Fisheries and Oceans Canada | Pêches et Océans Canada
Ecosystems and Oceans Science | Sciences des écosystèmes et des océans

Canadian Science Advisory Secretariat
Maritimes Region | Science Advisory Report 2024/013

# UPDATE ON THE STATUS OF AMERICAN EEL AND ELVER FISHERIES IN MARITIMES REGION AND SCIENCE ADVICE ON AVAILABLE REGIONAL INDICES

*American Eel, Anguilla rostrata (Lesueur 1817). From United States Fish and Wildlife Service.*

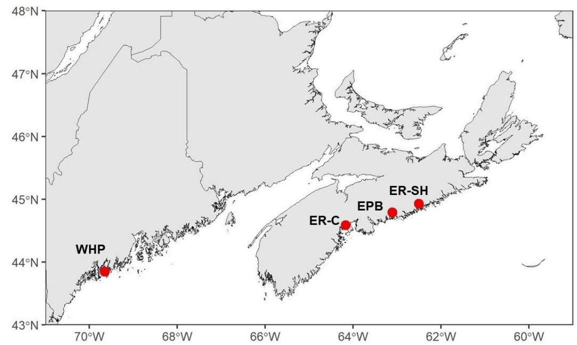


*Figure 1. Map of elver monitoring sites (ER-SH=East River-Sheet Harbour; EPB=Eel Pond Brook; ER-C=East River-Chester; WHP=West Harbor Pond) as considered in this assessment by Fisheries and Oceans Maritimes Science.*

## Context:

*The American Eel (*Anguilla rostrata*) fisheries in Fisheries and Oceans Canada (DFO) Maritimes Region were last assessed in 2018 (DFO 2019; Bradford et al. 2022). At the time, spawner-per-recruit (SPR) analysis (ICES 2001; Chaput and Cairns 2011) was used to define mortality reference points for all directed fisheries and hydroelectric facilities. The assessment of mortality relative to reference points was limited to the elver fishery because of a lack of information concerning large eel harvest, biomass, and survival. The mortality rate that results in a 70% loss of spawning biomass relative to the population without losses from human activities (SPR30) was recommended as the limit mortality reference point for the elver fishery. The East River-Chester (ER-C) elver recruitment index was recommended as the primary indicator of American Eel productivity in the Maritimes Region.*

*Since 2018, direct monitoring has been reduced in some years and not possible in other years due to fishery closures for conservation and public safety reasons. This has led to increased uncertainty in the information available to inform decisions on watershed-based harvest levels relative to the maximum acceptable fishing mortality rate. Given data deficiencies and uncertainties in annual estimates of elver recruitment and escapement at ER-C for the last five years, there could be negative impacts to regional American Eel productivity if directed and unreported elver harvesting continues at levels considered to be unsustainable. While DFO Science continues to review methods and data sources in support of the precautionary management of Maritimes Region American Eel and elver fisheries, DFO Maritimes Resource Management asked for, to the extent possible, updated information on the status, trends, and distribution of large eel and elver fisheries from 2017 to 2022.*

*This Science Advisory Report is from the regional peer review on October 11–12, 2023, on the Updated Science Advice on Status of American Eel and Elver Fisheries in Maritimes Region. Additional* *publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.*

## SUMMARY


- Based on reported landings from the large eel fishery, the number of commercial licenses that are active has decreased over the past decade. In recent years, it appears that the fishery has been prosecuted by a small (9% to 11% of the total licenses), consistent group of license holders. As a result, significantly fewer eels are now landed than in the past when participation, in terms of both participants and deployed gear, was much higher.
- There is a large number of commercial eel licences that are not actively fished at present, which represents a high level of latent gear. There is known to be a high level of unauthorized harvesting directed towards elvers at present. These factors represent sources of potential and realized eel exploitation, respectively, in the Maritimes Region not reflected in the reported catches for eel and elver, and are sources of uncertainty for this assessment.
- East River-Chester (ER-C) elver index was completed in three of the five years since the last assessment. This index suggests that the average elver run size is above the 1996-2018 reference level median run size estimate of 320 kg (2.33 kg/km$^2$) and either approximately equivalent to or greater than the 75th quantile run sizes for the 1996–2018 time period (466 kg, 3.40 kg/km$^2$).
- Catch and catch per unit effort (CPUE) were evaluated as potential alternative or supplemental sources of information. While a CPUE index may provide some useful supplemental information to help with interpretation of other indices, or assisting interpretation of years for which other indices are not available, there are issues related to the ability to standardize and to the impact of external factors such as market and price. It is not a replacement for fishery-independent indices.
- Two other current and former regional elver abundance indices were evaluated, and while they could provide supplemental information for comparison with the ER-C index, they were not considered to be an immediate alternative to the ER-C index, as they were either not correlated with the ER-C index (e.g., West Harbor Pond (WHP)) or have been discontinued (Eel Pond Brook (EPB)).
- Analyses of the Maritimes Salmon Electrofishing Database provide some information on eels and have been reported previously as indices of standing stock. Analysis of the existing data for the LaHave, St. Mary's and Nashwaak rivers show differing trends from 2002–2022, with an increasing trend in LaHave and no trend in St. Mary's or Nashwaak. Estimates of eel densities for 2021 and 2022 were above the 50th quantile for all three rivers.
- There are no indications that silver eel escapement from either Eel Pond Brook or Oakland Lake Stream has changed appreciably since the inception of monitoring in 2014 and 2011, respectively. Adult production in both catchments is approximately one adult per hectare of catchment area.
- Directed monitoring of young migratory yellow eels at fixed locations has potential to provide information to supplement the ER-C elver index and the electrofishing-based estimates of eel standing stock, with lags of several years (the duration of which may be dependent on distance from the head of tide). However, the episodic nature of high catches of juveniles both within and among years indicates that uninterrupted monitoring for an extensive period of time beginning in the spring and extending into the autumn may be required.

- This assessment demonstrated the importance of having consistent and accurate time series of information for analysis, and the importance of accounting for removals, including the implications of high levels of unauthorized harvesting directed towards elvers.

## BACKGROUND

American Eel (*Anguilla rostrata*) are fished at the elver (recruiting), yellow eel (rearing), and silver eel (adult) stages in DFO Maritimes Region. Elvers, defined in regulations as American Eels less than 10 cm in total length, are managed through an Integrated Fisheries Management Plan (IFMP; DFO 2018) as a distinct fishery. Directed fisheries for yellow eel and silver eel, referred to as ‘large eels’ or simply ‘eels’, occur for Food, Social, and Ceremonial (FSC), commercial, communal commercial, and recreational purposes. An Integrated Fishery Management Plan has not been developed for the eel fishery.

The ability to detect trends in large eel catch and effort over decadal or longer time scales is limited by availability of detailed fishing records, but, in combination with licence information, recent landings can be examined in the context of participation rates and fishery potential (gear types and amounts under licence; DFO 2017). Elver fishery landings and fishing locations have been well documented in logbooks since the inception of the commercial fishery in 1996, but use of daily catch and effort records is hampered by inconsistencies in the manner of reporting daily catches that persist among licence holders.

Since 2018, monitoring of the annual elver runs to East River-Chester (ER-C; Lunenburg County, N.S.) has been reduced in some years and not possible in other years due to fishery closures for conservation and public safety reasons. Estimates reported previously (DFO 2018) for the years 1996–2002, 2008–2018 are supplemented with one credible estimate acquired in 2019 and underestimates for 2021 and 2022. No data was collected in either 2020 or 2023; therefore, the continuing utility of the ER-C index as an indicator of recruitment is uncertain. DFO Maritimes Resource Management requested an assessment of alternative and supplemental annual indices from the region.

While not quantitatively documented, high levels of unauthorized harvesting directed towards elvers were known to be wide-spread and occurred in all years since the 2018 assessment to the extent that the elver fishery was closed by Fishery Management Order in 2020 and again in 2023. The extent of spatial overlap in fisheries removals of eels as elvers versus older life-stages since 2018 (e.g., how fisheries for different life stages are separated geographically) is uncertain.

