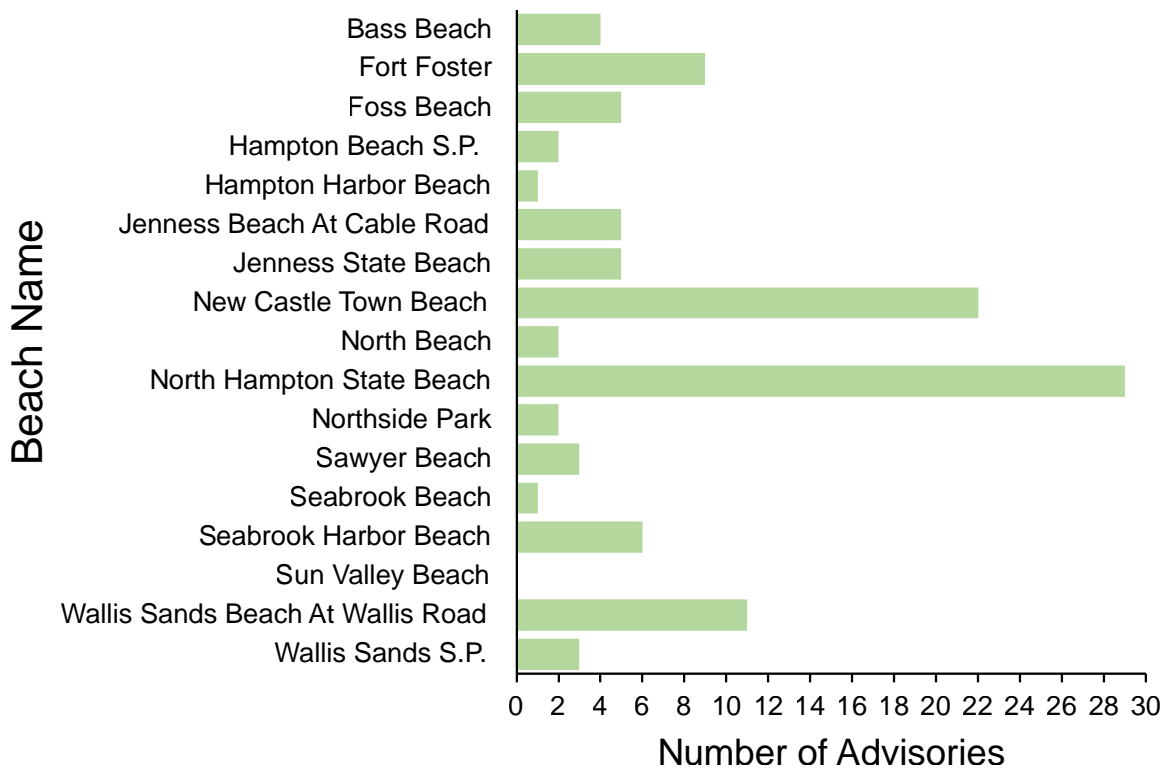


Figure 19.1: Beach advisories per tidal beach in the Piscataqua Region Watershed, 2003 – 2021. Data source: NH Department of Environmental Services and Maine Department of Environmental Protection

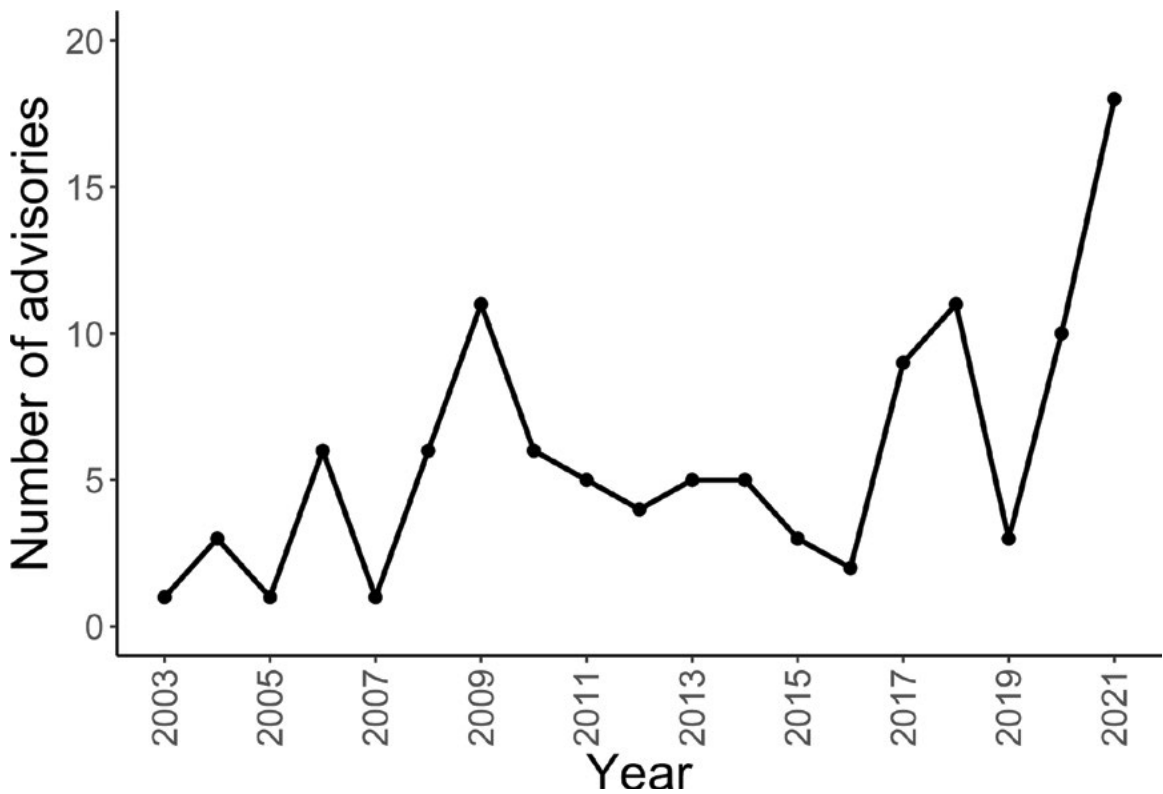


Figure 19.2: Number of advisories in the Piscataqua Region Watershed, 2003 – 2021. Data source: NH Department of Environmental Services and Maine Department of Environmental Protection

Migratory Fishes



How have migratory fish returns to the Piscataqua Region Watershed changed over time?

Estimates of more than 260,000 river herring returned to Piscataqua Region tributaries in 2021, a ~30% increase from 2016. This increase was driven by high returns to the Exeter River, likely due to a combination of the removal of the Great Dam in 2016 and to changes in counting methods. However, the average returns over the past two decades (2000s and 2010s) are ~30% lower than those observed in the 1980s and 1990s. Given the importance of river herring in linking freshwater, estuarine, and marine ecosystems, efforts to restore rivers and improve herring passage and health continue to be high priorities.

River restoration continues to be a priority in the region, with two dams removed from the Bellamy River since the last report in 2018. Additionally, in March 2022 the Town of Durham, NH voted to remove the Mill Pond Dam, which will improve accessibility for river herring.

Rainbow smelt have been monitored by the New Hampshire Fish and Game Department since 2010. They spawn in freshwater rivers downstream of river herring in early spring at head-of-tide. Removal of head-of-tide dams has resulted in increases in the relative abundance of spawning rainbow smelt on the Winnicut and Squamscott Rivers.



Why We Track This Indicator

Diadromous fish such as river herring and rainbow smelt migrate from the rivers of their birth to ocean waters and back again to freshwater habitats to reproduce. These fishes are important sources of nutrients for upstream systems and food for wildlife in freshwater habitats (birds, turtles, fishes, and mammals). They are also prey for important coastal fisheries including striped bass, bluefish, and groundfish. River herring are considered “forage fish” and are prey for numerous predators in marine food webs.

