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

Canadian Science Advisory Secretariat (CSAS)

Research Document 2026/021

Maritimes Region

Updated Science on the Status of American Eel and Elver Fisheries in Maritimes Region

R.G. Bradford, E.A. Miller, and M. Wilson

Population Ecology Division, Science Branch
Fisheries and Oceans Canada
Bedford Institute of Oceanography
PO Box 1006, 1 Challenger Drive
Dartmouth, NS B2Y 4A2

March 2026

Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

Published by:

Fisheries and Oceans Canada
Canadian Science Advisory Secretariat
200 Kent Street
Ottawa ON K1A 0E6

http://www.dfo-mpo.gc.ca/csas-sccs/
DFO.CSAS-SCAS.MPO@dfo-mpo.gc.ca

ISSN 1919-5044
ISBN 978-0-660-98535-0 Cat. No. Fs70-5/2026-021E-PDF

Correct citation for this publication:

Bradford, R.G., Miller, E.A., and Wilson, M. 2026. Updated Science on the Status of American Eel and Elver Fisheries in Maritimes Region. DFO Can. Sci. Advis. Sec. Res. Doc. 2026/021. v + 66 p.

Aussi disponible en français :

Bradford, R.G., Miller, E.A. et Wilson, M. 2026. Mise à jour des données scientifiques sur l'état des pêches de l'anguille d'Amérique et de la civelle dans la région des Maritimes. Secr. can. des avis sci. du MPO. Doc. de rech. 2026/021. v + 71 p.

TABLE OF CONTENTS

ABSTRACT

Review of the catch and licensing information for the Maritimes Region large eel fisheries gathered by Fisheries and Oceans Canada (DFO) since the last assessment in 2018 indicated that effort has remained low (<30 active licences per year) as well as yield (<30 t per year) relative to the fisheries of the mid-1980's to the late 1990's. Total reported elver landings have continued to trend higher with time, reaching 8.3 t (83% of the 9.96 t total allowable catch). The 2020 and 2023 elver fisheries were closed mid-season by fishery management order resulting in reduced catches of 2.95 t and 5.50 t respectively. The East River-Chester (ER-C) elver index of recruitment, the recommended primary indicator of regional eel status, was not conducted in either 2020 or 2023, and estimates obtained for the 2019 and 2020 elver runs are considered underestimates. Available post-2019 estimates were above the 1996–2018 median run size estimate of 320 kg (2.33 kg/km^2) and were 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). Changes to elver harvest levels presently in effect should consider that elver recruitment is highly variable from year to year (80% on average), and that a high level of unauthorized harvesting directed towards elvers has occurred on rivers presently licensed for fishing, and in drainages that had until recently either not been fished (fallow) for any life-stage of eel or were fished for large eels. Analyses of commercial elver catch and effort indicate that these data are not highly informative with respect to the size of elver runs in a given year of fishing, particularly when recruitment is high, owing to the low number of observations available. Elver run indices generated elsewhere either within or adjacent to Maritimes Region waters were either not correlated with the ER-C index (e.g., West Harbor Pond, Maine) or if correlated, had not been operational during years when ER-C indices were not available. Eel abundances derived from electrofishing or directed monitoring of juvenile eel runs have potential as supplemental indices of general eel status but will lag elver recruitment by several years. There are presently no regional indices available to serve as an alternative to the ER-C elver index.

INTRODUCTION

The American Eel, *Anguilla rostrata*, is a widely distributed fish that occurs from northern South America to Greenland and Iceland (Scott and Scott 1988). They are panmictic (all are members of a single population), generally catadromous (spawn at sea and spend a portion of their lives in freshwater) and semelparous (a single reproductive episode followed by death). Spawning occurs in the Sargasso Sea well to the south of Canadian territorial waters. Juveniles recruit as glass eels (elvers) to Canadian continental waters in the year following the year of their hatch. In Canada, eels can be found in nearly all the accessible fresh, brackish, and protected coastal waters from the Canada-United States of America border in the south to Lake Melville, Labrador in the north, including the Laurentian Basin of the provinces of Ontario and Québec and the island of Newfoundland (Scott and Crossman 1973, Scott and Scott 1988). They have historically been fished by Indigenous Peoples for food, social, and ceremonial purposes, and these fisheries remain culturally important. Eels have also supported commercial and recreational fisheries throughout much of their Canadian range. The Maritimes Region (Figure 1) commercial fishery is the only eel fishery in Canada that results in significant removals of eels as recruits (glass eels or elvers), and as juveniles (yellow eel), and as adults (silver). All removals by fisheries occur pre-spawning.

In the Maritimes Region, elvers are defined in regulations as eels less than 10 cm (4 inches) in total length and are managed by Fisheries and Oceans Canada (DFO) as a distinct fishery. An integrated fisheries management plan (IFMP) was developed in 1998 (DFO 1998) to help guide Maritimes regional fisheries management decisions for the elver fishery. The IFMP was updated in 2018 (DFO 2018).

The fisheries for yellow eel and silver eel, generally referred to as large eels or simply eels, are managed collectively. An IFMP has not been developed for the eel fishery.

The Maritimes Region American Eel and elver fisheries were last assessed in 2018 (DFO 2019; Bradford et al. 2022). The assessment included spawner-per-recruit (SPR) analyses (ICES 2001; Chaput and Cairns 2011) to define mortality reference points (RP) for all directed fisheries and hydroelectric facilities as recommended under the DFO precautionary fisheries management framework (DFO 2017). In accordance with ICES (2001) 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 removal reference (i.e., the maximum acceptable human-induced mortality rate). The mortality rate that results in a 50% loss of spawning biomass was the recommended target value (SPR50). The fishing mortality rates for elver fisheries corresponding to SPR30 and SPR50 were estimated to be 1.2 and 0.69, respectively (equal to exploitation rates of 0.70 and 0.50), considering mortality from elver fishing only. Application of RP was limited to the elver fishery because of a lack of information concerning large eel harvest, biomass, and survival (Bradford et al. 2022).

The long-term median estimate of East River-Chester (ER-C) elver index of recruitment was recommended as the primary indicator of eel productivity in the Maritimes Region (DFO 2019).

Since 2018, accurate total run size estimates from direct monitoring of the annual ER-C elver runs have not been acquired in some years and not possible in other years due to factors outside of the authorized fishery. This has led to increased uncertainty in the advice provided to DFO Resource Management (RM) to support 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 eel productivity if directed and unreported elver harvesting continues at levels considered to be unsustainable. While DFO continues to review methods and data sources in support of the precautionary management of Maritimes Region eel and elver fisheries, RM has asked DFO Science to provide, to the extent possible, updated information on the status, trends, and distribution of large eel and elver fisheries from 2017 to 2022.

TERMS OF REFERENCE

The specific terms of reference (ToRs) for this regional peer-review process are:

- Update large eel fishery catch and effort information for the years 2017 to 2022.
- Update from 2018 the East River-Chester Elver recruitment index.
- Assess alternative and supplemental annual indices of eel and elver abundance from the region.

The assessment includes reviews and update of abundance indices that have been applied to recent (Cornic et al. 2021) evaluations of the status of the American Eel in Canada.

The American Eel was designated by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) as Special Concern in 2006 (COSEWIC 2006) and Threatened in 2012 (COSEWIC 2012). They remain under consideration for listing under the *Species at Risk Act*.

This report describes the fishery management framework for eel and elver fisheries, sources and limitations of data available to address the ToRs, and methods of analysis applied to the data. The outcomes of analyses and discussion of results are then presented for each ToR.

FISHERY MANAGEMENT

In addition to the *Species at Risk Act*, four other pieces of legislation have direct or indirect application to American Eel and its fisheries, namely, the *Fisheries Act*, the *Fishery (General) Regulations [F(G)R]*, the *Maritime Provinces Fishery Regulations (MPFR)*, and the *Aboriginal Communal Fishing Licences Regulations (ACFLR)*. The *Fisheries Act* is directed at protecting fish habitat, while its supporting regulations provide the tools to protect, conserve, and manage fisheries. Some of the most important regulatory provisions as applied to eel and elver fisheries are:

- Sections 36–38 of the MPFR, which establish gear restrictions, close times (fishing seasons), length restrictions, and quotas for recreational fishing;
- Section 6 of the F(G)R, which provides for the issuance of variation orders to change or close any fishing season, or size limit, set out in regulations; and
- Section 22 of the F(G)R's which provides for the issuance of licence conditions.

Eel licences are valid for a county and for both tidal and non-tidal waters. Elver licences are valid only for the coastal drainages that are named in the conditions of licence and are specific to each licence.