The purposes of this assessment are to update the large eel fishery catch and effort information for the years 2017 to 2022, update from 2018, to the extent possible, the ER-C elver recruitment index, and to assess alternative and supplemental annual indices of eel and elver abundance from the region.

## ASSESSMENT

### TOR 1: Update Large Eel Fishery Catch and Effort Information for the Years 2017 to 2022

The number of licences reporting eel catches by year, province, and licence type, as well as their associated reported catches and estimated landed value from 2017 to 2022 are provided in Table 1. Note that COVID-related factors are thought to have influenced the number of active participants (n=16) in 2020.

*Table 1. The number of active commercial licences reporting eel catches by year, province, and their associated reported catches (kg) and estimated landed values ($). Dashes (–) indicate that the aggregation of these data by individual province do not meet confidentiality requirements under DFO's Rule of Five policy, and can therefore not be shared publicly. Data from 2019–2022 are considered preliminary. Data for communal commercial and recreational fishing is not reported to DFO.*

| Year | Province | Licence Type | Licences Fished | Total Landings Live Weight (kg) | Total Landings Value ($) |
|---|---|---|---|---|---|
| 2017 | NB | Commercial | 8 | 22,967 | – |
| 2017 | NS | Commercial | 24 | 14,007 | – |
| 2017 | NS + NB | Totals | 32 | 36,974 | 243,051 |
| 2018 | NB | Commercial | 6 | 19,072 | – |
| 2018 | NS | Commercial | 23 | 13,927 | – |
| 2018 | NS + NB | Totals | 29 | 32,999 | 187,665 |
| 2019 | NB | Commercial | 6 | 12,464 | – |
| 2019 | NS | Commercial | 24 | 5,206 | – |
| 2019 | NS + NB | Totals | 30 | 17,670 | 97,353 |
| 2020* | NS + NB | Totals | 16 | 8,191 | 34,666 |
| 2021 | NB | Commercial | 9 | 12,955 | 64,957 |
| 2021 | NS | Commercial | 17 | 9,631 | 52,018 |
| 2021 | NS + NB | Totals | 26 | 22,586 | 116,975 |
| 2022 | NB | Commercial | 7 | 23,895 | 83,158 |
| 2022 | NS | Commercial | 16 | 12,169 | 39,754 |
| 2022 | NS + NB | Totals | 23 | 36,064 | 122,912 |

* *The aggregation of these data by individual province for the fishing year 2020 does not meet Fisheries and Oceans Canada's rule of five for the protection of privacy of the fishers involve, and can therefore not be shared publicly. The rule of five guideline means there must be a minimum number of five units for aggregation of data in each category.*

Based on reported landings, the number of commercial licences that are active has decreased since the high landings in 1995 (Figure 2). In recent years, it appears that the fishery is being prosecuted by a small, consistent group of licence holders, in the range of 23 to 30 per year, or 9% to 11% of the total licences. As a result, significantly fewer eels are now landed than in the past when participation, in terms of both participants and deployed gear, was much higher. The data from 2019–2022 should be considered preliminary.

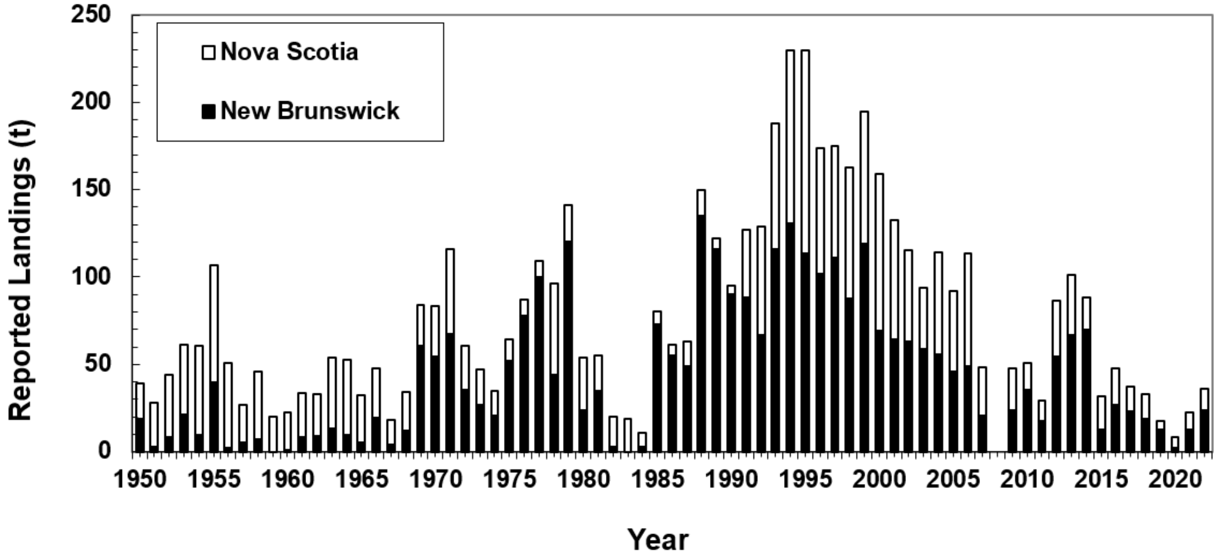


*Figure 2. Summary of annual reported commercial landings (t) of American Eel (large eel only) for the years 1950 to 2022 by province by year (open bars: Nova Scotia, solid bars: New Brunswick).*

The New Brunswick sector remained smaller (approximately 20–35%) than the Nova Scotia sector of the fishery in terms of active licences, but accounted for 50% or more of the reported landings in some years.

The number of eel licences available has continued to decline with time, from 436 in 2016 (DFO 2019) to 370 in 2022. Since 2016, 22 licences have been exchanged for green crab licences. The practice of not renewing recreational licences as participants leave the fishery resulted in a decline of 10 recreational eel licences, from 119 in 2017 to 109 in 2022. The commercial sector remains larger than either the communal commercial or recreational sectors. The quantities of gear authorized to fish for eels has declined with time, from 25,289 units in 2016 (DFO 2019) to 21,106 units in 2022. The quantity of gear associated with commercial licences reporting eel catches remains a minor component of the total quantity that could potentially be set, between 9–11% per year.

Quantities of all substantive gear types declined between 2017 and 2022. Pots declined from 21,929 units to 19,199 units, fyke nets from 2,075 units to 1,880 units, and weirs from 25 installations to 19 installations. The number of commercial longlines remained unchanged at six.

There are a large number of commercial eel licences that are not actively fished at present, which represents a high level of latent gear. Neither recreational nor FSC catch of large eels is reported consistently on an annual basis, though available information indicates these fisheries are of a smaller scale. These factors represent a source of potential and realized eel exploitation in the Maritimes Region not reflected in the reported catches for eel, and are sources of uncertainty for this assessment.

## TOR2: Update from 2018 the East River-Chester elver recruitment index

The ER-C recruitment index was completed in only three (2019, 2021, 2022) of the five years since the last assessment due to fishery closures for conservation and public safety reasons. All three of the available estimates were above the 1996–2018 reference level median run size estimate of 320 kg (2.33 kg/km$^2$; Table 2, Figure 3) and either approximately equivalent to or greater than the 75$^{th}$ quantile run sizes for the 1996–2018 time period (466 kg, 3.40 kg/km$^2$).

Two (2019, 2022) of the three estimates were greater than the 75th quantile run size for the time series extended to 2022 (499 kg, 3.64 kg/km$^2$; Figure 3).

The ER-C recruitment index shows high interannual variability, as is typical for many recruitment indices. The estimate of 1,610 kg obtained in 2022 is larger by a factor of 1.8 from the previous time series high of 896 kg estimated in 2018 and larger by a factor of 19 from the time series low of 85 kg estimated in 1999. Other sources of information available for consideration in this review were consistent with an interpretation of high recruitment in these two years.