Explanation

Diadromous fish are those that migrate between freshwater and marine ecosystems to complete their life cycles. These fish require estuarine habitat that effectively links coastal ecosystems to bays and their freshwater tributaries. Across North America, diadromous fish have experienced dramatic population declines over the past century due in part to dams, overfishing, loss of habitat resulting from coastal development, and decreases in water quality.

In the Gulf of Maine, migratory species that use the Hampton-Seabrook and Great Bay Estuaries, such as river herring, have similarly experienced declines. The term “river herring” is actually a common name that refers to two different species: blueback herring (*Clupea aestivalis*) and alewife (*Clupea pseudoharengus*). Since 2008, the New Hampshire Fish and Game Department has estimated the numbers of each species returning to each river. Most tributaries of

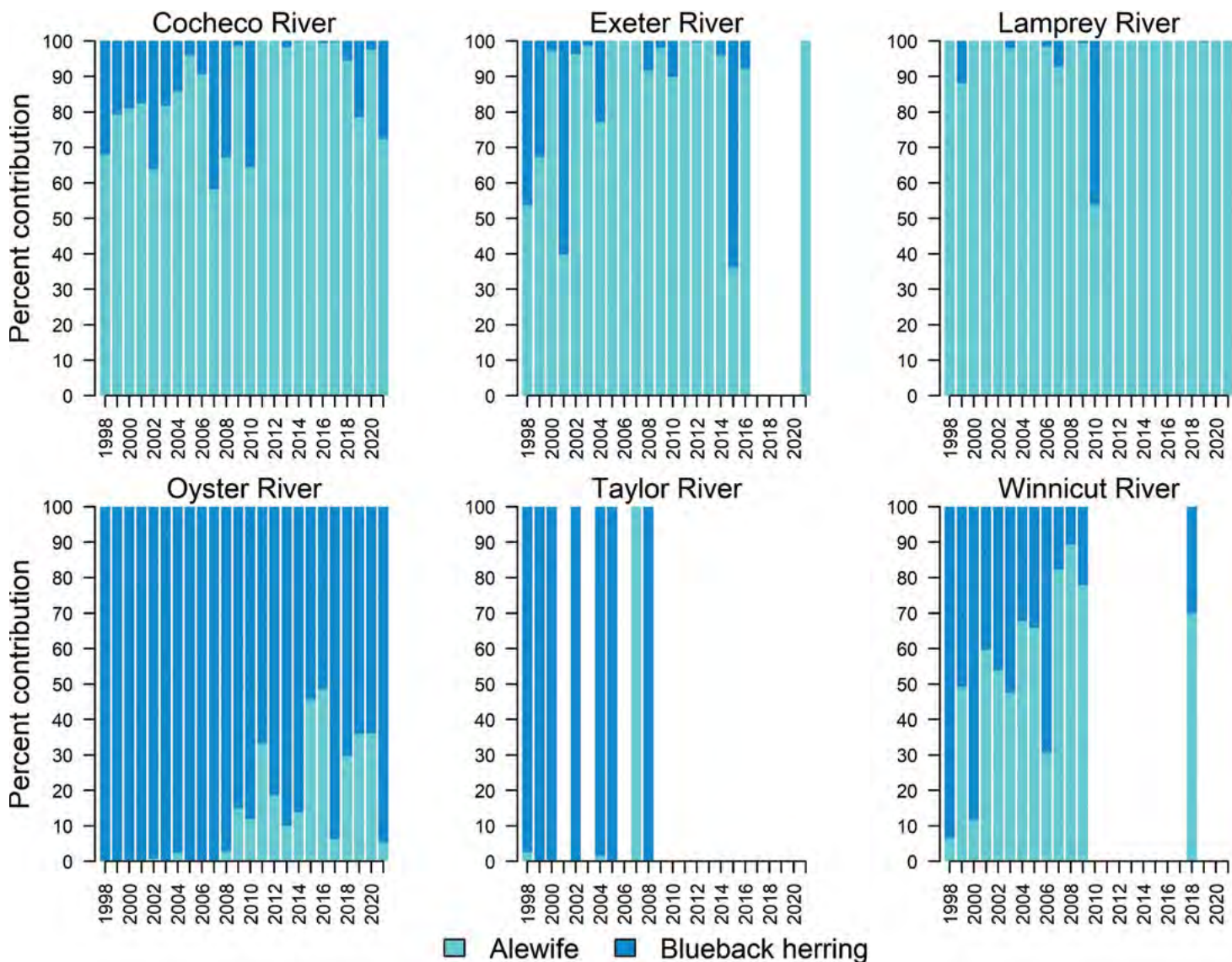


Figure 20.1: Percent contribution of alewife (dark) and blueback herring (light) to total river herring returns to New Hampshire coastal tributaries 1998 – 2021. Years with no data or insufficient data are presented as white. Data source: NH Fish and Game Department

the Great Bay are dominated by one species or the other. For example, most river herring returning to the Cocheco River, Exeter River, and Lamprey River are alewife (Figure 20.1). In contrast, most river herring returning to the Oyster River are blueback herring, but the relative contribution of alewife to this river has increased over the past decade.

Observed river herring returns to the coastal rivers of the Piscataqua Region Watershed varied during the 1972 – 2021 period (Figure 20.2). From ~1975 – 1985, returns were dominated by the Taylor River and, to a lesser degree, the Lamprey River.

From the mid-1980s to the early 2000s, returns on the Oyster River and Cocheco River dominated total returns. In the early 2000s, the Taylor River run collapsed and returns to the Oyster River dropped considerably, leaving returns to be driven by the Lamprey River and Cocheco River through 2020. Total river herring returning in 2021 reached 260,065 (30.6% increase from 2016), but this was driven by the highest returns recorded on the Exeter River (167,400); note that the Exeter River is the freshwater portion of the Squamscott River. This increase was likely in response to the removal of the Great Dam in 2016.

Migratory Fishes

Fewer than 10 fish were reported for the Taylor and Winnicut Rivers in 2021, and returns have decreased in the Oyster River over the past ~20 years. Overall, the mean annual river herring returns among all monitored rivers over the past two decades (118,222 in 2011 – 2021 and 121,590 in 2001 – 2010), are lower than those observed in the 1980s (179,076) and 1990s (188,386).

Rainbow smelt (*Osmerus mordax*) are also migratory and monitored by the New Hampshire Fish and Game Department (NHFG). Removal of head-of-tide dams on the Winnicut (completed in 2012) and Squamscott (2016) Rivers resulted in time-series highs in rainbow smelt catches within approximately three years after restoration of each respective river (Figure 20.3). Whereas rainbow smelt spawn in the Squamscott River, river

herring continue upstream into the Exeter River, and they all share the same migratory pathway to the Great Bay. The catches of rainbow smelt on these rivers have continued to be considerably higher than they were during the time period before dam removal. In addition, in the most recent years, the catches are composed of a higher proportion of 2-year-old fish relative to 1-year-olds (Figure 20.4). There are many possible explanations for this, such as poor spawning effort or poor survival of juveniles. More data will be necessary to understand these dynamics.

Acknowledgments and Credit

Nathan B. Furey (UNH), with contributions from Kevin Sullivan (NHFG) and Robert Atwood (NHFG).

Extended Report

In 2019, a research partnership between NHFG and UNH began to investigate the migrations of rainbow smelt in Great Bay. See the Extended Report for preliminary results, and for more details on river herring and rainbow smelt returns.