LARGE EELS (YELLOW AND SILVER)

There are no management targets or catch quotas for the following eel fisheries in Maritimes Region: commercial, communal commercial, recreational, or Indigenous food social ceremonial (FSC). However, both regulations and licensing policies have changed with time in response to conservation concerns. Since May 1993, no new commercial eel licences have been issued, and re-issuance of licences has been permitted only to registered licence holders in the preceding year. The number of recreational eel licences was frozen in 1997. Catches were subject to size and bag limits, and effort was restricted to use of a maximum of four pots. All remaining recreational licences are non-transferable and terminal.

Regulations presently in effect require:

- a licence to fish commercially (including communal commercial) or recreationally, except for angling or for spearing in tidal waters. Authorized fishing methods include angling, pots, traps (fyke nets and weirs), dip nets, and spears. Longlines and setlines are permitted in New Brunswick (NB). In inland waters the season is varied closed for eel traps from November 1 to August 14, and for spears all year;
- a distance of 200 m be maintained from any fishing gear previously set;
- fishing gear not be left unattended for more than 72 hours;
- fishing gear be marked with the owner's name and, where a vessel is used, with the vessel registration;
- that from sunrise to sunset in inland waters of Nova Scotia, eel traps must have a 90 cm opening to allow fish to escape and fyke nets must be rendered incapable of catching fish;
- eels less than 35 cm total length (TL) be returned live to the wild;
- escape mechanisms with 1 inch (2.5 cm) by ½ inch (1.27 cm) openings for all gear;
- that eels cannot be retained as a bycatch in any fishery (Section 33 of the F(G)R's); and
- licence holders, as a condition of licence (beginning in 2014), to submit their logbooks to a dockside monitoring company (DMC) for data entry. Because possession of the licence conditions is a requirement for commercial fishing activity to proceed, this measure essentially requires licence holders to report their fishing activities of the previous year (or to indicate that they did not fish) before engaging in commercial fishing during the current year. The returned logbooks provide information on daily catch and effort, by gear type, and by watershed.

ELVERS

Fishing locations

Commercial elver fishing began as an enterprise allocation fishery in 1996, following several years of experimental fishing that began in 1989. Between 1998 and 2021, the number of licences was limited to nine: eight commercial and one communal commercial. Two additional communal commercial licences were issued in 2022 and 2023 to support increased participation by First Nations in the fishery. All licences issued by DFO authorize specific fishing areas (named rivers and streams), defined quantities and types of gear, and a defined maximum number of fishers that can be deployed to fish for a non-transferable and individual quota.

Fishing areas were approved on the basis that no commercial fishing for large eels had occurred in any of the three previous years. The effectiveness of this practice, as a means to discourage large eel and elver fishing in the same drainage was evaluated in 2018 and found to help maintain area overlap between the large eel and elver fisheries to less than 10% (DFO 2019). Maintaining spatial separation between large eel and elver fisheries remains an important consideration when reviewing requests from licence holders to exchange an existing licenced river for a new fishing site and for authorizing sites that can increase the participation of First Nations in the elver fishery.

Total Allowable Catch and Individual Licence Quotas

Both the individual quotas (IQ) and the circumstance in which the elver licence holders can fish above their quota have changed with time. From 1998 to 2004, the IQ was set at 1,333 kilograms (kg) wet-weight for the eight commercial licence holders and at 400 kg wet-weight for the communal commercial licence, yielding an overall total allowable catch (TAC) of 11.06 tons (t). Each licence holder could apply for a quota increase of 30% once their IQ had been reached, which increased the potential annual maximum catch to 1,733 kg for the commercial licences and 520 kg wet-weight for the communal commercial licence.

In 2005, in response to conservation concerns expressed for the status of American Eel in Canada (DFO 2010; COSEWIC 2012), IQ's were reduced by 10% to 1,200 kg (n =8) and 360 kg (n =1) wet-weight, resulting in a reduction in the TAC to 9.96 t. The option to apply for a 30% increase in an IQ was removed. However, licence holders could apply for authorization to fish an additional 10% (120 kg and 36 kg) of quota if the fish were acquired to support conservation stocking in Canadian waters[1].

In 2021 DFO re-allocated 1,200 kg of quota in the commercial elver fishery to support enhanced Indigenous participation in the fishery by members of the Kespukwitk District First Nations in Nova Scotia and Wolastoqey Nations in New Brunswick. The IQ for the eight commercial licences were all reduced by 14% resulting in a 1,035.6 kg IQ for seven commercial licences and 310.7 kg IQ for the other. The IQ for communal commercial licence was not reduced.

River Catch Limits

Elver landings on individual rivers were capped at 400 kg from the onset of commercial elver fishing in 1996 (Figure 2) as a measure to reduce the risk of local overfishing by essentially requiring licence holders to fish a number of rivers to fill their individual quotas. Informal review of the fishery (around 2008) for the East River-Chester, Nova Scotia (ER-C), where estimates of elver escapement past the fishery were available for the years 1996–2002, indicated annual runs of less than 400 kg in six of the seven years. Thereafter fisheries managers have adopted a number of practices successively to help reduce the risk of local overfishing. Beginning around 2010 river catch limits (RCL) that were equivalent to 1.5 kg of elvers per km^2 of receiving habitat, with removals not to exceed 400 kg per river, were implemented whenever licence holders requested an exchange of one river currently under licence for another. Changes in RCL with time are summarized in Figure 2. The RCL were adjusted for all rivers commencing with the 2019 fishing season, following development of recommended limit and target mortality reference levels (DFO 2019). The RCL were set at 200 kg and 300 kg for river catchments ≤150 km^2 and 150 km^2 to ≤300 km^2 respectively. The RCL for river drainages >300 km^2 remained at 400 kg (or less if previously adjusted down using the 1.5 kg per km^2 standard). Beginning in 2021 all RCL were based on a catch equivalent of 1.5 kg per km^2 up to a maximum RCL of 400 kg per river. The RCL's currently in effect for catchments less than 750 km^2 in area are shown in Figure 3 along with the SPR30 and SPR50 reference points.F

[1] Approximately 6,215,500 elvers acquired from commercial elver fishery licence holders were stocked into the Laurentian Basin between 2005 and 2010 (Stacey et al. 2014). The proportion of the stocked elvers that were fished as part of the 10% additional quota allocated for conservation stocking is not known but was probably low-modest.

Fishing Gear

Licence holders are not restricted to use of a single gear type while fishing a specific fishing location (i.e., dip netting can occur while set gear is installed and fishing). However, there are limits on the number of traps that can be set in a named fishing river, usually no more than two or three, depending upon the licence. Minimum distances between gear are defined. There is no limit on the number of persons who can dip net for elvers on a given river at the same time, provided their numbers do not exceed the maximum stated on the licence. Use of wings when dip netting is limited and subject to restrictions on the maximum width of the channel that can be blocked (one third and two thirds in tidal and non-tidal waters respectively).

DATA SOURCES AND DATA LIMITATIONS

FISHERIES DEPENDENT INDICES

Large Eel Fishery Potential and Catch and Effort

Records for eel fishing activities prior to 2008 do not provide detailed information concerning fishing locations, catch per licence, catch per unit of effort, or catch by gear type for the Maritimes Region fishery (Bradford 2013). Unlike the elver fishery where licence holders are authorized to fish only within specific river drainages, eel licences are valid for a county lying within the New Brunswick and Nova Scotia portions of Maritimes Region (Figure 4). The river systems where fishing occurred within the county were not reported. An attempt initiated in 2000 to collect locations of commercial fishing through logbooks was not successful. Compliance with the request for additional detail was low and the logbook return rate was low (DFO unpublished). Logbooks were not distributed for the 2008 fishing season.

A re-designed logbook that allowed for the recording of daily fishing activity by location, gear type, number of gears, and soak time was available for the 2009 fishing season. Compliance with the condition of licence that required return of the logbook to DFO prior to the next fishing season remained low.

Since the beginning of the 2014 fishing year, licence holders have not been issued their conditions of licence until they have demonstrated that their logbooks for the previous year had been submitted to a DMC for data entry. Possession of the licence conditions is a requirement before commercial fishing activity can proceed. Many licence holders do not submit their logbooks to a DMC until shortly before they plan to fish which can result in a lag of about one year in the completion of logbook reporting. As a result landings should be considered to be potentially incomplete for the year during data compilation and the year prior to data compilation.

The geographic extent of FSC fishing activity for eel is not well known and, therefore, the extent of overlap between FSC and commercial fisheries is not known. It is assumed that FSC fisheries can occur in all coastal/inland waters contained within Maritimes Region.

The reported landings by province for the years 1950 to 2016 are summarized in Bradford et al. (2022). Catch and effort data are subject to the same limitations concerning using logbook returns as described for locations of fishing activity. Records of eel catch and effort for the years prior to 2008 are poor and better suited as a record of reported annual landings than an indicator of regional status (Bradford 2013). Efforts to improve both the quality of the data received and the level of compliance with the requirement to return logbooks since 2008 have not been successful. Stricter conditions on eel fishing since 2015, including requiring that licence holders submit records of their fishing activity from the previous season to a DMC before receiving authorization to fish in the following year, has resulted in more detailed catch records. There may still be a lag of up to one year as discussed above. Evaluation in this report of annual fishing activities relative to the number of licences issued, the type and the amount of gear that could potentially be fished, and participation in the fishing is considered to be provisional for 2022.