*Table 2. Annual numbers (n) of elvers to East River-Sheet Harbour, Nova Scotia (NS; ER-SH), East River-Chester, NS (ER-C), Eel Pond Brook, NS (EPB), and West Harbor Pond, Maine, United States of America (WHP). Run size to ER-C is also reported in kilograms (kg). Regression (kg) and regression (n) for ER-C are derived from the predicted linear relationship between ER-SH and ER-C as calculated for the years 1996–1999. Dashes (–) indicate years where sampling did not occur. NA indicates not applicable.*

| Year | ER-SH (n) | ER-C (n) | ER-C (kg) | Regression (kg) | Regression (n) | EPB (n) | WHP (n) |
|---|---|---|---|---|---|---|---|
| **1990** | 218,300 | – | – | 189 | 1,021,688 | – | – |
| **1991** | 376,000 | – | – | 313 | 1,692,051 | – | – |
| **1992** | 219,200 | – | – | 190 | 1,025,596 | – | – |
| **1993** | 134,100 | – | – | 120 | 650,076 | – | – |
| **1994** | 309,900 | – | – | 262 | 1,414,184 | – | – |
| **1995** | 101,500 | – | – | 93 | 502,030 | – | – |
| **1996** | 336,500 | 1,367,609 | 277 | 282 | 1,526,472 | – | – |
| **1997** | 467,400 | 1,887,151 | 359 | 383 | 2,070,596 | – | – |
| **1998** | 109,200 | 594,729 | 117 | 99 | 537,273 | – | – |
| **1999** | 134,600 | 530,760 | 85 | 121 | 652,324 | – | – |
| **2000** | – | 879,854 | 149 | NA | NA | – | – |
| **2001** | – | 647,516 | 120 | NA | NA | – | 52,638 |
| **2002** | – | 2,689,021 | 536 | NA | NA | – | 82,359 |
| **2003** | – | – | – | NA | NA | – | 15,905 |
| **2004** | – | – | – | NA | NA | – | 2,401 |
| **2005** | – | – | – | NA | NA | – | 73,178 |
| **2006** | – | – | – | NA | NA | – | 4,812 |
| **2007** | – | – | – | NA | NA | – | 988 |

| Year | ER-SH (n) | ER-C (n) | ER-C (kg) | Regression (kg) | Regression (n) | EPB (n) | WHP (n) |
|---|---|---|---|---|---|---|---|
| **2008** | – | 1,970,988 | 458 | NA | NA | – | 46,167 |
| **2009** | – | 1,426,196 | 280 | NA | NA | – | 12,811 |
| **2010** | – | 774,811 | 156 | NA | NA | – | 10,314 |
| **2011** | – | 2,390,790 | 468 | NA | NA | – | 9,658 |
| **2012** | – | 2,587,177 | 439 | NA | NA | – | 156,472 |
| **2013** | – | 2,214,696 | 387 | NA | NA | – | 84,509 |
| **2014** | – | 2,748,237 | 499 | NA | NA | 15,535 | 140,706 |
| **2015** | – | 1,430,167 | 277 | NA | NA | 26,685 | 31,666 |
| **2016** | – | 2,951,576 | 610 | NA | NA | 40,175 | 106,990 |
| **2017** | – | 1,150,707 | 253 | NA | NA | 4,173 | 236,080 |
| **2018** | – | 3,793,992 | 896 | NA | NA | 149,315 | 67,380 |
| **2019** | – | 2,515,559 | 534 | NA | NA | 110,976 | 160,211 |
| **2020** | – | * | * | NA | NA | – | – |
| **2021** | – | 2,071,555** | 463** | NA | NA | – | – |
| **2022** | – | 7,273,401** | 1,610** | NA | NA | – | – |

**Sampling on the East River-Chester did not occur in 2020 due to COVID-19 restrictions.*

***The East River-Chester elver index in 2021 and 2022 is considered to represent an underestimate of total run size due to unreported catch*

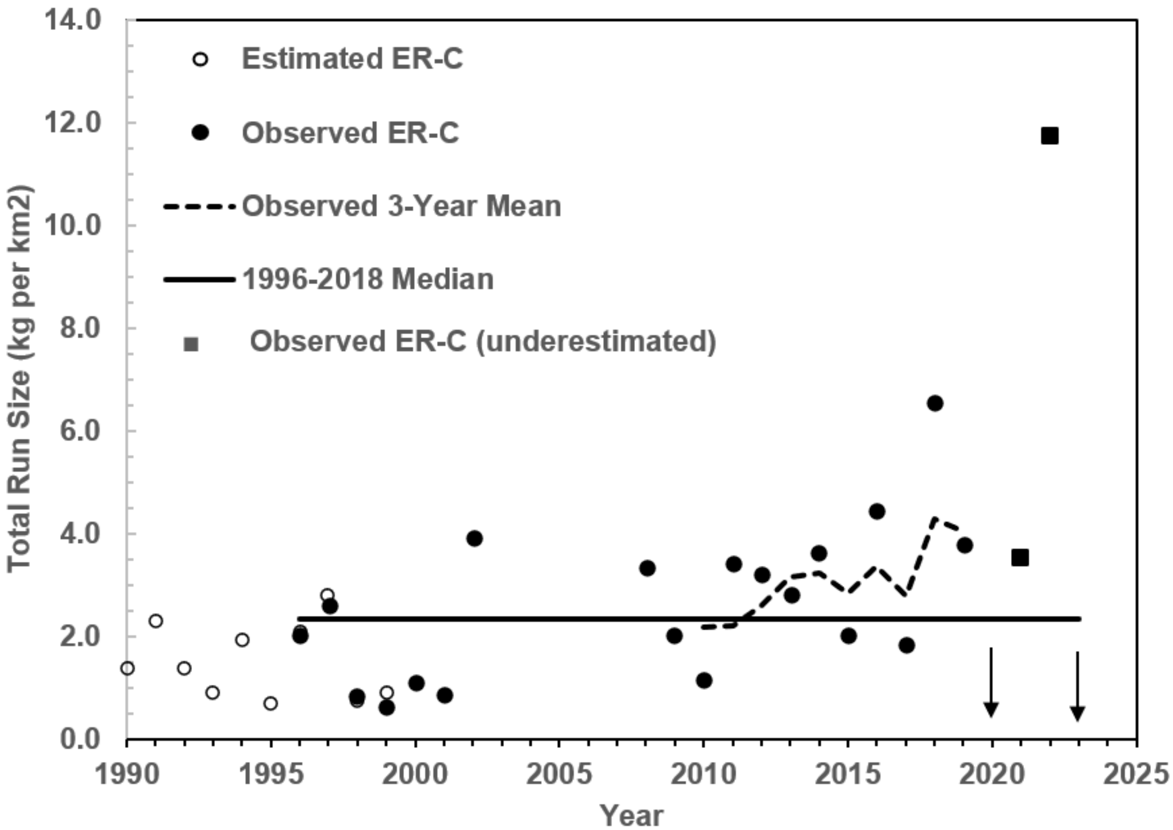


*Figure 3. The East River-Chester (ER-C) elver abundance index expressed in terms of elver weight (kg per km²) of receiving habitat. Open circles represent predicted values from the regression of ER-C run size with East River-Sheet Harbour run size for the years 1996 to 1999. The closed circles are the observed estimates for ER-C. The solid black line represents the 1996–2018 reference-level median run size. The dashed line represents the 3-year running mean. Arrows indicate years since 2018 when the ER-C survey was not conducted. Solid squares depict years since 2018 where the index is considered to represent an underestimate of total run size due to unreported catch.*

## TOR3: Assess alternative and supplemental annual indices of eel and elver abundance from the region

Alternative and supplemental annual indices were assessed because high levels of unauthorized harvesting directed towards elvers on the ER-C raises uncertainty that the index can continue into the future.

### Commercial Elver Catch and Effort Data

The total annual elver catch since the last assessment in 2018 continued to trend up in the years when fishing activity was not truncated by early closure of the fishery by Fisheries Management Order (FMO; Figure 4). Reported landings in 2019 (8.05 t), 2021 (6.40 t), and 2022 (8.30 t) represented respectively 0.81, 0.64, and 0.83 of the overall Total Allowable Catch (TAC) of 9.96 t. Reported landings in the years the fishing season was shortened by FMO, shortly after the onset of authorized commercial fishing reported landings were 2.95 t in 2020 and 5.50 t in 2023, representing 0.30 and 0.55 of the TAC, respectively.