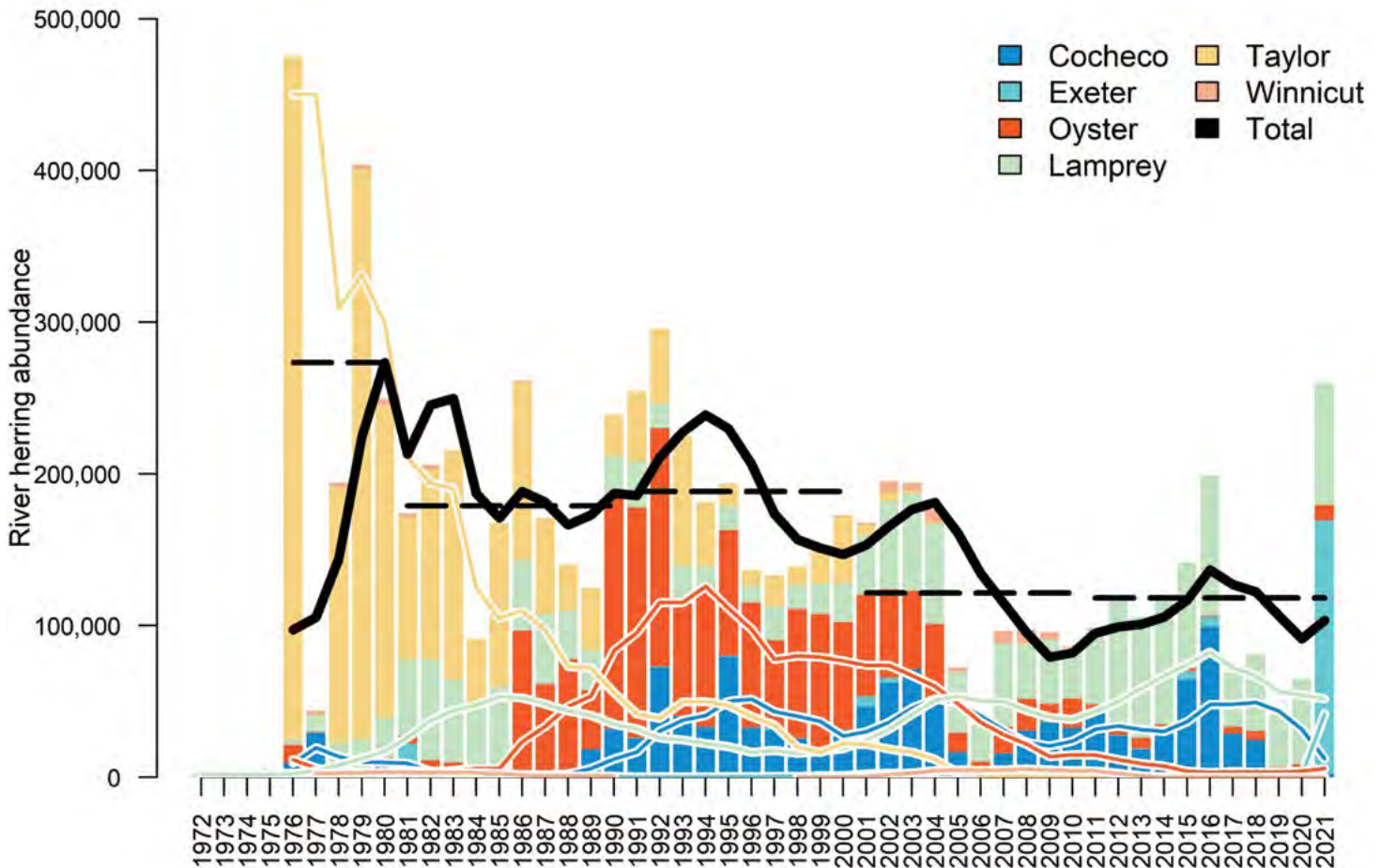


Figure 20.2: Returns of river herring to New Hampshire coastal tributaries 1972 – 2021. Bars indicate estimated abundance of returning river herring. The solid black line indicates 5-year rolling averages of total abundance (of the previous four years and current year) and the dashed lines represent means of total abundance for 1975 – 1980, 1981 – 2000, and 2000 – 2021. The colored solid lines are rolling averages for each of the tributaries. Note that in 2017 – 2020, abundance was not estimated on the Exeter River after removal of the Great Dam.

Data source: NH Fish and Game Department

Rainbow smelt relative abundance

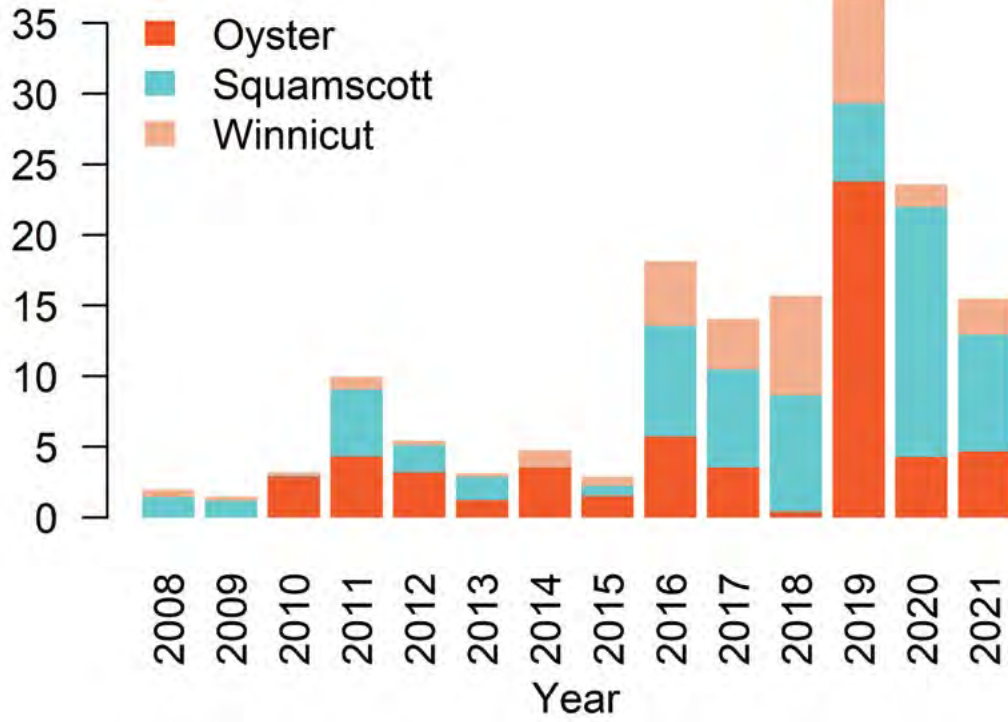


Figure 20.3: Relative abundance of rainbow smelt observed by New Hampshire Fish and Game Department spring spawning surveys 2008 – 2021. Data source: NH Fish and Game Department