There is no systematic analysis of information for landings resulting from FSC fishing activities. Licensing information, including statement of the types and number of gear authorized to be fished under each licence, is available for the commercial, communal commercial, and recreational sectors.

Elver Fishery Potential and Catch and Effort

Annual fishing records are available since 1996 except for 2008 when logbooks were not distributed to licence holders. Raw logbook data contain numerous inaccuracies attributable to data entry errors, inconsistent reporting among years of catch in terms of wet versus dry (wet weight less 25%), and inconsistent naming of fishing locations. Prior to 2016 daily catch and effort for individual fishing sites were not consistently separated by gear type particularly between dip netting and fyke netting activities. While many of the substantive data quality issues have been resolved for existing records, licence holders are inconsistent in their estimation of catch weights by gear type at streamside prior to transport to holding facilities. Assessment of elver catch and effort for individual licence holders and for the entire fishery therefore remains limited to coarse evaluations of catch and effort, i.e., total annual catch and total hours fished with no sub-division by gear type or by fishing location.

The sub-set of the information that is specific to the ER-C has continued to be extensively reviewed and edited with the assistance of the licence holder and includes the catch for 2008 which is not available for the other licences. These records allow for assessment of annual fishing success and exploitation relative to the annual estimates of elver recruitment to the river which are available for the years 1996–2002, 2008–2019, 2021–2022.

There are no commercial, communal commercial, or recreational fisheries with significant bycatches of either eels or elvers.

FISHERIES INDEPENDENT INDICES

Regional Electrofishing Surveys

Freshwater fish communities are monitored in numerous Nova Scotia (NS) and New Brunswick (NB) rivers using either annual or periodic electrofishing surveys. The main goal of these surveys is to estimate juvenile Atlantic Salmon abundance and trends (e.g., Bowlby et al. 2013). Although these surveys were not specifically designed for eel, they represent the only regional data source available to develop a fishery-independent index of eel abundance in freshwater. Accordingly, the average annual bycatch of eel in the first sweep for both closed and open sites in a sub-set of the surveyed rivers, i.e., the LaHave and St. Mary’s rivers (NS), Nashwaak River (NB), (Figure 5) have been reported previously (Cairns et al. 2014; Cornic et al. 2021) as status indices. These series, last updated to 2015, portrayed a mutually consistent pattern of higher abundance estimates in the earlier years (late 1980’s or mid-1990’s depending on data series) than in the later years of the survey indicating an overall decrease in abundance with abundance fairly stable in recent years (Cornic et al. 2021).

An extensive analysis of the annual and periodic surveys conducted in NS rivers (summarized in DFO (2017) and Bowlby (2018)) affirmed the patterns of decline from series highs, perhaps by as much as 89% over 10 years (DFO 2017). The analysis also indicated that incorporation of site specific catch data is required in order for estimates of year over year change in eel abundance to be statistically robust. Analyses of electrofishing eel bycatch data for the Nashwaak, St. Mary's, and LaHave rivers data sets in Cornic et al. (2021) indicated that river flow and water temperature influenced catch rates.

Silver Eel Abundance Indices

There are no published estimates of silver eel escapement for any of the major rivers located in Maritimes Region. Annual monitoring of the run size of silver eels from Oakland Lake Stream (OLS) and Eel Pond Brook (EPB), two small coastal drainages along Atlantic coastal Nova Scotia (Table 1, Figure 5), began in the years 2011 and 2014, respectively. Count data, representing relative annual run sizes, are available for the years 2011–2017 and 2022 for Oakland Lake Stream, and for the years 2014–2021 for Eel Pond Brook. There are no authorized fisheries for elvers on either catchment. Commercial fishing for large eels is not known to have occurred in either location in recent years.

Elver Abundance Indices

East River-Chester Rivers

Industry-supported monitoring of the timing, abundance, and biological traits of the annual runs to ER-C, a 137 km^2 watershed in southwestern Nova Scotia (Figure 5, 6), has occurred during the years 1996 to 2002, 2008-2019, and 2021–2022. The combined elver count and harvest data for ER-C has seen frequent use as an indicator of elver status for the region (Bradford 2013, Cairns et al. 2008, Cairns et al. 2014, COSEWIC 2006, COSEWIC 2012, DFO 2014, 2018, Cornic et al. 2021). Details of the elver monitoring protocols are available in Bradford et al. (2022).

Briefly, collection traps are installed along the bank of the river below a rock sill during the spring when river and weather conditions allow. The sill impedes the upstream migration of the elvers. River water supplied via gravity feed to the traps acts as attraction flow and leads elvers into holding boxes that are checked once or twice per day depending upon the intensity of the run. The resulting abundance data (number of elvers and wet weight of trap catches), in combination with daily catch and effort data for the commercial fishery that occurs in tidal waters downstream of the monitoring site (Figure 6) is used to generate estimates of total run size, escapement past the fishery, and exploitation by fishing.

Elver body size can decline significantly over the duration of annual runs. These changes present a challenge to estimating run-size in terms of number of elvers when daily catches are large and hand counts become impractical. Prior to 2016, run size was measured volumetrically. Elver per unit volume conversion factors were used to convert volumetric estimates to number of elvers. Since 2017 daily run size has been estimated as kg wet weight, following the protocols for weighing catch defined in the conditions of licence (Bradford et al. 2022). Sub-samples of approximately 100 elvers per gram sample are weighed (0.1g) and total elvers counted to report catch as number of elvers per gram.

Elver Abundance Indices for other rivers

Two other current or former regional elver abundance indices were evaluated for their potential usefulness as supplemental or alternatives to the ER-C elver index: West Harbor Pond in the US state of Maine (WHP) and Eel Pond Brook, Nova Scotia (EPB; locations shown in Figure 5).

Eel Pond Brook, Nova Scotia, Canada

Eel Pond Brook, NS (Figure 5) is a 3.7 km^2 catchment area located approximately 100 km east of East River-Chester. Estimates of the total run size of elvers to EPB were acquired under a scientific licence by South Shore Trading Inc. Ltd , Port Elgin, N.B., for the years 2014 to 2019. Daily run size estimates were acquired by hand counts and volumetrically, with subsequent conversion to number of elvers using elver per unit volume conversion factors, when hand counts were not practical.

Eel Pond Brook shares an estuary with the much larger Musquodoboit River catchment (719 km^2) where elvers are fished commercially. The impact of the commercial fishing activity on the elver run size estimates for EPB are assumed low because the specific commercial fishing locations are located 1–2 km further inland from the head of tide in mouth of EPB.

West Harbor Pond, Maine, USA

The following information is quoted from ASMFC (2023, page 35) concerning an elver survey conducted at the head of tide at West Harbor Pond (WHP), Maine, U.S.A. from 2001 to 2020:

- West Harbor Pond is the site of Maine's state-mandated YOY survey which has been in operation since 2001. The survey uses an Irish elver ramp and typically samples April through June depending on the run. During the run, gear is left to soak for 6–24 hours and checked 3–5 times a week.
- [Elver] length, weight, and pigmentation of 60 samples is done once or twice a week. Water temperature, level, and discharge are collected as part of the survey.
- GLMs were attempted for the West Harbor Pound data but the models had convergence issues. A nominal index was developed as was done for the 2012 benchmark.
- The index of YOY abundance at West Harbor Pond has varied throughout the time series with many lows and highs. In 2017, the survey experienced its highest YOY abundance in the time series, but the last few years have seen higher numbers similar to the first few years of the survey.

ASMFC (2023, page 126) reports that a Mann-Kendall (M-K) trend analysis (ASMFC 2023) inferred a positive trend in the index with time ($n=19$, $\tau=0.35$, $p=0.042$). Catchment area for WHP was estimated to be 13.3 km^2 using a hand-drawn polygon to link the heights of land represented on the digital ArcGIS basemap.

Juvenile Abundance Indices

Counts of yellow eels have been acquired infrequently (2002, 2004, 2007, 2021, and 2022) at the DFO assessment facility located at Morgan Falls on the LaHave River, New Germany (Figure 5), as part of an ongoing effort to establish eel passage and monitoring capability at the site. Ramps and traps similar to those used at ER-C for elvers have been installed along the edge of a concrete pool and weir fishway that bypasses the falls. Sub-samples of the catches were measured and weighed and otoliths taken from sub-samples of eels for ageing.

The counts are not a complete census of eels migrating upstream in any of the five years of sampling. However, the 'run-timing' and size- and age-traits of the sampled runs are presented here to support discussions on the feasibility of establishing indices for age classes older than elvers and younger than the yellow eels typically captured in the Maritimes Region electrofishing surveys.