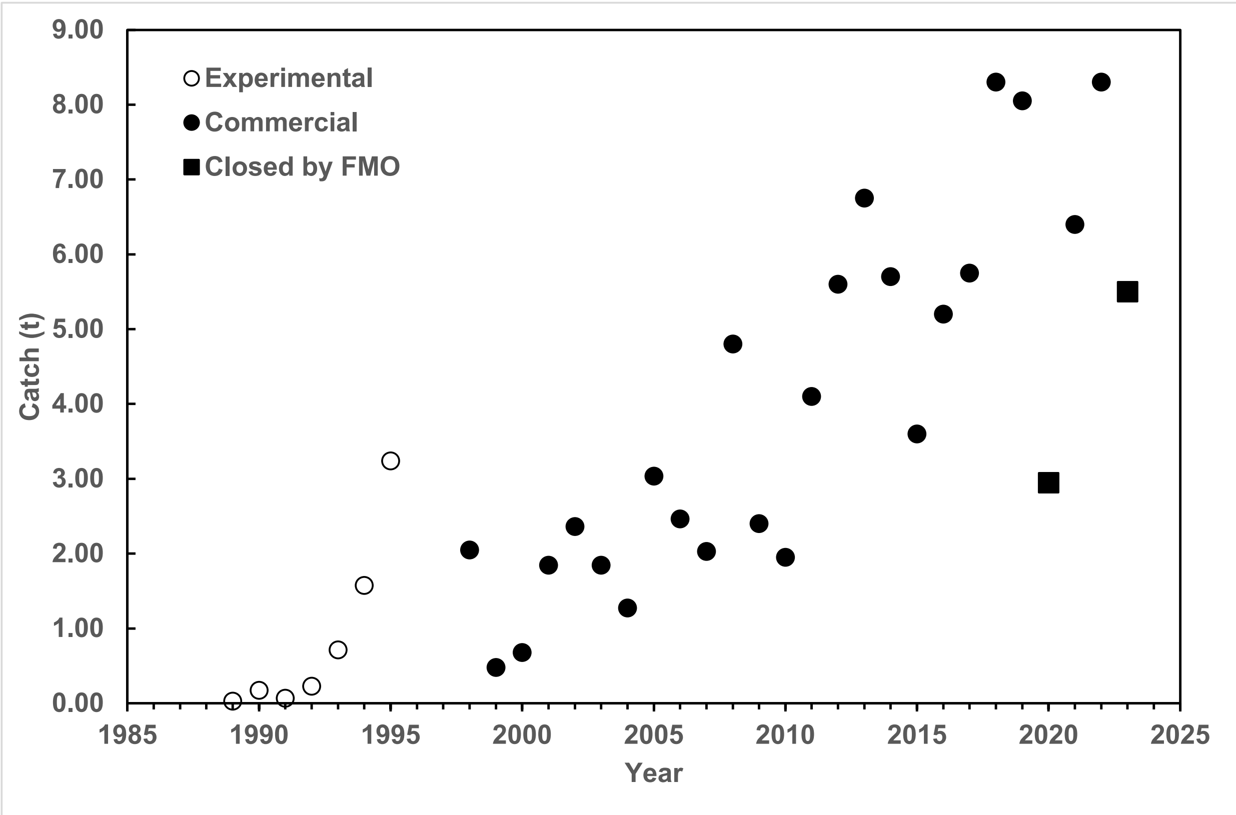


*Figure 4. Elver landings (mt) versus time (years). Estimates for the years 2008 to 2018 have been revised from those reported previously in DFO 2018 and Bradford et al. 2022. Open and closed circles represent years of experimental and commercial fishing respectively. Closed squares indicate the years that the fishery was closed, via Fishery Management Order, for conservation and public safety reasons shortly after the onset of authorized commercial fishing.*

A total of 131 of the 160 annual catch and effort records, distributed among six of the eight commercial licences, for the years 1996 to 2022 were considered suitable for exploring the potential relationship between annual reported commercial catches (kg) and time (year). All annual catch records were truncated to the date that the individual quota (IQ) was reached. Generalized Linear Mixed Models (GLMM) were constructed treating each of the six licences as a random effect, log effort as an offset, and a number of indices for elver price and fishing success relative to the IQ as factors.

The best model for the elver catch versus year with licence defined as a random effect retained log area as an offset and Q90 (reported catch within 90% of IQ) with both Year and Q90 being statistically significant at $p \leq 0.05$ when defined as factors. Predicted and nominal catch and catch per unit effort (CPUE; Figure 5) are relatively high in the first years of the fishery (1996 and 1997), declining to series lows in 1999 and 2000 from which an evident increase with time had occurred.

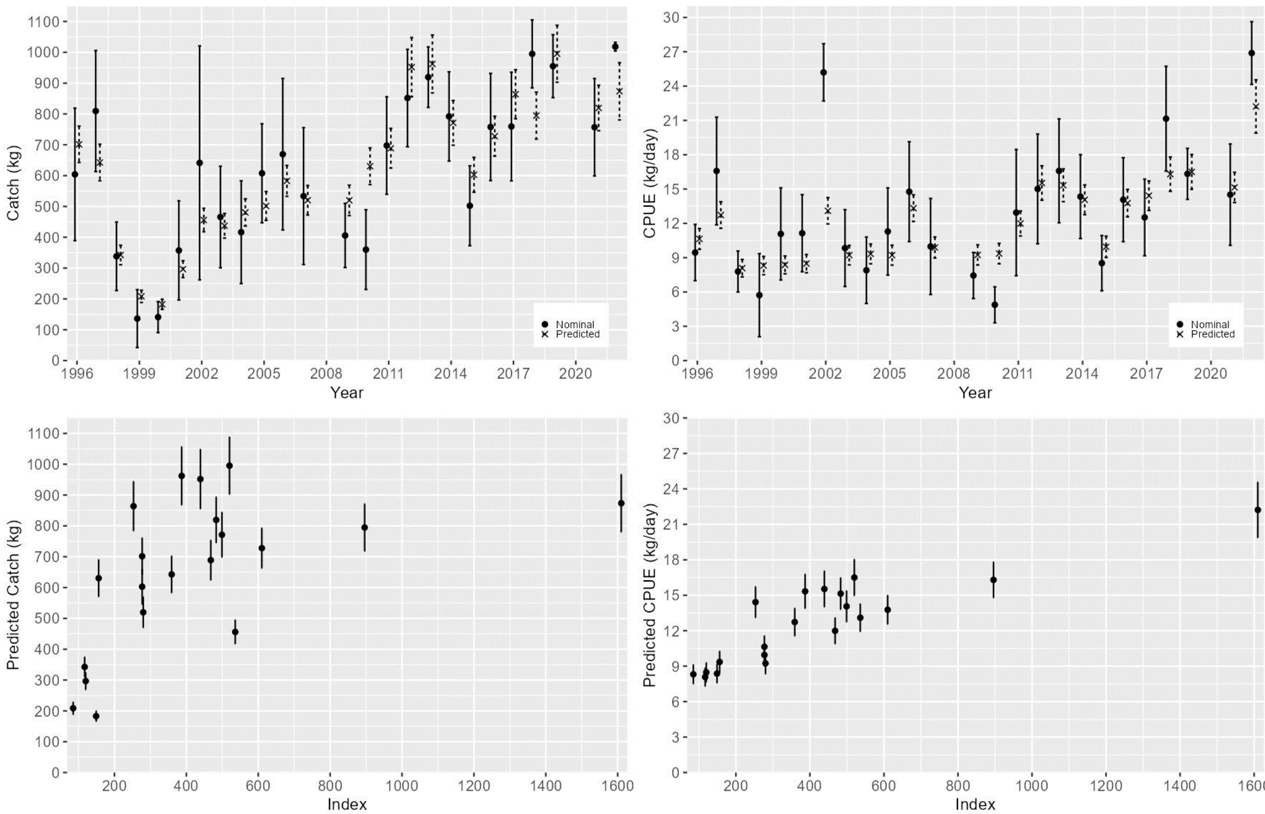


*Figure 5. Predicted and nominal relative elver catch weight (top left) and elver catch per unit effort (CPUE; top right) by year. The lower left and lower right panels show the predicted catch and predicted CPUE, respectively, versus the East River-Chester elver index. Vertical lines represent the standard error ranges of the estimates.*

Both data series exhibit statistically significant positive trends with time (Mann-Kendall tests, Table 3). Autoregressive integrated moving average (ARIMA) analyses indicated that both the aggregate predicted catch and aggregate predicted CPUE estimates for the years 2019, 2020, and 2021 are not likely to be less than the 75$^{th}$ quantiles for either the1996–2022 or the 1996–2018 series (Table 3).