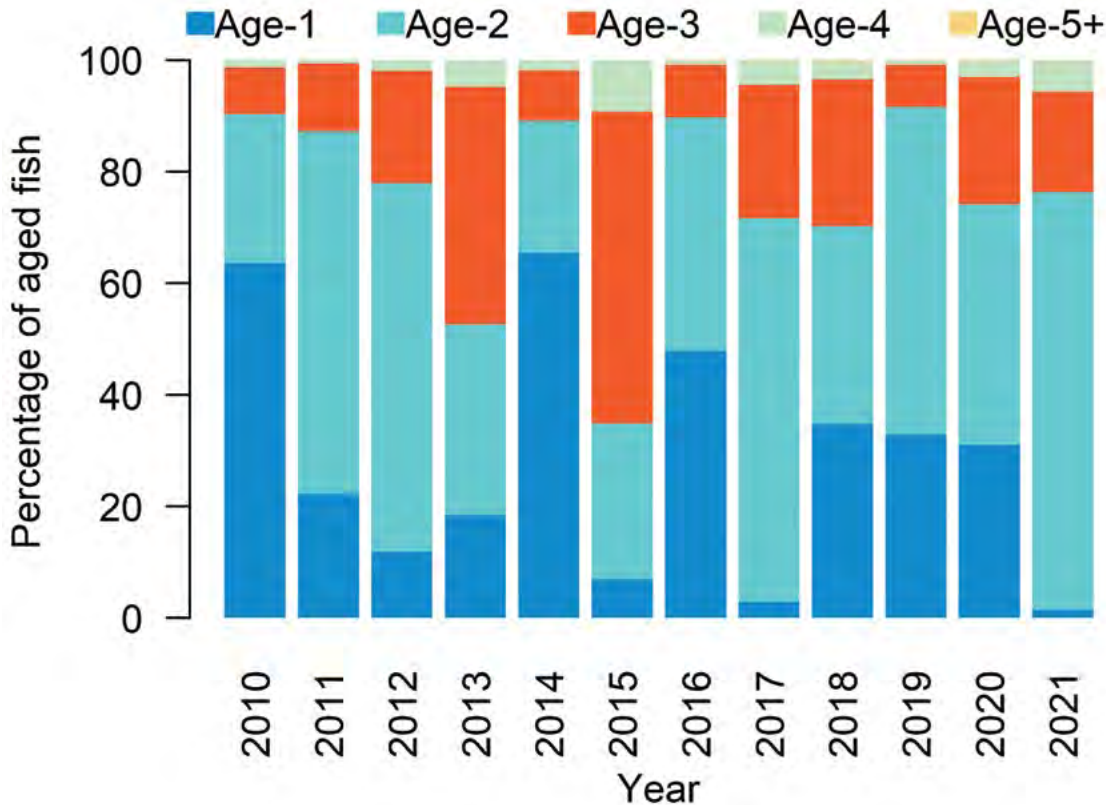


Figure 20.4: Percent contribution of each age class of rainbow smelt to the total of those aged via scales among the three rivers collectively (Oyster, Squamscott, and Winnicut Rivers) 2010 – 2021. Please note this figure aggregates data across all three rivers. Data source: NH Fish and Game Department

Toxic Contaminants



How much toxic contamination is in blue mussel tissue and how has it changed over time? What is the status of mercury in sediments? What are contaminants of emerging concern and what do we know about their impacts on ecosystems and human health?

In blue mussel tissue, most concentrations of inorganic (e.g., heavy metals such as mercury and lead) and organic (e.g., polychlorinated byphenyls (PCBs)) chemicals from 1993 – 2016 were declining or not changing. Mercury concentrations in sediments were highest in Great Bay, the Piscataqua River, and Portsmouth Harbor; lowest values were found in Hampton Harbor. No trends were detected in time series beginning in 2000. Contaminants of emerging concern, per- and poly-fluoroalkyl substances (PFAS), pharmaceuticals, and personal care products, were widely detected. There are no regulatory advisories for these chemicals currently, but research and monitoring are ongoing.

Goal

All sampling stations in the Hampton-Seabrook and Great Bay Estuaries show shellfish tissue concentrations below stated levels of concern and for there to be no increasing trends for any contaminants.

Why We Track This Indicator

Toxic and persistent contaminants, such as PCBs, mercury, and contaminants of emerging concern, can accumulate in the tissue of filter-feeding bivalves (e.g., mussels, clams, and oysters) and other marine organisms, posing health risks to people and non-human organisms when consumed.⁶⁶ Tracking contamination in blue mussel tissue over time offers insight into temporal and spatial changes in distributions and contaminant levels in estuarine and coastal ecosystems that reflect direct (e.g., runoff) and indirect (e.g., sediments) sources of these contaminants.

Explanation

The 2018 State of Our Estuaries report noted that most legacy contaminants — metals, pesticides, polycyclic aromatic hydrocarbons (PAHs), and polychlorinated biphenyls (PCBs) — showed either decreasing or no overall trends from 1993 through the year 2014. Two additional years of data from 2015 and 2016 resulted in no change for 26 contaminants, five changed from no trend to decreasing, and five contaminants changed from decreasing to no trend (Table 21.1). No contaminants were added to the “increasing” category. In addition, none of the recent data have exceeded US Food and Drug Administration “tolerance” or “action” levels for mercury or PCBs in shellfish and seafood (Figure 21.1).

Determining concentrations of contaminants in sediment is another useful way to track where contaminants end up in the Piscataqua Region Watershed. The EPA conducted surveys throughout the United States as part of the National Coastal Condition Assessment, collecting data in 2000–2006, 2010, and 2015 on toxic contaminants in sediments and fish tissue. In sediments, mercury concentrations $\geq 0.7 \mu\text{g/g}$ are considered likely to cause adverse health effects, while levels $\leq 0.13 \mu\text{g/g}$ are not.⁶⁷ Results indicate that the possibility for

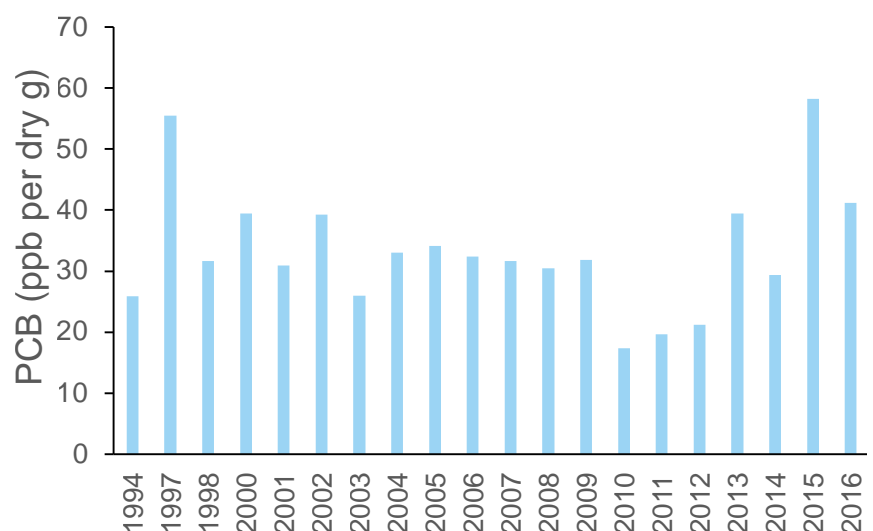


Figure 21.1: Average concentrations (parts per billion dry wt.) of PCBs in blue mussel samples from Dover Point (NHDP) from 1994 to 2016.

Data source: NOAA Mussel Watch Program /Jackson Estuarine Laboratory, UNH

Station	Parameter	Period	Trend at 2014	Change with 2015 – 16 data
MECC	Aluminum	1993 – 2014	No significant trend	No change
	Cadmium	1993 – 2014	No significant trend	No change
	Chromium	1993 – 2014	Decreasing	Change to no trend
	Copper	1993 – 2014	No significant trend	No change
	Iron	1993 – 2014	No significant trend	Change to decreasing
	Lead	1993 – 2014	Decreasing	No change
	Mercury	2003 – 2014	No significant trend	Change to decreasing
	Nickel	1993 – 2014	Decreasing	No change
	Silver	2003 – 2014	Decreasing	No change
	Zinc	1993 – 2014	No significant trend	No change
	PAH-Total	1993 – 2014	No significant trend	No change
	PCB-Total	1993 – 2014	No significant trend	Change to decreasing
NHDP	Aluminum	1994 – 2014	No significant trend	No change
	Cadmium	1994 – 2014	Decreasing	No change
	Chromium	1994 – 2014	Decreasing	Change to no trend
	Copper	1994 – 2014	No significant trend	No change
	Iron	1994 – 2014	Decreasing	No change
	Lead	1994 – 2014	Decreasing	No change
	Mercury	2003 – 2014	No significant trend	Change to decreasing
	Nickel	1994 – 2014	Decreasing	Change to no trend
	Silver	2003 – 2014	Decreasing	No change
	Zinc	1993 – 2014	Decreasing	No change
	PAH-Total	1993 – 2014	No significant trend	No change
	PCB-Total	1993 – 2014	No significant trend	No change
NHHS	Aluminum	1993 – 2014	No significant trend	No change
	Cadmium	1993 – 2014	Increasing	No change
	Chromium	1993 – 2014	Decreasing	Change to no trend
	Copper	1993 – 2014	No significant trend	No change
	Iron	1993 – 2014	No significant trend	No change
	Lead	1993 – 2014	Decreasing	No change
	Mercury	2003 – 2014	No significant trend	Change to decreasing
	Nickel	1994 – 2014	Decreasing	Change to no trend
	Silver	2003 – 2014	Decreasing	No change
	Zinc	1993 – 2014	Decreasing	No change
	PAH-Total	1993 – 2014	No significant trend	No change
	PCB-Total	1993 – 2014	Decreasing	No change

Table 21.1. Trends in contaminant concentrations in mussel tissue in Clark Cove, Portsmouth Harbor (MECC), Dover Point (NHDP), and Hampton Harbor (NHHS), 1993 – 2016.