DATA ANALYSES

FISHERY LICENCES, LANDINGS, AND GEAR EFFORT

Information on commercial eel licences concerning licence availability and the total amount of gear by type (pots, traps, weirs) previously reported in Bradford et al. (2022) for the years 2015–2016 was extended to provide summaries up to the 2022 fishing season. Logbook returns were used to update to the 2022 fishing season the tallies of licences issued, the number of licences that were actively fished, the amounts of gear (by type), and the weights (kg) of reported catch at their time of sale by province.

This assessment does not update the annual extents of spatial separation between the large eel and elver fisheries, as reported for the years 2015 and 2016 in Bradford et al. (2022). Unauthorized, widespread, elver fishing activity, while not quantitatively documented, occurred in all years since the 2018 assessment to the extent that the elver fishery was closed by a fishery management order in 2020 and again in 2023. The extent of spatial separation associated with removals of eels as elvers versus older life-stages since 2018 is uncertain with the result that estimates of the extent of separation of the fisheries for the years since 2018 would not be accurate.

DFO did not receive any reports of fishing activity under communal commercial licences (large eel) for the 2015 and 2016 fishing years.

ELVER ABUNDANCE INDICES

The annual total weight (kg) of elvers on the ER-C (escapement) trapped in the collection boxes, and reported landings (catch) from the commercial fishery that occurs a short distance downstream from the counting sites were used to estimate annual total run size (kg and number of elvers) for the years 1996–2002 and 2008–2018.

The quality of the data gathered concerning the annual run size (commercial catch plus escapement) of elvers in ER-C since the last assessment (DFO 2018) is poor. Monitoring in 2019 proceeded in accordance with established protocols. There were no indications that unauthorized elver fishing activity had resulted in undocumented removals of elvers. Monitoring was suspended for 2020 owing to COVID-19 restrictions. The commercial fishery on the river was closed mid-season by a fishery management order.

Unauthorized elver fishing occurred in both 2021 and 2022. Run-size estimates for these years are accordingly considered to be minimum estimates. No authorization to fish elvers for scientific purposes on ER-C was provided in 2023 and no monitoring occurred. These factors collectively constrain analysis of the data to considerations of the level of elver recruitment relative to the 1996–2018 mean. This time series mean represents the basis for establishing RCL for the commercial elver fishery (DFO 2018, Bradford et al. 2022).

Linear regression was used to evaluate whether or not annual elver recruitment either to Eel Pond Brook or to West Harbor Pond was correlated with ER-C.

Relative run size variability among the three index drainages was examined after standardizing run size to a per unit area (km^2) of receiving habitat. Run sizes in both kilograms and number of elvers were available for ER-C, whereas estimates for both Eel Pond Brook and West Harbor Pond were reported in number of elvers. A conversion factor of 5,000 elvers/kg was applied to provide a coarse comparison of run sizes in terms of weight (kg). Tests of significance (ANOVA, Tukeys HSD) were only applied to run sizes reported as number of elvers.

ELECTROFISHING

Evaluation of the electrofishing data for the LaHave, St. Mary's, and Nashwaak rivers analysed by Cornic et al. (2021) identified substantive issues concerning the catch and area estimates for a number of sites (up to year 2017). This appears largely to be a result of assumed (standard) areas being reported in the data set provided to Cornic et al. (2021) which in turn were used to estimate eel densities (eel per 100 m^2). Comparison of water temperatures recorded in field books at the time of sampling with those contained in the data sets analysed by Cornic et al. (2021) revealed numerous inaccurate data entries. Therefore, and prior to updating the time series to 2022, all data sets were subject to reconstruction following consultation with the original data. Only records containing area estimates determined empirically on the date of sampling and only verifiable flow and water temperature values were retained. Years were culled when zero catches were either under- or over-represented in the data set containing only validated areas (e.g., where catches at sites with no credible area estimate indicated the remaining data were biased).

Nominal indices were generated for each data set using the arithmetic mean and standard errors of eel density for each year. Generalized Linear Mixed Models (GLMM) using a zero-inflated negative bionomial structure, were used to generate three additional indices representing, in order, 1) all observations containing location and area (m^2) estimates; 2) all observations containing location, area and flow (m^3/sec) information; and, 3) all observations containing location, area, flow, and water temperature (^{0}C) information (Table 2).

The TMB package in R (Brooks et al. 2017) was used to fit the GLMM. All statistical analyses were implemented in R (R Core Team, 2019).

The GLMM were generated following the order of entry and evaluation protocols adopted in Cornic et al. (2021) to the time series of catch, effort, and environmental factors. Models were selected on the basis of Aikake Information Criteria (AIC).

Power trend analysis was not attempted for any of the electrofishing indices because of the high proportion and length (years) of gaps in survey years for two (LaHave, St. Mary's) of the three rivers. Autoregressive Integrated Moving Average (ARIMA) models were run and fitted with no interpolation for missing values to the best fitting GLMM model for each river series using the surveyfit and surveyref functions contained in the fishmethods R package (Nelson 2018). All ARIMA models were run using the default order of c(0,1,1) for the surveyref function. The probabilities that the terminal year(s) of the data set were less than the 25th, 50th, and 75th quantiles were determined. An MK trend analysis, a non-parametric test for monotonic trend in time-ordered data (Gilbert 1987), was applied to the ARIMA-fitted data series to inspect the data for presence of increasing, decreasing, or no trend. The null hypothesis is that the time series is independent and identically distributed, i.e., there is no significant trend across time. Normality among residuals was tested (Shapiro-Wilk test).

COMMERCIAL ELVER FISHING CATCH AND EFFORT

Total annual catch (t) and effort, defined as the duration (days) of fishing activity between the first day with a reported catch and the last day with a reported catch, were used to explore variability in fishing success among years, and the relationship to the ER-C elver index for a sub-set of the elver fisheries licensed by DFO. Catch records associated with licences that either had a low IQ or licensed fisheries wherein substantive changes in fishing locations had occurred with time were not considered. The remaining six licensed fisheries were assigned a random numeric identifier and treated in all subsequent modelling exercises as a random effect.

In order to help accommodate the changes with time in the IQs and tolerances for fishing above the IQ assigned to each licence (see the section on total allowable catch and individual licence quotas), all annual catch records were truncated to the date that the IQ was reached. Factors considered in the analyses included the incentive to fish in a given year (a binary value to indicate whether the price per kg exceeded $400) and whether the annual catch was within 90% of the IQ (another binary to account for cessation of fishing prior to meeting quota for reasons intrinsic to individual fisheries).

The relationship between catch and effort and CPUE (kg/day) versus year and the nominal ER-C elver index were explored via linear regression. The GLMM were constructed, assuming a tweedie distribution, 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. Catch and CPUE versus year, indices generated via the GLMM with no reference to the ER-C index were subsequently regressed against the ER-C index.

All analyses were based on the catches reported in logbooks; however, these cannot be reported directly owing to privacy constraints. Catches are accordingly portrayed in this report as a proportion of the highest annual catch recorded in any year for the fishery as a whole and for each individual licenced fishery.

RESULTS AND DISCUSSION

TOR1: UPDATE LARGE EEL FISHERY CATCH AND EFFORT INFORMATION FOR THE YEARS 2017 TO 2022

The active sector of the large eel fishery has remained small relative to the fishery with full participation by all licence holders. The number of licences reporting catches varied between 16 to 32 per year since 2016 (Table 3). The fishery is thought to have been reduced in 2020 owing to covid-related factors. The information available for 2022 is considered to be preliminary because not all active licence holders may have reported by the time the data was compiled. A range of 24-30 active licences between years is considered reasonable. The New Brunswick sector was about 20-25% smaller than the Nova Scotia sector of the fishery in terms of active licences but accounted for 50% or more of the reported landing in some years.

Based on reported landings, the number of commercial licenses that are active has decreased over the past decade.

The number of eel licences available has continued to decline with time, from 426 in 2017 to 370 in 2022 (Table 4; Figure 7). Twenty-two licences were exchanged for green crab licences: 4 in 2017, 6 in 2018, 5 in 2019, 3 in 2020 and 4 in 2021. The practice of not renewing recreational licences as participants leave the fishery resulted in a decline of 10 licences, from 119 in 2017 to 109 in 2022 (Table 4). The commercial sector remains larger than either the communal commercial or recreational sectors. Active licences represented between 6 to 11% of available eel licences from 2017 to 2022.

The quantities of gear authorized to fish for eels has also declined with time, from 24,035 units in 2017 to 21,106 units in 2022 (Table 4). The quantity of gear associated with commercial licences reporting eel catches remains a minor component of the total quantity that could be set, between 6–11% per year (Table 4, Figure 7).