*Table 3. Autoregressive integrated moving average (ARIMA) and trend analyses results for elver Catch and elver CPUE. The 1996–2022 reference range (RR) represents the entire time series whereas the 1996–2018 RR corresponds to the data that was available for the past assessment. The years 2019, 2020, and 2021 are selected as the reference years (RY) as these represent the sum total of the catch data for the years since the last assessment in 2018. The 75th Quantile (Q75) is the reference level and Pr is the probability that the RY value lies below the Q75. Mann-Kendall (M-K) tau (τ) statistics for trend and Shapiro-Wilks (S-W) statistic (W) is shown with the probability that the residual values from the ARIMA are not normally distributed. Dashes (–) indicate not applicable.*

| Series | RR Start | RR End | n | RY Year | Pr(RY < Q75) | M-K τ | p-value | Trend | S-W W | p-value |
|---|---|---|---|---|---|---|---|---|---|---|
| Catch | 1996 | 2022 | 25 | 2022 | 0.31 | 0.613 | <0.001 | Positive | 0.95 | 0.3 |
| Catch | 1996 | 2018 | 25 | 2022 | 0.19 | – | – | – | – | – |
| PUE | 1996 | 2022 | 25 | 2019, 2021, 2022 | 0.06 | 0.624 | <0.001 | Positive | 0.95 | 0.3 |
| CPUE | 1996 | 2018 | 25 | 2019, 2021, 2022 | 0.17 | – | – | – | – | – |

Plots of predicted catch versus the ER-C elver index value corresponding to the catch prediction year (Figure 5) corroborates the perception that catch is not a good indicator of elver availability as measured at ER-C. Predicted catches of between approximately 450 kg per year and approximately 995 kg per year have occurred at runs sizes of between 520 kg and 536 kg per year (Figure 5). Catches within this range have been predicted for run sizes that exceed 500 kg by factors of nearly two (896 kg) and three (1600 kg). Predicted average CPUE of 18 kg per day or higher may be indicative of run sizes exceeding 1,000kg (Figure 5).

Catch and CPUE were evaluated as potential alternative or supplemental sources of information. While a CPUE index may provide some useful supplemental information to help with interpretation of other indices, or assisting interpretation of years for which other indices are not available, there are issues related to the ability to standardize and to the impact of external factors such as market and price. It is not a replacement for fishery-independent indices.

## Elver Abundance Indices Other Than for East River-Chester

Two other current or former regional elver abundance indices were evaluated for their potential usefulness as supplemental or alternatives to the ER-C recruitment index: West Harbor Pond, Maine, United States of America (WHP) and Eel Pond Brook, Nova Scotia (EPB; see index locations in Figure 1).

The average elver run size (n) for ER-C (2.1 million ± 1.5 million standard deviation (SD)), WHP (68 thousand ± 89 thousand SD) and EPB (58 thousand ± 58.5 thousand SD) exhibited significant variability, both among data series and among years within series (Table 2). The order of average total run size relative to catchment area (137 $km^2$ for ER-C, 13.3 $km^2$ for WHP, and 3.7 $km^2$ for EPB) is consistent with the interpretation of Bradford et al (2022), based on a pattern of increasing elver catch with increasing catchment area, that elver recruitment, and therefore availability of elvers to capture, is associated with the amount of attraction flow discharged from individual waterways.

The ER-C and WHP indices are not statistically significantly correlated for the years data were available for both indices (2001–2002, 2008–2019; Table 4a), but differ significantly (t-test Table 4b). For the years common to all three index series (2014–2019) only the EPB and ER-C pair exhibited a statistically significant positive relationship (n=6, $r^2$=0.66, $p<0.05$; Figure 6).

*Table 4a. Results of analysis of variance (ANOVA) among elver abundance indices scaled to number of elvers per km$^2$ of receiving habitat for East River-Chester (ER-C), Eel Pond Brook (EPB) and West Harbor Pond (WHP). The Years column indicates the years of observations associated with each test. DF = Degrees of Freedom.*

| Years | DF | F-Value | Pr(>F) |
|---|---|---|---|
| **All** | 2,43 | 6.178 | 0.01 |
| **2001–2002, 2008–2019** | 2,36 | 8.152 | 0.01 |
| **2014–2019** | 2,15 | 1.044 | 0.38 |

*Table 4b. Results of t-test between East River-Chester (ER-C) and West Harbor Pond (WHP) for years of common monitoring. The Years column indicates the years of observations associated with the test. DF = Degrees of Freedom.*

| Years | DF | t | p-value |
|---|---|---|---|
| **2001–2002, 2008–2019** | 24 | 3.9891 | 0.001 |

*Table 4c. Results of Tukeys highly significant difference tests between pairs of indices. The Years column indicates the years of observations associated with each test. East River-Chester (ER-C), Eel Pond Brook (EPB), West Harbor Pond (WHP).*

| Years | River Comparisons | Difference | Lower | Upper | p adjusted |
|---|---|---|---|---|---|
| **All** | EPB, ER-C | 367 | -10,540 | 11,273 | 0.99 |
| **All** | WHP, ER-C | -10,132 | -17,592 | -2,673 | 0.01 |
| **All** | WHP, EPB | -10,499 | -21,532 | 534 | 0.07 |
| **2001–2002, 2008–2019** | EPB, ER-C | 352 | -9,106 | 9,807 | 0.99 |
| **2001–2002, 2008–2020** | WHP, ER-C | -10,146 | -16,971 | -3,321 | 0.01 |
| **2001–2002, 2008–2021** | WHP, EPB | -10,499 | -19,573 | -1,424 | 0.02 |
| **2014–2019** | EPB, ER-C | -2,125 | -17,901 | 13,651 | 0.94 |
| **2015–2019** | WHP, ER-C | -8,439 | -24,215 | 7,338 | 0.37 |
| **2016–2019** | WHP, EPB | -6,313 | -22,090 | 9,463 | 0.56 |