Data source: Jackson Estuarine Laboratory, UNH

Toxic Contaminants

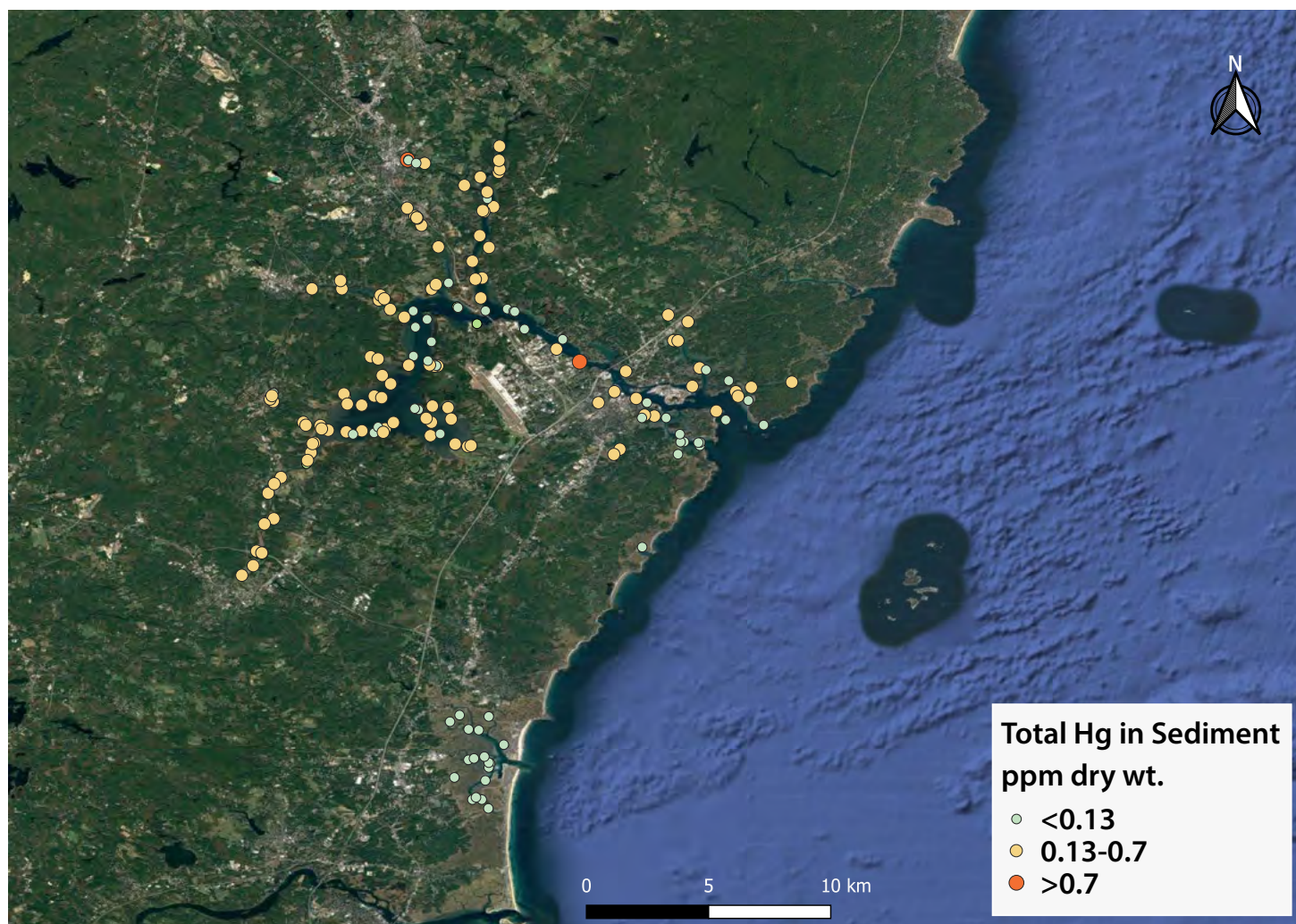


Figure 21.2: Distribution of sediment mercury concentrations in Piscataqua Region Watershed estuaries and tributaries from National Coastal Condition Assessment surveys 2000 – 2006, 2010, and 2015. Concentrations $>0.7 \mu\text{g/g}$ (orange) are considered likely to cause adverse effects; at levels $<0.13 \mu\text{g/g}$ (light green), effects are not expected⁶⁷. Intermediate concentrations between $0.13 - 0.7$ with less defined risk are shown in yellow.

Data source: National Coastal Condition Assessment, EPA

adverse effects exist throughout the Great Bay Estuary, whereas the Hampton-Seabrook Estuary's levels of mercury are lower and therefore less likely to cause adverse effects (Figure 21.2).

Apart from legacy contaminants, researchers are working to understand the presence and potential ecosystem and human health impacts of contaminants of emerging concern, including the family of chemicals referred to as PFAS. PFAS can be released from wastewater treatments facilities, current and former military sites due to firefighting foam use, and other runoff sources due to widespread use of these chemicals. In blue mussel tissue, PFAS (as PFOSA) were detected at five of eight sites in the Piscataqua Region Watershed, including Little Harbor (NHLH), New Castle (NHNC), North Mill Pond (NHNM), South Mill Pond (NHSM), and Clark Cove (MECC; Seavey Island, Portsmouth Naval Shipyard)

sites, but not at Hampton-Seabrook Harbor (NHHS), Dover Point (NHDP), or Peirce Island (NHPI) (Figure 21.3).⁶⁸

Currently, there are no published PFAS thresholds for ecosystem health, but there are thresholds for human health in terms of consuming shellfish and finfish. Based on recent sampling efforts, NHDES concluded that a shellfish consumption advisory for PFAS was not warranted⁶⁹ but advisories for finfish may be necessary in the future as state and academic partners investigate further. This is because PFAS tends to accumulate as they travel up the food chain to bigger organisms, especially in finfish. PFAS toxicity, their regulation, and their occurrence across New Hampshire is an evolving situation so people with concerns should check the latest news at the NHDES PFAS Response website (<https://www.pfas.des.nh.gov/>).