Quantities of all substantive gear types declined between 2017 and 2022 (Table 5). Pots declined from 21,929 units to 19,199 units, fyke nets from 2,075 units to 1,889 units, and weirs from 25 installations to 19 installations. The number of commercial longlines remained unchanged at 6.

Based on reported landings from the large eel fishery, the number of commercial licences 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 (Table 4). 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. (Figure 8).

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.

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.

TOR2: UPDATE FROM 2018 THE EAST RIVER-CHESTER ELVER RECRUITMENT INDEX

The ER-C elver index (Table 6) 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. The 2021 and 2022 (Table 6, Figure 9) estimates are considered to be underestimates because unknown numbers of elvers were removed by unlicensed and unreported fishing below the elver traps. Trend analysis for the entire time series beginning in 1996 is not advisable. 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 7, Figure 10) 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). Two (years 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 10). 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 for 1999.

Other sources of information available for consideration in this review were consistent with an interpretation of high recruitment in these two years.

Escapement in the local ER-C fishery has exceeded the SPR50 reference level since 2018 (Figure 11), as has been the case since 2016 and has remained above the SPR30 threshold since the inception of the fishery in 1996 (Figure 11). Fishing effort was relatively low during 1999–2001 presumably because the incentive to fish was lower owing to a significant drop in the value per kilogram of elvers.

Evaluation of the appropriateness of the 1996–2022 median run size as the basis for establishing RCL's would usually be a consideration during the five-year update status assessment (DFO 2018). However, the exceptionally large (for the time series) 2022 estimate represents a potentially significant high bias. The resultant impression of overall increasing elver run-size with time cannot be substantiated with run-size estimates for all five years since the last assessment and accurate run-size estimates were not acquired for two of the three years that monitoring occurred. The observation that all three of the estimates acquired since 2018 lie above the 1996–2018 mean needs to be considered in the context that high year-to-year variability in total run size is a characteristic of the ER-C elver run. For example, run size has varied 80% year-to-year on average and between 14% and 250% year-to-year (see Table 6).

Thus, changes to the RCL's should occur in the context of substantive unlicensed directed fishing for elvers, including on rivers presently licensed for fishing within a defined RCL, and in drainages that had until recently either not been fished (fallow) for any life-stage of eel or were fished for large eels.

TOR3: ASSESS ALTERNATIVE AND SUPPLEMENTAL ANNUAL INDICES OF EEL AND ELVER ABUNDANCE FROM THE REGION

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 there was no early closure of the fishery by a fishery management order (FMO, Figure 12) for conservation and public safety reasons. 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 TAC (Table 8). Reported landings in the years that the commercial fishing season was cut short by FMO were 2.95 t in 2020 and 5.50 t in 2023, representing 0.30 and 0.55 of the TAC, respectively.

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) (Figures 13 and 14). All annual catch records were truncated to the date that the individual quota (IQ) was reached. The 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 (Table 9).

Positive statistically significant trends with time are evident for both variables ($p < 0.05$) but with low explained variance ($r^2 = 0.07$ for catch and 0.17 for CPUE). Catch is not statistically correlated with effort (Figure 15).

Both catch and CPUE exhibit substantive variability in change with time among licences (Figures 16 and 17). Four of six exhibit statistically significant positive correlations with time in both catch and CPUE whereas neither variable is correlated with time for the other two licences (Figures 16 and 17). There is a tendency for the reported catch to flatten with time (Figure 16) indicating that quota-based constraints are a factor influencing annual fishing activities for some, but not all, licence holders.

Duration of fishing activity (days) varies among the six licences (Figure 18). Only two of the four licenced fisheries that exhibited statistically significant positive correlations with time exhibited a statistically significant relationship between catch and effort (Licence 3, $r^2 = 0.42$; Licence 6, $r^2 = 0.18$; Figure 18).

Plots of both catch (Figure 19) and CPUE (Figure 20) versus the ER-C elver index highlight the lack of information concerning the performance of the fishery at abundances above the mid-range (about 800 kg) of the observed run sizes. Evaluation of catch and CPUE as alternative or supplemental annual abundance indices via a direct association with the ER-C elver index is not advisable.

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 (Table 9). A tendency for residuals to trend downward is apparent in the plot of residual versus predicted values (Figure 21) but departures from expectations were not significant (Kolmogorov-Smirnov test $p > 0.2$) and no overdispersion was evident ($p = 0.77$).

Predicted and nominal catch and catch per unit effort (CPUE; Table 10, Figure 22) 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. Both data series exhibit statistically significant positive trends with time (MK tests, Table 11). The 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 75th quantiles for either the 1996–2022 or the 1996–2018 series (Table 11).

Plots of predicted catch versus the ER-C elver index value corresponding to the catch prediction year (Figure 22) corroborates the perception that catch is not a good indicator of elver availability as measured at the ER-C. Predicted catches of between approximately 450 and 995 kg per year have occurred at runs sizes of between 520 kg and 536 kg per year (Figure 22). Catches within this range have been predicted for run sizes that exceed 500 kg by factors of nearly two (896 kg) and three (1,600 kg). Predicted average CPUE of 18 kg per day or higher may be indicative of run sizes exceeding 1,000 kg.

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 for Other Rivers

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 12). 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 2001–2002, 2008–2019, 2021 (Figure 23), or for the years 2014–2019 (Figure 24), but differ significantly (t-test). 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 24). EPB has been discontinued and can therefore not be considered to be an alternative to the ER-C index on that basis alone.

Summaries of index-specific run sizes scaled to area (km^2) of receiving habitat (Table 13) indicate that the elver run to WHP is proportionally lower in scale than to either ER-C or EPB, irrespective of the years considered (e.g., all available data per index, years common to pairs or all three indices). However, statistically significant differences revealed by ANOVA and Tukey's HSD tests for data available for all years (degrees of freedom (DF)=2,43, F-Value=6.178, $p>0.01$) are not evident for the 6 years that are common to all three indices (DF=2,15, F-Value=1.044, $p=0.38$). A 2-sample t-test applied to the annual elver run densities acquired during years common to both indices indicate that the ER-C elver run is proportionally greater in size than the run to WHP (DF=24, t-value=3.9891, $p<0.001$).

The EPB elver run density does not differ statistically from the ER-C elver run density (Tukeys HSD $p=0.94$ for the years 2014 to 2019). 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 to 2019 time period (Tukeys HSD p=0.37; Table 14 a,b,c).

The average run density of 3.12 kg per km^2 to ER-C for the years 1996–2022 (Table13) is higher than the average run density of 2.58 elvers per km^2 estimated for the 1996–2018 time period.

Overall, there are no indications that other regional elver abundance indices could fulfil the role of the ER-C in the scientific and management frameworks established in Maritimes Region for the elver fishery. The indices are either not correlated (e.g., WHP) with the ER-C elver index and those that do exhibit some promise (EPB) were discontinued electrofishing-based abundance indices.

Electrofishing based abundance indicators

Four electrofishing abundance indices are reported herein for each river, the nominal index and three that represent the final GLMM model built using

1. area and location,
2. area, location, and flow, and
3. area, location, flow and water temperature (Table 15).

However, interpretation of change in abundance with time is limited here to the final models, displayed in Figure 25 along with the nominal indices, developed using sites for which area, location, flow and water temperature data were available even though this resulted in significant reductions in the sample sizes for the LaHave and St. Mary's rivers. The model with the lowest AIC value for all three river data series included both flow and water temperature when available (data not shown) thereby suggesting that environmental correlates are important determinants of site specific eel abundance. The results for individual rivers are shown in Tables 16–18. The results of ARIMA testing are shown in Table 19.

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

LaHave River, N.S.

The final model for LaHave River retained year, branch, flow, month, and temperature in the conditional part of the model. None of the models explored with a zero-inflated variable were ranked among the best models (Table 16). No outliers or obvious patterns in the residual plots were observed denoting the good fit of the data (Figure 26). The nominal and model abundance indices averages were the same, 0.51±0.21 eels/100 m^2 and 0.51±0.23 eels 100 m^2, respectively. Model abundance was higher during both 1995 and 1997 than during any other year thereafter (Table 16, Figure 25). The nominal series high (1.7 eels/100 m^2) was observed in 2017 when no temperature data were available for input into the model. However, the 2017 model index values generated from the location/area and location/area/flow data sets were the same (1.7 eels/100 m^2).

The revised, from Cornic et al. (2021), and updated data indicated that eel abundances exhibited no trend between 1995 and 2022, but that abundance has trended higher since 2002 (Table 18, M-K: τ=0.40, p=0.01). ARIMA models (Table 19) indicated an equal probability (p=0.50) that abundances were below the 75th quantile for the reference years 2022 and 2021-2022 when compared to the 2002–2022 reference range. The probability was high (Pr≥0.67) that abundances in all reference years were below the 75th quantile for the

1995-2017 reference range (Table 19). This interpretation is consistent with Cornic et al. (2021) that abundances remained low after declining from the highs observed in the mid to late 1990s.