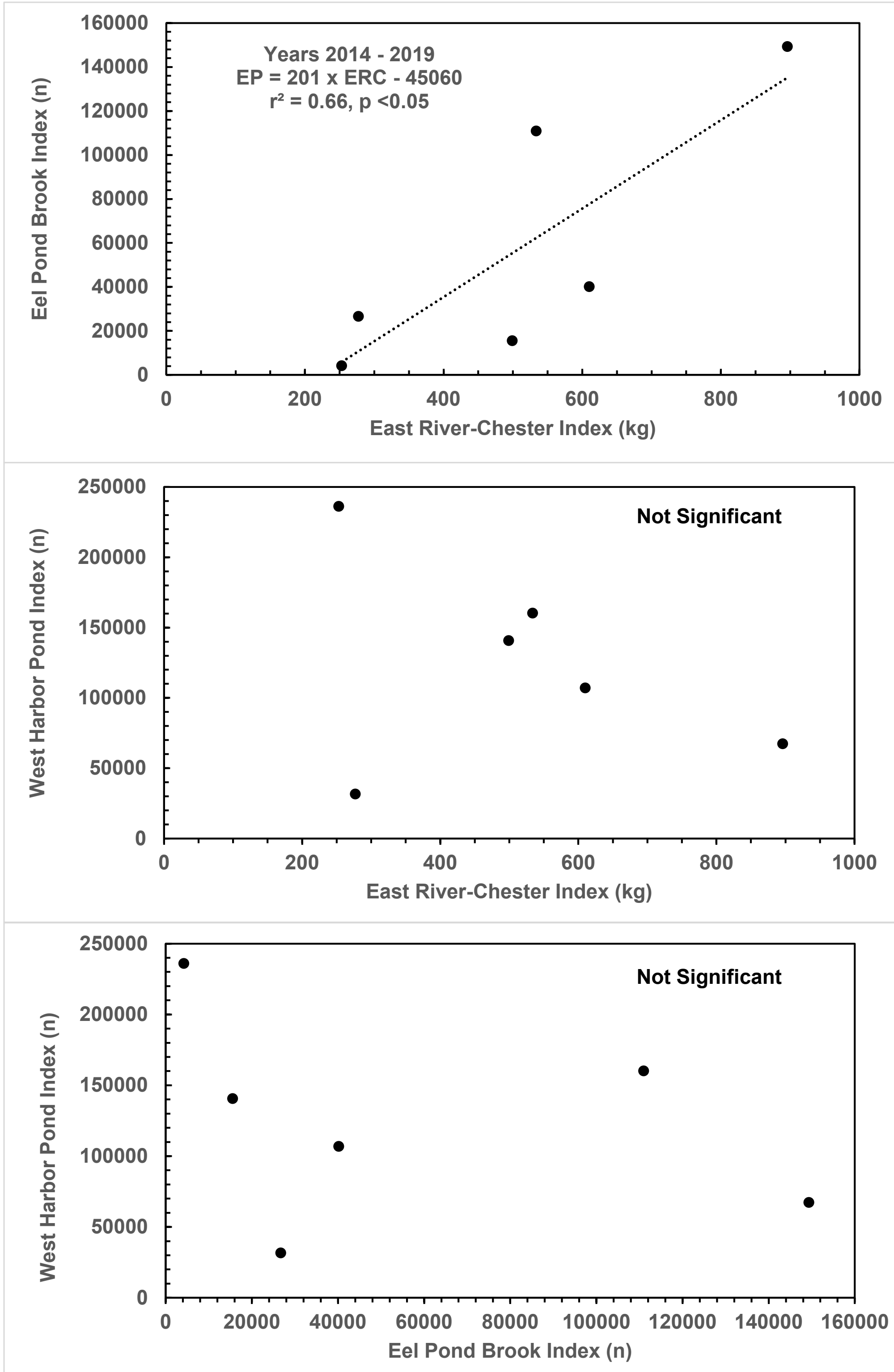


*Figure 6. Plots of estimated total annual run size for (upper panel) East River-Chester (kg) versus Eel Pond Brook (n), (middle panel) East River-Chester (kg) versus West Harbor Pond (n), and (lower panel) Eel Pond Brook (n) versus West Harbor Pond (n) elver for the years 2014 to 2019.*

EPB elver run density does not differ statistically from the ER-C elver run density (Tukeys HSD p=0.94 for the years 2014–2019, Table 4c). However, any inference that elver runs to Atlantic Coastal Nova Scotia are more similar in size (at least at a length scale of approximately 100 km) than they are to runs in the Gulf of Maine, needs to consider that elver run density does not differ statistically between EPB and WHP for the same 2014–2019 time period (Tukeys HSD p=0.37; Table 4c).

The average run density of 3.12 kg per km$^2$ to ER-C for the years 1996–2021 is higher than the average run density of 2.58 elvers per km$^2$ estimated for the 1996–2018 time period.

While the EPB index is consistent with the ER-C index, and could provide useful historical supplementation information, it was discontinued in 2019 and is therefore not an alternative to the ER-C index. The WHP index, while not correlated with the ER-C index, does provide supplementary information on spatial variability in elver recruitment in terms of total run size (n) and relative to size of receiving habitat (kg/km$^2$).

## Electrofishing-Based Abundance Indices

Figure 7 shows the results of GLMM models, revised and updated from those reported in Cornic et al. (2022), of eel densities (eel per 100 m$^2$) versus time using site information that included swept area (m$^2$), flow (m$^3$/sec), and water temperature ($^0$C) for the LaHave River, St. Mary’s River, and Nashwaak River.

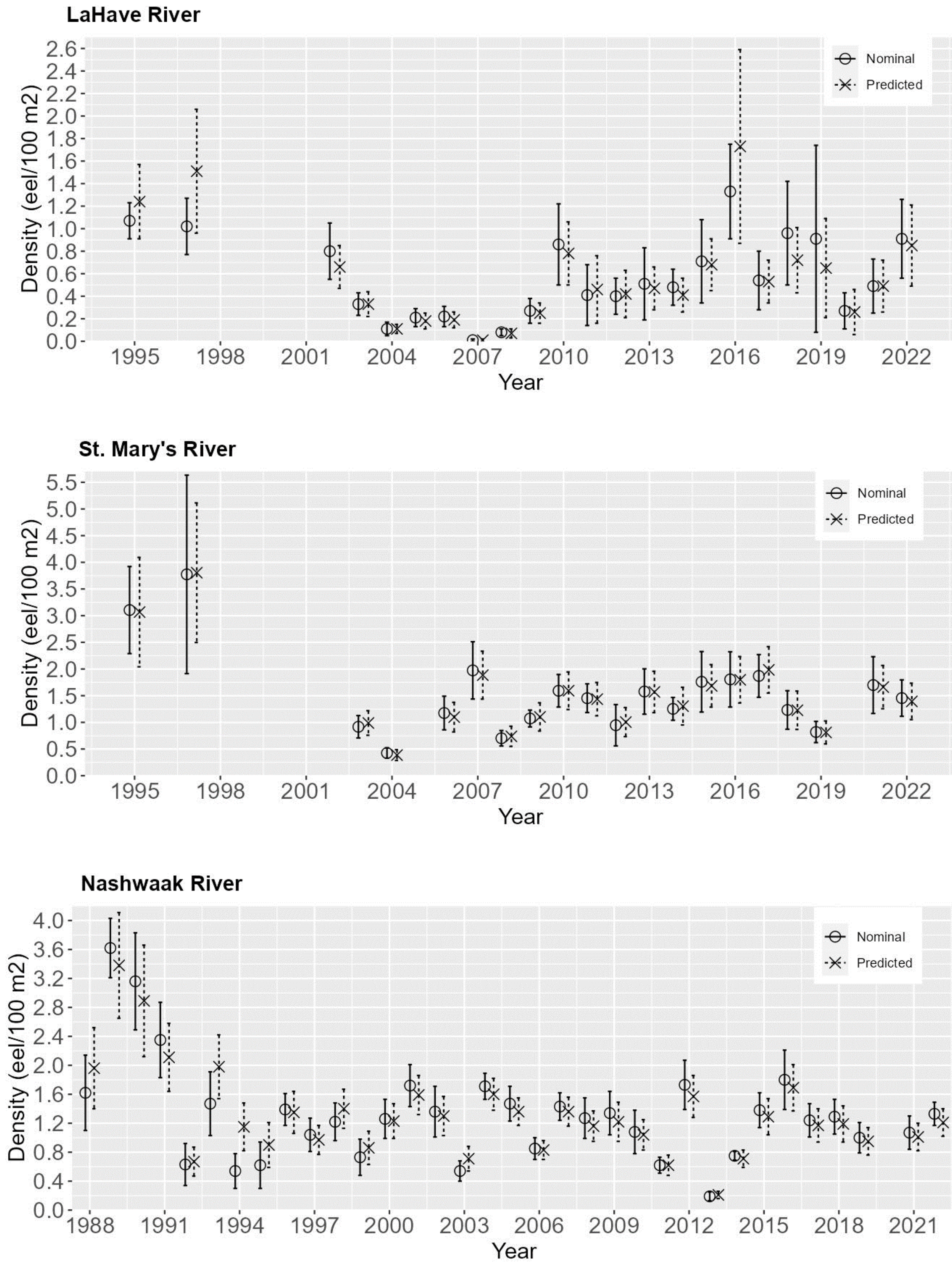


*Figure 7. Predicted and nominal abundance indices for American Eel density estimates obtained by electrofishing in the LaHave River (upper panel), St. Mary's River (middle panel), and Nashwaak River (lower panel). The vertical bars represent the standard errors of the estimates.*

### LaHave River, Nova Scotia

The revised, from Cornic et al. (2022), and updated data indicated that eel abundances exhibited no trend between 1995 and 2022, but that abundance has trended higher since 2002 (Table 5, M-K: $\tau=0.40$, $p=0.01$). ARIMA models (Table 5) indicated an equal probability ($p=0.50$) that abundances were below the 75$^{th}$ quantile for the reference years 2022 and 2021–2022 when compared to the 2002–2022 reference range. The probability was high ($Pr \geq 0.67$) that abundances in all reference years were below the 75$^{th}$ quantile for the 1995–2017 reference range (Table 5). This interpretation is consistent with Cornic et al. (2022) that abundances remained low after declining from the highs observed in the mid to late 1990s.