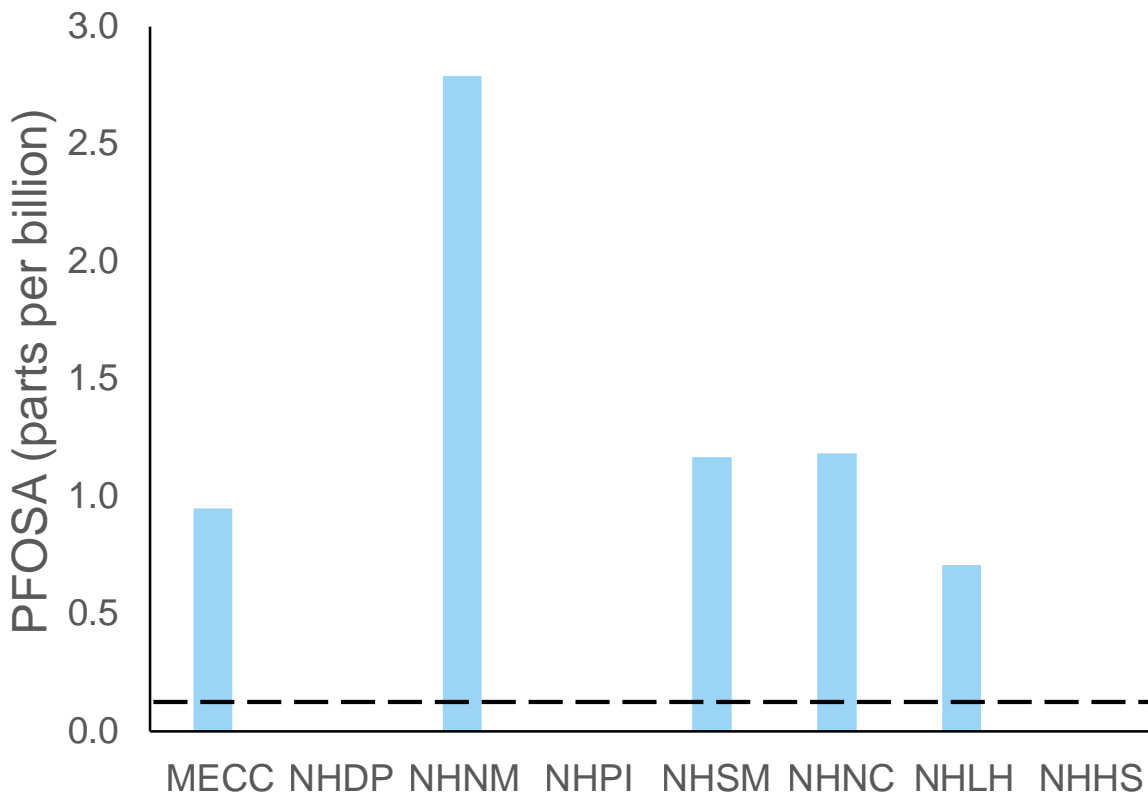


Figure 21.3: PFOSA concentrations (parts per billion, wet weight) in blue mussel tissue detected at monitoring sites in the Piscataqua Region Estuaries (see narrative on page 101 for site names). Dotted line represents the minimum weight corrected detection limit. Perfluorooctane sulfonamide (PFOSA) was the most frequently detected of the PFAS contaminants in this study, which used samples collected in 2015 and 2016 throughout the Gulf of Maine.⁷¹ Data source: NOAA Mussel Watch Program/Jackson Estuarine Laboratory, UNH



In addition to PFAS, blue mussel samples were analyzed for many other potentially harmful contaminants of emerging concern compounds, including current-use pesticides, pharmaceuticals, personal care products, and flame retardants. Many of these contaminants of emerging concern were not detected at the eight Piscataqua Region Watershed sites. However, a number of pharmaceuticals and personal care products were detected. DEET, a common insect repellent, was found at all eight sites, although concentrations were well below levels associated with adverse effects.⁷⁰

Future reports will contain more information on trends over time as well as potential impacts on ecosystem and human health.

Acknowledgment and Credits

Stephen Jones (NH Sea Grant/UNH) and Maria Florencia Fahnestock (UNH), with contributions from Kalle Matso (PREP).

Extended Report

The Extended Report includes more detailed data and analysis of legacy heavy metal and toxic organic contaminants in blue mussel tissue, and more sediment data with assessments of 15 metals, 26 PAHs, 44 PCBs, and 30 pesticides. The Extended Report also contains more contaminants of emerging concern data, including 249 chemicals at eight Piscataqua Region Watershed sites compared to 34 other sites around the Gulf of Maine.

Stewardship Behavior



How many volunteer hours were logged in the Piscataqua Region Watershed through the work of five New Hampshire stewardship groups between 2017 – 2021? How many sign-ups and events were completed in this timeframe?

From 2017 – 2021 there were 109,063 volunteer hours logged from five major organizations in the Piscataqua Region Watershed: Blue Ocean Society, NH Sea Grant, Great Bay National Estuarine Research Reserve (GBNERR), Gundalow Company, and the Seacoast Science Center. There were 458 volunteering events and 3,783 sign-ups from local individuals. These efforts amount to a total economic benefit of over \$2.5M, based on the current calculated value of volunteer time. The pandemic affected stewardship rates in 2020, but 2021 could indicate the beginning of a resurgence of environmental volunteering.

Why We Track This Indicator

Volunteer efforts are a critical component in the stewardship of our region; by tracking stewardship hours, we obtain a sense of how engaged the people of the Piscataqua Region are in the health of their estuaries.

Explanation

Stewardship can be defined as the careful and responsible management of something entrusted to one's care, and is a vital component of our community. Since data reporting began in 2015, stewardship activity showed a modest increase until the pandemic. Not surprisingly, there was a substantial decrease in stewardship hours in response to the COVID-19 outbreak (Figure 22.1, Table 22.1). Total volunteer hours in 2020 were 6,810, a 76% decrease compared to previous year's average, and the total number of volunteers decreased by 64%. However, with the distribution of the vaccine in 2021, stewardship efforts are seeing a resurgence. Most recently, in 2021, our region saw a total of 15,088 volunteer hours, from 582 volunteers across 63 events, and 2022 is looking even more promising (Table 22.2).

As human populations grow and greater strain is placed on natural resources, stewardship in our communities becomes more and more critical. Not only does volunteer stewardship have a positive impact on the ecosystem, but it also benefits the region economically. The Bureau of Labor Statistics calculates the value of volunteer work in New Hampshire at \$30.75 per hour. With a total of 109,063 hours logged from 2017 – 2021, the total economic value of these efforts was \$3,353,676 in just these 5 years.

Those who are passionate about the environment and feel compelled to get involved in local efforts can access a list of upcoming events at NatureGroupie.org. This website is a hub for volunteer events and citizen scientist opportunities in New England. The site connects volunteers with various organizations and individuals and identifies projects that fit volunteer interests. From 2017 to 2021, there were 458 events made possible from the contributions of 3,783 volunteers. This is likely an underestimation as there are countless groups and citizens who volunteer that go unreported.

Acknowledgments and Credits

Nathaniel Gruen (UNH) with contribution from Abigail Lyon (PREP).



Organization	2015	2016	2017	2018	2019	2020	2021
Gundalow Company	2,500	2,779	3,622	3,384	2,704	1,173	1,748
GBNERR	3,883	2,963	2,978	3,986	4,536	465	3,007
Seacoast Science Center	13,075	11,978	11,978	17,284	16,245	3,718	6,547
NH Sea Grant (Coastal Research Volunteers)	1,764	1,602	1,060	2,863	2,023	910	1,185
Blue Ocean Society	3,080	3,765	4,811	4,042	5,651	544	2,601
Grand Total	24,302	23,087	24,449	31,558	31,158	6,810	15,088

Table 22.1. Volunteer hours by selected stewardship groups by year. Volunteer Hours by Year (2015 – 2021)
Data source: Blue Ocean Society; NH Sea Grant; GBNERR; Gundalow Company; Seacoast Science Center. NHDRED data not reported due to reorganization of the agency. These organizations were chosen according to criteria established by PREP.⁷²

Year	Number of Events	Number of Volunteers
2017	134	872
2018	120	1018
2019	117	968
2020	24**	343
2021	63	582

Table 22.2. Number of stewardship events among chosen organizations.
**In 2020, uncertainties related to the COVID-19 pandemic led to a drop in events; only 38 total events were scheduled, and of those 14 were canceled resulting in a total of 24 events. Data source: Blue Ocean Society; NH Sea Grant; GBNERR; Gundalow Company; Seacoast Science Center. NHDRED data not reported due to reorganization of the agency. These organizations were chosen according to criteria established by PREP.⁷²