St. Mary's River, N.S.

The final model for St. Mary's River retained year, branch, flow, month, and temperature in the conditional part of the model. Zero-inflation was evident (zi=~1) but none of the models explored with a variable defined as being zero-inflated were ranked among the best models (Table 17). No outliers or obvious patterns in the residual plots were observed denoting the good fit of the data (Figure 27). 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 (Figure 25, middle panel) since either 1995 or since 2003 (Table 17). 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 2022 and 2021–2022 reference years are nominally above the 75th quantile, relative to the 2003-2022 reference range (Table 18), but below the 50th quantile relative to the 1995–2017 reference range (0.75). Abundance in both reference years are above the 25th quantile irrespective of the reference range.

Nashwaak River, N.B.

The final model for Nashwaak River retained year, branch, flow, month, and temperature in the conditional part of the model. Zero-inflation was evident (zi=~1), but none of the models explored with a variable defined as zero-inflated were ranked among the best models (Table 18). No outliers or obvious patterns in the residual plots were observed (Figure 28). 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 (Table 18; Figure 25). A statistically significant negative trend in abundance is evident for the years 1988 to 2022 (M-K: τ =-0.26, p =0.03, Table 19) but not for the 1996-2022 or 2002-2022 time periods (Table 20). Abundances during the 2022 and 2021–2022 reference years are generally below the 50th quantile, but all are above the 25th quantile (Table 19).

Indices of Adult (Silver) Eel Abundance

Counts of silver eels descending Oakland Lake Stream, Nova Scotia and Eel Pond Brook exhibited a general but not statistically significant decline with time (Table 20). Average annual adult production was estimated to be one adult (SD =0.34) per ha of catchment area for Oakland Lake Stream and one adult (SD =0.69) per ha for the catchment area of Eel Pond Brook.

DIRECTED SAMPLING FOR YOUNG JUVENILE EELS

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.

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 (Figure 29). 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 sampled populations in 2002 and 2004, respectively (Figure 29).

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.

The electrofishing data for LaHave River indicate that eel abundances at sites located above Morgan Falls are lower on average than at sites below Morgan Falls (Figure 31). Electrofishing may be a means to evaluate whether or not the improvements in upstream passage for eels at Morgan Falls result in measurable increases in eel standing stock above the falls.

Directed monitoring of young migratory yellow eels at fixed locations have potential as supplementary indices 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 elver 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.

ACKNOWLEDGEMENTS

The compiled elver count data for the East River-Chester represents the collective contributions of many field technicians, students, and interns. We thank them all. We acknowledge the past and continuing support of the commercial elver fishers who have generously supported monitoring activities at the river since the inception of the project in 1996. We thank Yvonne, Wayne, and Genna Carey for their readiness to pitch in on all matters related to the counting of elvers and for all other contributions to this work. We thank South Shore Trading Co. Ltd. for providing their elver and eel monitoring data to support this assessment.

REFERENCES CITED

ASMFC. 2023. American Eel Benchmark Stock Assessment and Peer Review Report. ASMFC, Arlington, VA. 320.

Bradford, R.G. 2013. 2010 status of American eel (*Anguilla rostrata*) in Maritimes Region. DFO Can. Sci. Advis. Sec. Res. Doc. 2012/083. iv + 39 p.

Bradford, R.G., Cook, A.M., and Smith, S. 2022. Assessment of the Maritimes Region American Eel and Elver fisheries. DFO Can. Sci. Advis. Sec. Res. Doc. 2022/009. v + 76 p.

Brooks, M.E., Kristensen, K., van Benthem, K.J., Magnusson, A., Berg, C.W., Nielsen, A., Skaug, H.J., Maechler, M., and Bolker, B.M. 2017. glmmTMB balances speed and flexibility among packages for zero-inflated Generalized Linear Mixed Modeling. The R Journal. 9: 378-400.

Bowlby, H.D. 2018. Productivity of riverine habitats may be changing for American eel. Can. J. Fish. Aquat. Sci. 75: 1773–1777.

Bowlby, H.D., Gibson, A.J.F., and Levy, A. 2013. Recovery Potential Assessment for Southern Upland Atlantic Salmon: Status, Past and Present Abundance, Life History and Trends. DFO Can. Sci. Advis. Sec. Res. Doc. 2013/005. v + 72 p.

Cairns, D.K., Tremblay, V., Caron, F., Casselman, J.M., Verreault, G., Jessop, B.M. , de Lafontaine, Y., Bradford, R.G., Verdon, R., Dumont, P., Mailhot, Y., Zhu, J., Mathers, A., Oliveira, K., Benhalima, K., Dietrich, J., Hallett, J.A., and Lagacé, M. 2008. American eel abundance indicators in Canada. Can. Data Rep. Fish. Aquat. Sci. No. 1207. 78 p.

Cairns, D.K., Chaput, G., Poirier, L.A., Avery, T.S., Castonguay, M., Mathers, A., Casselman, J.M., Bradford, R.G., Pratt, T., Verreault, G., Clarke, K., Veinott, G., and Bernatchez, L. 2014. Recovery Potential Assessment for the American Eel (*Anguilla rostrata*) for eastern Canada: life history, distribution, reported landings, status indicators, and demographic parameters. DFO Can. Sci. Advis. Sec. Res. Doc. 2013/134. xiv + 157 p.

Chaput, G., and Cairns, D. 2011. Mortality reference points for the American Eel (*Anguilla rostrata*) and an application for evaluating cumulative impacts of anthropogenic activities. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/053. iv + 28 p.

Chaput, G., Pratt, T.C., Cairns, D.K., Clarke, K.D., Bradford, R.G., Mathers, A., and Verreault, G. 2014. Recovery Potential Assessment for the American eel (*Anguilla rostrata*) for eastern Canada: description and quantification of threats. DFO Can. Sci. Advis. Sec. Res. Doc. 2013/135. vi + 90 p.

Cornic, M., Zhu, X., and Cairns, D.K. 2021. Stock-wide assessment framework for American eel: review of trends and approaches to assessment. DFO Can. Sci. Advis. Sec. Res. Doc. 2021/032. x + 77 p.

COSEWIC. 2006. COSEWIC assessment and status report on the American Eel (*Anguilla rostrata*) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa x + 71 pp.

COSEWIC. 2012. COSEWIC assessment and status report on the American eel (*Anguilla rostrata*) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xii + 109 pp.

DFO. 1998. Scotia-Fundy Elvers Integrated Fisheries Management Plan.

DFO. 2007. A New Ecosystem Science Framework in Support of Integrated Management. Fisheries and Oceans Canada, Ottawa, Ontario. DFO/2007-1296.

DFO. 2009. A fishery decision-making framework incorporating the precautionary approach.

DFO. 2010. Status of American eel and progress on achieving management goals. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2010/062.

DFO. 2013. Proceedings of the National Workshop for Technical Expertise in Stock Assessment (TESA): Maximum Sustainable Yield (MSY) Reference Points and the Precautionary Approach when Productivity Varies; December 13–15, 2011. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2012/055.

DFO. 2014. Recovery potential assessment of American eel (*Anguilla rostrata*) in eastern Canada. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2013/078.

DFO. 2017. Proceedings of the Regional Peer Review of the Stock Framework for American Eel (*Anguilla rostrate*) and Elvers. DFO Can. Sci. Advis. Sec. Proc. 2017/048.

DFO. 2018. Elver integrated fisheries management plan (evergreen) Maritimes Region.

DFO. 2019. Assessment of the Maritimes Region American Eel and Elver Fisheries. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2019/054.

Gilbert, R.O. 1987. Statistical methods for environmental pollution monitoring. Van Nostrand Reinhold, New York. 320 p.

ICES. 2001. Report of the Working Group on Eels St. Andrews, N.B., Canada, 28 August–1 September 2000. ICES CM 2001/ACFM:03.

Nelson G.A. 2018. fishmethods: fishery science methods and models. R package version 1.11-0.

R Core Team. 2019. R: A language and environment for statistical computing. R Foundation for Statistical Computing. Vienna, Austria.

Scott, W.B., and Crossman, E.J. 1973. Freshwater Fishes of Canada. Fish. Res. Bd. Can. Bull. 184. 966 p.

Scott, W.B., and Scott, M.G. 1988. Atlantic Fishes of Canada. Can. Bull. Fish. Aquat. Sci. 219: 731 p.

Stacey, J.A., Pratt, T.C., Verreault, G. and Fox, M.G. 2014. A caution for conservation stocking as an approach for recovering Atlantic eels. Aquat. Conserv. Mar. Freshw. Ecosyst. 25: 569–580.

TABLES

Table 1. Estimates of area (hectare-ha) of habitat associated with catchments where elver and/or silver eel monitoring activities have occurred. NA indicates not estimated.