*Table 5. ARIMA and trend analysis results for American eel sampled by electrofishing in the LaHave, St. Mary's, and Nashwaak rivers. The reference ranges (RR) used to calculate the 25th, 50th, and 75th Quantiles are shown. The probabilities that abundances in the reference years (RY) are less than the specified Quantile are shown. Mann-Kendall (M-K) tau (τ) statistics for presence of trend and Shapiro-Wilks (S-W) statistic (W) score for normality among ARIMA residuals are shown. na means not applicable; n.s. means not significant*

| River | RR Start | RR End | n | Quantile | RY-1 | Pr(RY-1<Q) | RY-2 | Pr(RY-2<Q) | M-K τ | p-value | Trend | S-W W | p-value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LaHave | 1995 | 2022 | 23 | 25 | 2022 | 0.10 | 2021–2022 | 0.13 | 0.19 | 0.22 | n.s | 0.93 | 0.1 |
| LaHave | 1995 | 2022 | 23 | 50 | 2022 | 0.34 | 2021–2022 | 0.38 | na | na | na | na | na |
| LaHave | 1995 | 2022 | 23 | 75 | 2022 | 0.67 | 2021–2022 | 0.71 | na | na | na | na | na |
| LaHave | 2002 | 2022 | 21 | 25 | 2022 | 0.05 | 2021–2022 | 0.06 | 0.40 | 0.01 | Positive | 0.76 | 0.01 |
| LaHave | 2002 | 2022 | 21 | 50 | 2022 | 0.22 | 2021–2022 | 0.24 | na | na | na | na | na |
| LaHave | 2002 | 2022 | 21 | 75 | 2022 | 0.50 | 2021–2022 | 0.50 | na | na | na | na | na |
| LaHave | 1995 | 2017 | 23 | 25 | 2022 | 0.11 | 2021–2022 | 0.14 | na | na | na | na | na |
| LaHave | 1995 | 2017 | 23 | 50 | 2022 | 0.31 | 2021–2022 | 0.34 | na | na | na | na | na |
| LaHave | 1995 | 2017 | 23 | 75 | 2022 | 0.67 | 2021–2022 | 0.71 | na | na | na | na | na |
| St. Mary's | 1995 | 2022 | 20 | 25 | 2022 | 0.33 | 2021–2022 | 0.34 | 0.05 | 0.77 | n.s. | 0.96 | 0.54 |
| St. Mary's | 1995 | 2022 | 20 | 50 | 2022 | 0.50 | 2021–2022 | 0.54 | na | na | na | na | na |
| St. Mary's | 1995 | 2022 | 20 | 75 | 2022 | 0.75 | 2021–2022 | 0.76 | na | na | na | na | na |
| St. Mary's | 2003 | 2022 | 18 | 25 | 2022 | 0.15 | 2021–2022 | 0.14 | 0.29 | 0.10 | n.s. | 0.98 | 0.91 |
| St. Mary's | 2003 | 2022 | 18 | 50 | 2022 | 0.30 | 2021–2022 | 0.29 | na | na | na | na | na |
| St. Mary's | 2003 | 2022 | 18 | 75 | 2022 | 0.46 | 2021–2022 | 0.47 | na | na | na | na | na |
| St. Mary's | 1995 | 2017 | 18 | 25 | 2022 | 0.34 | 2021–2022 | 0.37 | na | na | na | na | na |
| St. Mary's | 1995 | 2017 | 18 | 50 | 2022 | 0.51 | 2021–2022 | 0.54 | na | na | na | na | na |
| St. Mary's | 1995 | 2017 | 18 | 75 | 2022 | 0.75 | 2021–2022 | 0.74 | na | na | na | na | na |
| Nashwaak | 1988 | 2022 | 34 | 25 | 2022 | 0.41 | 2021–2022 | 0.41 | -0.26 | 0.03 | Negative | 0.98 | 0.7 |
| Nashwaak | 1988 | 2022 | 34 | 50 | 2022 | 0.67 | 2021–2022 | 0.67 | na | na | na | na | na |
| Nashwaak | 1988 | 2022 | 34 | 75 | 2022 | 0.87 | 2021–2022 | 0.89 | na | na | na | na | na |
| Nashwaak | 1995 | 2022 | 27 | 25 | 2022 | 0.26 | 2021–2022 | 0.28 | -0.08 | 0.56 | n.s. | 0.97 | 0.5 |
| Nashwaak | 1995 | 2022 | 27 | 50 | 2022 | 0.43 | 2021–2022 | 0.42 | na | na | na | na | na |
| Nashwaak | 1995 | 2022 | 27 | 75 | 2022 | 0.55 | 2021–2022 | 0.55 | na | na | na | na | na |
| Nashwaak | 2002 | 2022 | 20 | 25 | 2022 | 0.44 | 2021–2022 | 0.45 | -0.95 | 0.58 | n.s. | 0.97 | 0.81 |
| Nashwaak | 2002 | 2022 | 20 | 50 | 2022 | 0.58 | 2021–2022 | 0.57 | na | na | na | na | na |
| Nashwaak | 2002 | 2022 | 20 | 75 | 2022 | 0.70 | 2021–2022 | 0.69 | na | na | na | na | na |
| Nashwaak | 1988 | 2017 | 34 | 25 | 2022 | 0.41 | 2021–2022 | 0.43 | na | na | na | na | na |
| Nashwaak | 1988 | 2017 | 34 | 50 | 2022 | 0.66 | 2021–2022 | 0.70 | na | na | na | na | na |
| Nashwaak | 1988 | 2017 | 34 | 75 | 2022 | 0.88 | 2021–2022 | 0.91 | na | na | na | na | na |

### St. Mary's River, Nova Scotia

The nominal and model abundance indices averages were the same, 1.56±0.44 eels/100 $m^2$ and 1.56±0.42 eels 100 $m^2$, respectively. There is no evident trend in the abundance index (Figure 7, middle panel) since either 1995 or since 2003 (Table 5). Current abundance remains below the series highs observed in 1995–1996. There is no evident change in abundance relative to the 1995–2017 and 1995–2022 reference ranges. Abundances in the 2022 and 2021–2022 reference years are nominally above the $75^{th}$ quantile relative to the 2003–2022 reference range (Table 5).

### Nashwaak River, New Brunswick

The nominal and model abundance indices averages were the same, 1.32±0.28 eels/100 $m^2$ and 1.31±0.42 eels 100 $m^2$, respectively. A statistically significant negative trend in abundance is evident (Figure 7, lower panel) for the years 1988 to 2022 (M-K: $\tau$=-0.26, p=0.03, Table 5), but not for the 1996–2022 or 2002–2022 time periods (Table 5). Abundances during the 2022 and 2021–2022 reference years are generally below the 50th quantile but all are above the 25th quantile (Table 5).

It has been noted that these electrofishing surveys are designed for salmon and likely underestimate eel abundances. Development of an electrofishing index for eel would benefit from species-specific design or protocols.