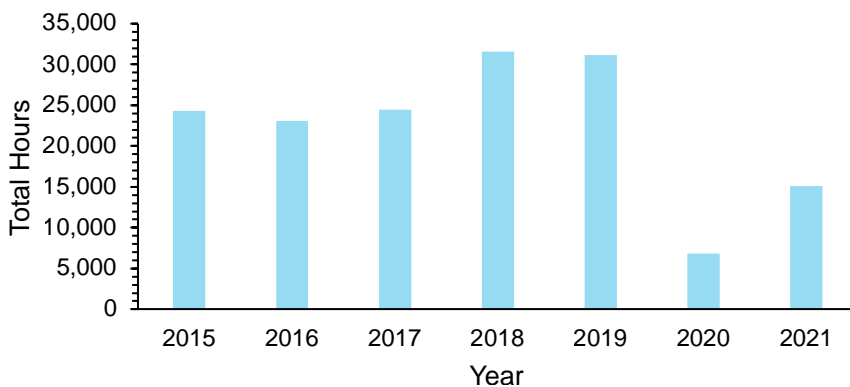


Figure 22.1: Total Volunteer Hours in the Piscataqua Region Watershed during 2015 – 2021.
Data source: Blue Ocean Society; NH Sea Grant; GBNERR; Gundalow Company; Seacoast Science Center. NHDRED data not reported due to reorganization of the agency. These organizations were chosen according to criteria established by PREP.⁷²



Acknowledgments and Credits

PREP Management Committee

Katie Ambrose, City of Rochester, NH
Jon Balanoff, Action Wakefield Watersheds Alliance
Erik Beck, US Environmental Protection Agency
Dea Brickner-Wood, Great Bay Resource Protection Partnership
Erik Chapman, NH Sea Grant/University of New Hampshire
Jim Chase, Seacoast Science Center
*Steve Couture, NH Department of Environmental Services Coastal Program
Annie Cox, Wells National Estuarine Research Reserve
Jennifer Czysz, Strafford Regional Planning Commission
*Ted Diers, NH Department of Environmental Services
Addie Halligan, ME Department of Environmental Protection
Russ Hilliard, Swell Oyster Company
Don Keirstead, USDA Natural Resources Conservation Service
Jessa Kellogg, Town of Kittery, ME
^Peter Kinner, Great Bay Stewards
Regina Lyons, U.S. Environmental Protection Agency
*Melissa Paly, Great Bay-Piscataqua Waterkeeper
*Cheri Patterson, NH Fish and Game Department
Jennifer Perry, Town of Exeter, NH
Kim Reed, Town of Rye, NH
*Cory Riley, Great Bay National Estuarine Research Reserve
*Todd Selig, Town of Durham, NH
Carl Spang, Lamprey River Watershed Association
John Storer, City of Dover, NH
*Technical Advisory Committee member

EPA Regional Coordinator

Erik Beck, U.S. Environmental Protection Agency

PREP Host Organization

Diane Foster, University of New Hampshire School of Marine Science and Ocean Engineering

PREP's Technical Advisory Committee

^Bill Arcieri, Vanasse Hangen Brustlin, Inc.
*^Robert Atwood, NH Fish and Game
Al Basile, Great Bay National Estuarine Research Reserve
^Garrison Beck, Vanasse Hangen Brustlin, Inc.
^Clifton Bell, Brown and Caldwell
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*David Burdick, University of New Hampshire Jackson Estuarine Laboratory
*Wilton Burns, University of New Hampshire
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*Katie Callahan, NH Fish and Game

^Dennis Chasteen
*Elizabeth Cianciola, University of New Hampshire
^Phil Colarusso, US Environmental Protection Agency
^Michelle Condon, NH Department of Environmental Services
Hannah Coon, Archipelago Law
Mikayla Cote
^Simon Courtenay, University of Waterloo, Canada, External Advisor
*Aneliya Cox, University of New Hampshire
Charles DeCurtis, The Nature Conservancy
Brooke Dejadon, NH Department of Environmental Services
Terry Desmarais, City of Portsmouth, NH
*Alyson Eberhardt, NH Sea Grant/UNH Extension
^Ken Edwardson, NH Department of Environmental Services
*Maria Florencia Fahnestock, University of New Hampshire
*^Nathan Furey, University of New Hampshire
*Neil Ganju, United States Geological Survey
*^Paul Geoghegan, Normandeau Associates Inc.
*Amanda Giacchetti, University of New Hampshire, Jackson Estuarine Laboratory
Jenny Gibson, University of New Hampshire
*Tom Gregory, University of New Hampshire, Jackson Estuarine Laboratory
*Ray Grizzle, University of New Hampshire
^Brianna Group, The Nature Conservancy
*Nathaniel Gruen, University of New Hampshire/PREP
^Dan Hammond, Brown and Caldwell
Larry Harris, University of New Hampshire
*Elizabeth Harvey, University of New Hampshire
^Cynthia Hays, Keene State University
^Brian Howes, UMass Dartmouth, External Advisor
Chris Hunt, University of New Hampshire
^Ralph Jimenez
*Steve Jones, University of New Hampshire
*David Justice, NH GRANIT
^Jud Kenworthy, NOAA (retired), External Advisor
*Adrienne Kovach, University of New Hampshire
^Barbara Kravitz, Hampton Beach Area Commission
*Jake Kritzer, NERACOOS
John Larochelle, City of Rochester, NH
Sarah Leighton
Miguel Leon, University of New Hampshire
*Kevin Lucey, NH Department of Environmental Services Coastal Program

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*^Lara Martin, University of New Hampshire
Jackson Estuarine Laboratory

*Art Mathieson, University of New Hampshire

Atsushi Matsuoka, University of New Hampshire

Bill McDowell, University of New Hampshire

*Grant McKown, University of New Hampshire

Erik Meserve

Kelsey Meyer, University of New Hampshire

*Anna Mikulis, University of New Hampshire

*Gregg Moore, University of New Hampshire

Paula Mouser, University of New Hampshire

^Julianna Mullen, NERACOOS

*Chris Nash, NH Department of Environmental Services

*Anna Ormiston, The Nature Conservancy

^Troy Payne

*Andrew Payne, University of New Hampshire

*Chris Peter, Great Bay National Estuarine Research Reserve

^Suzanne Petersen, Lamprey River Advisory Committee

*Chris Phaneuf, NH GRANIT

*Jody Potter, University of New Hampshire

Joe Rankin

*Michael Routhier, University of New Hampshire

*^Michelle Shattuck, University of New Hampshire

^Fred Short, University of New Hampshire
Jackson Estuarine Laboratory (retired)

^Megan Sims, ME Department of Environmental Protection

*Peter Steckler, The Nature Conservancy

*Rachel Stevens, Great Bay National Estuarine Research Reserve

*^Kevin Sullivan, NH Fish and Game

Danna Truslow, Truslow Consulting

^Stacy Villanueva, Brown and Caldwell

*Krystin Ward, University of New Hampshire

Alison Watts, University of New Hampshire

*^Easton White, University of New Hampshire

*Natalie White, University of New Hampshire

^Wil Wollheim, University of New Hampshire

^Matt Wood, NH Department of Environmental Services

^Celia Y. Chen

^Gretchen Young, City of Dover, NH

* **Technical Author/Lead**

^ **Technical Review**

Additional Support

Great Bay National Estuarine Research Reserve
NH Department of Environmental Services
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Piscataqua Region Monitoring Collaborative

PREP Staff

Kalle Matso, Director
Abigail Lyon, Community Engagement Manager
Trevor Mattera, Habitat Program Manager
Fay Rubin, Special Projects Manager
Sierra Kehoe, Communications Coordinator

Special Recognition

Nathaniel Gruen, University of New Hampshire/PREP
Easton White, University of New Hampshire
Miguel Leon, University of New Hampshire
Julia Saltzman, University of New Hampshire
Wilton Burns, University of New Hampshire
Alicen Armstrong-Brown, Tangram 3DS
Sara Odom, Tangram 3DS
Dolores Leonard, Roca Communications
Matt Wood, NH Department of Environmental Services
Bonnie Brown, University of New Hampshire
Wil Wollheim, University of New Hampshire
Lara Martin, University of New Hampshire
Jackson Estuarine Laboratory
Amanda Giacchetti, University of New Hampshire
Jackson Estuarine Laboratory
Denise Pouliot, Sag8moskwa of the Cowasuck
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of the Pennacook-Abenaki People