System	Area (ha)	Catchment (ha)
Eel Pond Brook (includes Eel Pond, East, Otter, Squints lakes	117	370
Oakland Lake Stream	66	406
West Harbor Pond	NA	1,330
East River-Chester	NA	13,770

Table 2. Summary of the number of observations (n) available to support generalized linear models using electrofishing-based eel densities for the LaHave and St. Mary's rivers (Nova Scotia) and the Nashwaak River (New Brunswick).

River	Total (n)	Subset 1* (n)	Subset 2** (n)	Subset 3*** (n)
LaHave	293	205	205	193
St. Mary's	319	180	180	179
Nashwaak	446	442	440	440

*Location, Electrofished Area (100 m^2)
**Location, Electrofished Area (100 m^2), Flow (m^3/s)
***Location, Electrofished Area (100 m^2), Flow (m^3/s), Water Temperature (°C)

Table 3. The number of active commercial licences reporting eel catches by year, province, and their associated reported catches (kg) and estimated landed values ($). Dash (–) indicates the aggregation of these data by individual province do not meet confidentiality requirements under Fisheries and Oceans Canada (DFO) Privacy and Protection Policy, and can therefore not be shared publicly. Data from 2019–2022 are considered preliminary. Data for communal commercial and recreational fishing are not reported to DFO. Bold type indicates totals by year.*

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**	**Total**	**32**	**36,974**	**243,051**
2018	NB	Commercial	6	19,072	—
2018	NS	Commercial	23	13,927	—
2018	**NS + NB**	**Total**	**29**	**32,999**	**187,665**
2019	NB	Commercial	6	12,464	—
2019	NS	Commercial	24	5,206	32,564
2019	**NS + NB**	**Total**	**30**	**17,670**	**97,353**
2020*	**NS + NB**	**Total**	**16**	**8,191**	**34,666**
2021	NB	Commercial	9	12,955	—
2021	NS	Commercial	17	9,631	52,018
2021	**NS + NB**	**Total**	**26**	**22,586**	**116,975**

Year	Province	Licence Type	Licences Fished	Total Landings Live Weight (kg)	Total Landings Value ($)
2022	NB	Commercial	7	23,895	—
2022	NS	Commercial	16	12,169	39,754
2022	**NS + NB**	**Total**	**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 involved 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.

Table 4. The number of communal commercial (CC), recreational (R), and commercial (Com) licences and gear available for deployment by fishery sector, the number commercial licences actively fished (AF), commercial gear units actively fished by licences holders reporting eel catches and proportion (P) of available licences and gears units actively fished by year.

Year	CC Licence	R Licence	Com Licence	Total Licence	Total Gear	Com Gear	Com Licence AF	P (Com Licence AF)	Com Gear AF	P (Com Gear AF)
2017	13	119	294	426	24,035	22,363	32	0.11	2,450	0.11
2018	13	119	278	410	22,930	21,258	29	0.10	2,054	0.10
2019	13	118	265	396	22,096	20,428	30	0.11	2,324	0.11
2020	13	112	259	384	21,509	19,909	16	0.06	1,120	0.06
2021	13	109	253	375	21,379	19,791	26	0.10	2,199	0.11
2022	13	109	248	370	21,106	19,518	23	0.09	1,254	0.06

Table 5. The number (n) of gear units of different types of gear licenced to eel fisheries reporting having caught eels by year, province and licence type (NS – Nova Scotia, NB – New Brunswick).Bold type indicates totals by year.

Year	Province	Licence Type	Licences Available	Pots (n)	Trap Nets (n)	Weirs (n)	Longlines (n)
2015	NB	Commercial	28	1,817	788	0	0
2015	NB	Communal Commercial	1	120	40	0	0
2015	NS	Commercial	286	20,686	1,169	24	6
2015	NS	Communal Commercial	12	700	24	2	0
2015	NS	Recreational	139	880	69	0	0
2015	**NS + NB**	**All licence types combined**	**466**	**24,203**	**2,090**	**26**	**6**
2016	NB	Commercial	26	1,695	777	0	0
2016	NB	Communal Commercial	1	120	40	0	0
2016	NS	Commercial	278	19,946	1,169	24	6
2016	NS	Communal Commercial	12	700	24	2	0
2016	NS	Recreational	119	720	66	0	0
2016	**NS + NB**	**All licence types combined**	**436**	**23,181**	**2,076**	**26**	**6**
2017	NB	Commercial	26	1,695	777	0	0
2017	NB	Communal Commercial	1	120	40	0	0
2017	NS	Commercial	268	18,694	1,168	23	6
2017	NS	Communal Commercial	12	700	24	2	0
2017	NS	Recreational	119	720	66	0	0
2017	**NS + NB**	**All licence types combined**	**426**	**21,929**	**2,075**	**25**	**6**
2018	NB	Commercial	24	1,695	697	0	0
2018	NB	Communal Commercial	1	120	40	0	0
2018	NS	Commercial	254	17,624	1,215	21	6

Year	Province	Licence Type	Licences Available	Pots (n)	Trap Nets (n)	Weirs (n)	Longlines (n)
2018	NS	Communal Commercial	12	700	24	2	0
2018	NS	Recreational	119	720	66	0	0
2018	**NS + NB**	**All licence types combined**	**410**	**20,859**	**2,042**	**23**	**6**
2019	NB	Commercial	22	1,545	677	0	0
2019	NB	Communal Commercial	1	120	40	0	0
2019	NS	Commercial	243	16,970	1,210	20	6
2019	NS	Communal Commercial	12	700	24	2	0
2019	NS	Recreational	118	716	66	0	0
2019	**NS + NB**	**All licence types combined**	**396**	**20,051**	**2,017**	**22**	**6**
2020	NB	Commercial	22	1,545	677	0	0
2020	NB	Communal Commercial	1	120	40	0	0
2020	NS	Commercial	237	16,546	1,115	20	6
2020	NS	Communal Commercial	12	700	24	2	0
2020	NS	Recreational	112	648	66	0	0
2020	**NS + NB**	**All licence types combined**	**384**	**19,559**	**1,922**	**22**	**6**
2021	NB	Commercial	22	1545	677	0	0
2021	NB	Communal Commercial	1	120	40	0	0
2021	NS	Commercial	231	16,468	1,078	17	6
2021	NS	Communal Commercial	12	700	24	2	0
2021	NS	Recreational	109	636	66	0	0
2021	**NS + NB**	**All licence types combined**	**375**	**19,469**	**1,885**	**19**	**6**
2022	NB	Commercial	22	1,545	677	0	0
2022	NB	Communal Commercial	1	120	40	0	0
2022	NS	Commercial	226	16,198	1,073	17	6
2022	NS	Communal Commercial	12	700	24	2	0
2022	NS	Recreational	109	636	66	0	0
2022	**NS + NB**	**All licence types combined**	**370**	**19,199**	**1,880**	**19**	**6**

Table 6. Elver run sizes in the East-River Chester by year estimated as commercial catch plus escapement, escapement estimates, and proportion of the run estimated to have been removed by commercial fishing by year of sampling. All estimates expressed as both weight (kg) and numbers (n). NA indicates years that commercial fishing activity was closed by fishery management order part way through the season.

Year	Run Size (kg)	Run size (n)	Escapement (kg)	Escapement (n)	Proportion fished (kg)	Proportion fished (n)
1996	277	1,367,609	162	863,350	0.42	0.37
1997	359	1,887,151	196	1,145,448	0.45	0.39
1998	117	594,729	40	247,407	0.66	0.58
1999	85	530,760	83	521,936	0.02	0.02
2000	149	879,854	149	879,854	0.00	0.00
2001	120	647,516	99	544,885	0.18	0.16
2002	536	2,689,021	322	1,742,610	0.40	0.35
2008	458	1,970,988	196	1,182,193	0.57	0.40
2009	280	1,426,196	114	696,376	0.59	0.51
2010	156	774,811	56	361,804	0.64	0.53
2011	468	2,390,790	295	1,696,852	0.37	0.29
2012	439	2,587,177	311	2,073,432	0.29	0.20
2013	387	2,214,696	262	1,661,407	0.32	0.25

Year	Run Size (kg)	Run size (n)	Escapement (kg)	Escapement (n)	Proportion fished (kg)	Proportion fished (n)
2014	499	2,748,237	269	1,657,916	0.46	0.40
2015	277	1,430,167	113	669,030	0.59	0.53
2016	610	2,951,576	496	2,377,902	0.19	0.19
2017	253	1,150,707	178	831,634	0.30	0.28
2018	896	3,793,992	835	3,592,404	0.07	0.05
2019	534	2,515,559	293	1,479,336	0.45	0.41
2020	NA	NA	NA	NA	NA	NA
2021	463	2,071,555	299	1,363,650	0.35	0.34
2022	1,610	7,273,401	1,409	6,408,052	0.12	0.12
2023	NA	NA	NA	NA	NA	NA

Table 7. Aggregate summary of the East River-Chester elver abundance index comparing median run size estimate (kg) and kg per km² of receiving habitat from 1996–2018, and for the run-size time series updated to the end of 2022. Run sizes represent the 75th quantile catch (kg and kg per km² of receiving habitat) for the two time series.