## Indices of Adult (Silver) Eel Abundance

Counts (assumed complete except where noted in Table 6) of silver eels descending Oakland Lake Stream, Nova Scotia and EPB exhibited a general, but not statistically significant, decline with time (Table 6). Average annual adult production was estimated to be one adult (SD=0.34) per hectare (ha) of catchment area for Oakland Lake Stream and one adult (SD=0.69) per ha for the catchment area of EPB.

*Table 6. Estimates of adult (silver) eel escapement acquired at counting traps installed in Oakland Lake Stream and Eel Pond Brook by Year. Estimates are reported relative to lake habitat (lh) and catchment area (ca) in terms of number (n) and kilogram (kg) per hectare (ha). Dashes (-) mean not calculated.*

| Year | Location | Catch (n) | Sampled (n) | Mean Weight (kg) | Total Weight (kg) | n/lh ha | kg/lh ha | n/ca ha | kg/ca ha |
|---|---|---|---|---|---|---|---|---|---|
| 2011* | Oakland Lake Stream | 272 | 228 | 0.10 | 27.8 | 4.1 | 0.42 | 0.7 | 0.07 |
| 2012 | Oakland Lake Stream | 374 | 373 | 0.16 | 61.1 | 5.7 | 0.93 | 0.9 | 0.15 |
| 2013 | Oakland Lake Stream | 526 | 526 | 0.14 | 74.5 | 8.0 | 1.13 | 1.3 | 0.18 |
| 2014 | Oakland Lake Stream | 488 | 392 | 0.14 | 67.1 | 7.4 | 1.02 | 1.2 | 0.17 |
| 2015 | Oakland Lake Stream | 523 | 410 | 0.12 | 63.6 | 7.9 | 0.96 | 1.3 | 0.16 |
| 2016* | Oakland Lake Stream | 153 | 144 | 0.14 | 19.3 | 2.3 | 0.29 | 0.4 | 0.05 |
| 2017 | Oakland Lake Stream | 385 | 307 | 0.12 | 41.5 | 5.8 | 0.63 | 0.9 | 0.10 |
| 2018* | Oakland Lake Stream | 82 | 31 | 0.29 | – | 1.2 | – | 0.2 | – |
| 2019 | Oakland Lake Stream | 158 | 123 | 0.12 | 41.5 | 2.4 | 0.63 | 0.4 | 0.10 |
| 2020 | Oakland Lake Stream | – | – | – | – | – | – | – | – |
| 2021 | Oakland Lake Stream | – | – | – | – | – | – | – | – |
| 2022 | Oakland Lake Stream | 178 | 116 | 0.13 | 23.1 | 2.7 | 0.35 | 0.4 | 0.06 |
| 2014* | Eel Pond Brook | 214 | 203 | 0.10 | 21.8 | 1.8 | 0.19 | 0.6 | 0.06 |
| 2015 | Eel Pond Brook | 944 | 944 | 0.09 | 85.7 | 8.1 | 0.73 ** | 2.6 | 0.23 |
| 2016 | Eel Pond Brook | 383 | 382 | 0.11 | 21.8 | 3.3 | 0.19 | 1.0 | 0.06 |
| 2017 | Eel Pond Brook | 524 | 504 | 0.09 | 21.8 | 4.5 | 0.19 | 1.4 | 0.06 |
| 2018 | Eel Pond Brook | 321 | 321 | 0.14 | 21.8 | 2.7 | 0.19 | 0.9 | 0.06 |
| 2019 | Eel Pond Brook | 421 | 397 | 0.11 | 47.6 | 3.6 | 0.41 | 1.1 | 0.13 |
| 2020 | Eel Pond Brook | 199 | 199 | 0.12 | 23.2 | 1.7 | 0.20 | 0.5 | 0.06 |
| 2021 | Eel Pond Brook | 137 | 137 | 0.16 | 22.3 | 1.2 | 0.19 | 0.4 | 0.06 |

[*] *Partial Counts.*
[**] *1.13 for Eel Pond Brook only.*

### Directed Sampling for Young Juvenile Eels

Exploratory monitoring of eels moving upstream in the LaHave River at Morgan Falls Fishway revealed considerable variability among years in body-length frequency distributions and pronounced change among years in modal length. Eels ≤12 cm total length (TL), the maximum length observed for aged 3+ year old eels from the collection site, were the dominant component of the catch (≥71% of total catch) in 2007, 2021, and 2022. By comparison, eel ≤12 cm TL comprised 39% and 22% of the sample populations in 2002 and 2004, respectively. Run-timing appears to be largely episodic within a given year, and there is no consistent pattern in run timing among the years of monitoring. The existing information indicate that while development of indices for young eels (e.g., ≤ 3+ years old) are feasible, the potential influence of environmental factors, such as water temperature and the timing, duration, and intensity of freshet events should be considered, and provisions to acquire counts from as early in spring, to as late in the fall as is practical, may be required.

Directed monitoring of young migratory yellow eels at fixed locations has potential as a supplementary index to both the ER-C elver index and to electrofishing-based estimates of eel standing stock, with lags of several years (the duration of which may be dependent on distance from the head of tide). However, the episodic nature of high catches of juveniles, both within and among years, indicates that uninterrupted monitoring for an extensive period of time beginning in the spring and extending into the autumn may be required.

### Sources of Uncertainty

There is known to be a high level of unauthorized harvesting directed towards elvers at present. This represents a significant source of uncertainty for elver abundance indices that are operated on the assumption that all removals by fishing are included in the annual census.

Years with missing data lend uncertainty to analyses of trends with time in the major fishery-independent indices at the elver, yellow eel, and silver eel life-history stages.

Available data cannot establish a link between measures of elver recruitment (i.e., ER-C index) and either yellow eel standing stock or silver eel production. It remains uncertain whether the apparent lack of response to apparent increases in recruitment are wholly a function of the lag (years) required to detect change or whether there are issues with eel productivity in freshwater that impede repopulation of regional waterways with eels.

The extent of spatial overlap between large eel fishing and elver fishing activity in Maritimes Region since the last assessment is not known.

The extent of spatial variability throughout Maritimes Region in elver availability to capture has not been assessed.

The dynamics of the elver fishery during years of higher than usual elver recruitment are not well understood.

The electrofishing data sets represent the bycatch of eels in surveys designed to monitor another fish species. The efficacy of the protocols established to monitor juvenile salmonids has not been evaluated for co-distributed eels.

## CONCLUSIONS AND ADVICE

Based on reported landings, the number of commercial licenses that are active has decreased over the past decade. In recent years, it appears that the fishery has been prosecuted by a small (23–30), consistent group of license holders. As a result, significantly fewer eels are now landed than in the past when participation, in terms of both participants and deployed gear, was much higher. There are a large number of commercial eel licenses that are not actively fished at present, which represents a high level of latent gear. There is known to be a high level of unauthorized harvesting directed towards elvers at present. These factors represent a source of potential and realized eel exploitation in the Maritimes Region not reflected in the reported catches for eel and elver, and are sources of uncertainty for this assessment.

The ER-C index was completed in three of the five years since the last assessment. This index suggests that the average run size is above the 1996–2018 median run size estimate of 320 kg (2.33 kg/km$^2$) and either approximately equivalent to, or greater than, the 75$^{th}$ quantile run sizes for the 1996–2018 time period (466 kg, 3.40 kg/km$^2$).

A number of other sources of information were evaluated as potential alternatives or supplemental indices to the ER-C recruitment index. No alternatives were evident. A number of indices may provide useful supplemental information concerning stock status, but none were considered to be immediately applicable as replacement indices for the science and management frameworks established in the Maritimes Region for the elver fishery.

This assessment demonstrated the importance of having consistent and accurate time series of information for analysis, and the importance of accounting for removals, including the implications of high levels of unauthorized harvesting directed towards elvers.

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## SOURCES OF INFORMATION

This Science Advisory Report is from the regional peer review on October 11–12, 2023, on the Updated Science Advice on Status of American Eel and Elver Fisheries in Maritimes Region. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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