Photography

Todd Selig, Town of Durham, NH
Tim Briggs, NH Sea Grant
Atsushi Matsuoka, University of New Hampshire
John Carroll
Emily Lord
Nature Groupie
Krystin Ward, University of New Hampshire
Jackson Estuarine Laboratory
Jerry Monkman
Rayann Dionne, Seabrook-Hampton Estuary Alliance
Anna Mikulis, University of New Hampshire
Lara Martin, University of New Hampshire
Jackson Estuarine Laboratory

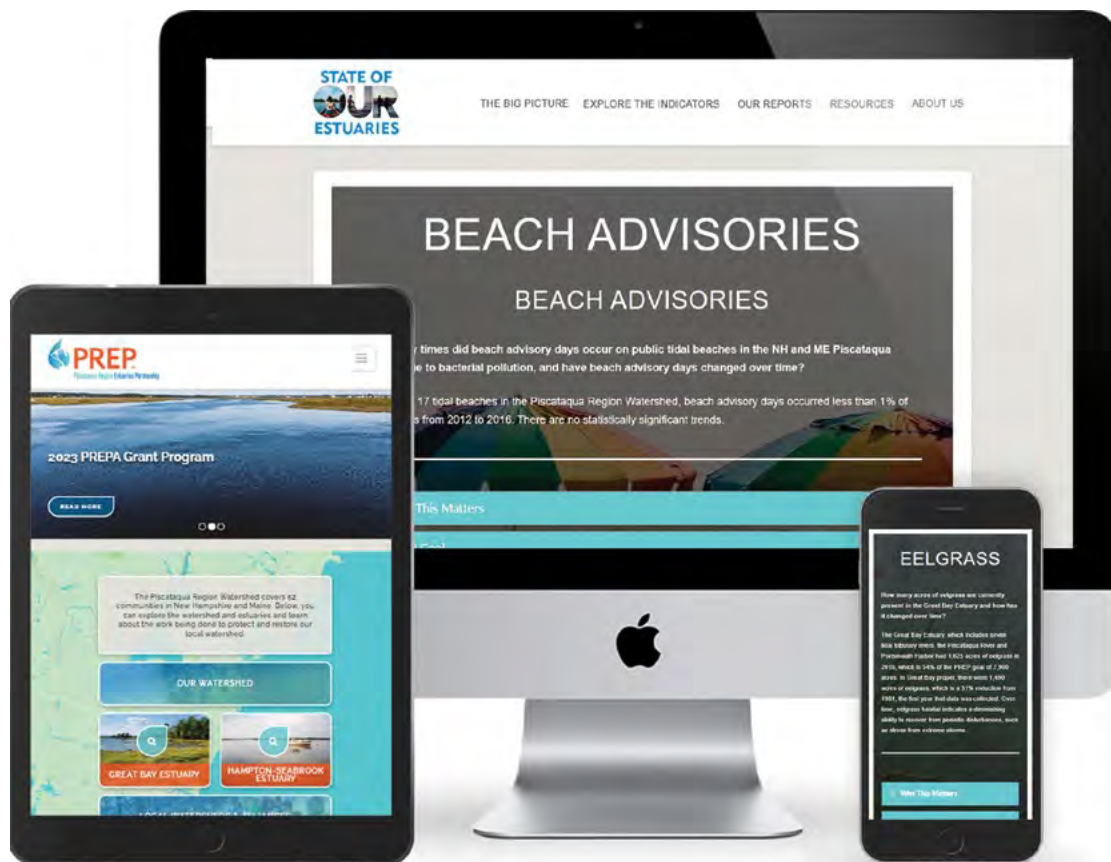
Moral Support

Spouses, Partners, Families, and Friends for emotional support

End Notes

1. See Mallin et al. (2000)
2. See Brabec et al. (2002)
3. See NH Department of Business and Economic Affairs (2021)
4. See U.S. EPA (2009)
5. See UNH Stormwater Center and Vanasse Hangen Brustlin, Inc. (2015)
6. See NHDES (2022)
7. Title 38, §420-D
8. See SWA (2012)
9. See U.S. EPA Office of Wastewater Management (2015)
10. See NHDES (2020)
11. See Western Kentucky University (2021)
12. See PREP (2010)
13. See Wasson et al. (2019)
14. See Anderson and Barnett (2017)
15. See Payne et al. (2019)
16. See Burdick et al. (2020)
17. See Steckler and Ormiston (2021)
18. See Anderson et al. (2020)
19. See ME Department of Inland Fisheries and Wildlife (2017)
20. See NH Fish and Game Department (2020a)
21. See NH Fish and Game Department (2020b)
22. See Steckler and Brickner-Wood (2019)
23. See Steckler et al. (2016)
24. See Zankel et al. (2006)
25. See Walker et al. (2010)
26. See Jones et al. (1992)
27. See Jones (2000)
28. See Lemcke-Stampone et al. (2022)
29. See Jayhoe et al. (2007)
30. See Runkel et al. (2004)
31. See U.S. EPA (2012)
32. See Bricker et al. (2003)
33. See Batiuk et al. (2009)
34. See Morrell and Gobler (2020)
35. See Batiuk et al. (2009)
36. See Barker (2019)
37. See Jones (2000)
38. See Short et al. (1993)
39. See Moore et al. (2014)
40. See U.S. EPA (2012)
41. See Kemp (2004)
42. See Trowbridge (2009)
43. See Bierman (2014)
44. See NH Estuaries Project and Jones (2000)
45. See Jones (2021)
46. See Urquhart et al. (2016)
47. See Xu et al. (2015)
48. See Hartwick et al. (2021)
49. See Ao et al. (2017)
50. See Grizzle and Ward (2020)
51. See Odell et al. (2006)
52. See Stasse et al. (2021)
53. See NH Fish and Game Department (2013)
54. See Grizzle et al. (2021)
55. See Capone et al. (2008)
56. See Grizzle et al. (2021)
57. See Atwood and Grizzle (2020)
58. See Glenn (2016)
59. See Glenn et al. (2020)
60. See Metzger et al. (2015)
61. See Metzger et al. (2016)
62. See Metzger et al. (2018)
63. See Carballal et al. (2015)
64. See Geoghegan et al. (2021)
65. See Normandeau (2021)
66. See NHDES (2017)
67. See Canadian Council of Ministries of the Environment (2023)
68. See Apeti et al. (2021)
69. See NHDES (2021)
70. See Weeks et al. (2011)
71. See Apeti et al. (2021)
72. See Barley-Greenfield (2017)

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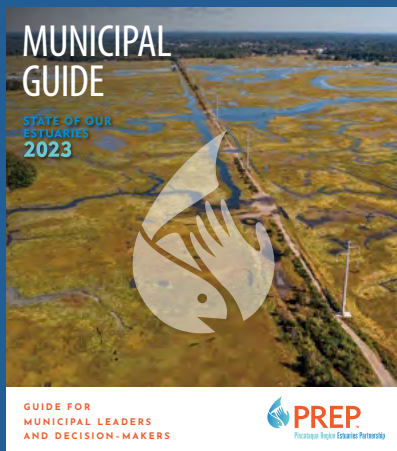
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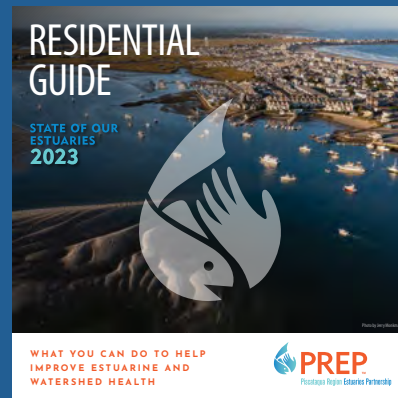
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