Attribute	kg	kg/km²
Median 1996–2018	320	2.33
Median updated to 2022 (Series, Nominal)	387	2.82
75th Quartile to 2018	466	3.40
75th Quartile updated to 2022 (Series, Nominal)	499	3.64

Table 8. Elver annual total allowable catch (TAC) (t) and landings (t) from experimental and commercial fishing from 1989–2023 in the Maritimes Region. P(TAC) is the proportion of the quota landed. All weights are wet. Estimates previously reported in DFO (2019) and Bradford et al. (2022) for 2008–2018 have been revised following review. NA represent no TAC set. Dashes represent no revision required.

Year	Fishery	TAC (t)	Commercial landings (t)	P(TAC)	Revised Commercial landings (t)	Revised P (TAC)
1989	Experimental	None	0.03	NA	—	—
1990	Experimental	None	0.17	NA	—	—
1991	Experimental	None	0.07	NA	—	—
1992	Experimental	None	0.23	NA	—	—
1993	Experimental	None	0.71	NA	—	—
1994	Experimental	None	1.57	NA	—	—
1995	Experimental	None	3.24	NA	—	—
1996	Commercial	None	2.86	NA	—	—
1997	Commercial	None	4.13	NA	—	—
1998	Commercial	13.3	2.05	0.15	—	—
1999	Commercial	13.3	0.48	0.04	—	—
2000	Commercial	13.3	0.68	0.05	—	—
2001	Commercial	13.3	1.84	0.14	—	—
2002	Commercial	13.3	2.36	0.18	—	—

Year	Fishery	TAC (t)	Commercial landings (t)	P(TAC)	Revised Commercial landings (t)	Revised P (TAC)
2003	Commercial	13.3	1.84	0.14	—	—
2004	Commercial	13.3	1.27	0.10	—	—
2005	Commercial	9.96	3.04	0.30	—	—
2006	Commercial	9.96	2.46	0.25	—	—
2007	Commercial	9.96	2.03	0.20	—	—
2008	Commercial	9.96	3.59	0.36	4.80	0.48
2009	Commercial	9.96	1.81	0.18	2.40	0.24
2010	Commercial	9.96	1.47	0.15	1.95	0.20
2011	Commercial	9.96	3.08	0.31	4.10	0.41
2012	Commercial	9.96	5.59	0.56	5.60	0.56
2013	Commercial	9.96	6.76	0.68	6.75	0.68
2014	Commercial	9.96	5.71	0.57	5.70	0.57
2015	Commercial	9.96	3.58	0.36	3.60	0.36
2016	Commercial	9.96	5.20	0.52	5.20	0.52
2017	Commercial	9.96	5.61	0.56	5.75	0.58
2018	Commercial	9.96	6.96	0.70	8.30	0.83
2019	Commercial	9.96	NA	NA	8.05	0.81
2020	Commercial	9.96	NA	NA	2.95	0.30
2021	Commercial	9.96	NA	NA	6.40	0.64
2022	Commercial	9.96	NA	NA	8.30	0.83
2023	Commercial	9.96	NA	NA	5.50	0.55

*Table 9. Generalized linear models developed for standardized abundance indices of elver catch and elver catch per unit effort. Delta corrected Akaike information criterion (dAICc), deviance (Dev), Kolmogorov-Smirnov test (KS), dispersion test (Disp), root mean square error (rmse), r_2 marginal (r_2 marg), r_2 conditional (r_2 cond), variance statistical significance of the variables tested *p < 0.05, **p=0.01, ***p < 0.01.*

Conditional Model	Zero-Inflated Model	Distribution	dAICc	df	KS	Disp p-value	rmse	r2cond	r2 marg
Scatch~Year*+offset(log(SEffort))+1|fLicence+fQ90***	0	Tweedie	0	6	0.22	0.78	252.07	0.13	0.08
Scatch~Year**+offset(log(SEffort))+1|fLicence+fQ90*** +fQuota	0	Tweedie	1.6	8	0.46	0.74	247.04	0.13	0.08
Scatch~Year**+offset(log(SEffort))+1|fLicence +fIncentive+fQ90***	0	Tweedie	1.7	7	0.20	0.81	250.69	0.13	0.08
Scatch~fYear+offset(log(SEffort))+1|fLicence+fQ90***	0	Tweedie	22.7	29	0.37	0.96	226.80	0.21	0.13
Scatch~fYear+offset(log(SEffort))+1|fLicence+fIncentive +fQ90***	1	Tweedie	26.1	30	0.51	0.90	226.80	0.21	0.13

Table 10. Modeled abundance indices of elver catch and catch per unit effort (CPUE) in the East River-Chester and the nominal abundance index for each variable. SE is standard error of the mean. The indices were generated using catch truncated at the individual quota, therefore they do not reflect all fishing activity. Index represents the estimated total annual run size (kg).

Year	Catch Index	Catch SE	Nominal abundance	SE	CPUE Index	CPUE SE	Nominal CPUE	CPUE SE	Index (kg)
1996	701.6	58.8	604.0	214.9	10.6	0.9	9.5	2.5	277
1997	642.7	59.2	809.4	196.3	12.7	1.2	16.6	4.7	359
1998	342.5	31.6	338.3	111.2	8.1	0.8	7.8	1.8	117
1999	208.5	19.8	136.3	93.9	8.3	0.8	5.7	3.6	85
2000	182.7	16.5	141.0	50.2	8.4	0.8	11.1	4.0	149
2001	296.6	27.3	357.4	160.8	8.5	0.8	11.1	3.4	120
2002	456.0	38.0	641.3	379.5	13.1	1.2	25.2	2.5	536
2003	437.5	40.0	465.8	164.7	9.2	0.9	9.8	3.4	NA
2004	480.8	44.1	416.5	166.7	9.3	0.9	7.9	2.9	NA
2005	501.5	46.8	607.6	160.7	9.2	0.9	11.3	3.8	NA
2006	582.8	50.0	669.5	245.7	13.3	1.2	14.8	4.4	NA
2007	520.2	47.9	533.5	222.1	9.9	0.9	10.0	4.2	NA
2009	519.7	49.4	405.8	104.0	9.2	0.9	7.4	2.0	280
2010	630.4	59.5	360.0	129.4	9.4	0.9	4.9	1.6	156
2011	688.8	64.2	697.7	158.0	12.0	1.1	12.9	5.5	468
2012	951.8	95.9	851.7	158.0	15.5	1.5	15.0	4.8	439
2013	962.2	93.8	919.3	98.0	15.3	1.4	16.6	4.5	387
2014	771.2	72.4	792.0	144.7	14.1	1.3	14.3	3.7	499
2015	602.7	56.4	502.2	129.4	10.0	0.9	8.5	2.4	277
2016	727.9	64.5	757.8	173.8	13.8	1.2	14.1	3.7	610
2017	863.9	79.4	759.3	176.1	14.4	1.3	12.5	3.3	253
2018	794.7	76.2	994.8	110.4	16.3	1.5	21.2	4.6	896
2019	995.3	92.4	955.0	102.0	16.5	1.5	16.3	2.2	520
2021	819.4	73.6	757.0	157.9	15.1	1.3	14.5	4.4	483
2022	873.5	92.8	1018.2	13.9	22.2	2.3	26.9	2.7	1610

Table 11. Autoregressive integrated moving average (ARIMA) and trend analyses results for elver catch and elver catch per unit effort (CPUE). The 1996–2022 reference range (RR) represents the entire time series, and the 1996–2018 RR represents the data 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 is shown with the probability (p-value) that the residual values from the ARIMA are not normally distributed. Dashes (–) indicate not applicable.

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

Table 12. 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.

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	—	—	—	—
2001	—	647,516	120	—	—	—	52,638
2002	—	2,689,021	536	—	—	—	82,359
2003	—	—	—	—	—	—	15,905
2004	—	—	—	—	—	—	2,401
2005	—	—	—	—	—	—	73,178
2006	—	—	—	—	—	—	4,812
2007	—	—	—	—	—	—	988
2008	—	1,970,988	458	—	—	—	46,167
2009	—	1,426,196	280	—	—	—	12,811
2010	—	774,811	156	—	—	—	10,314
2011	—	2,390,790	468	—	—	—	9,658
2012	—	2,587,177	439	—	—	—	156,472
2013	—	2,214,696	387	—	—	—	84,509
2014	—	2,748,237	499	—	—	15,535	140,706
2015	—	1,430,167	277	—	—	26,685	31,666
2016	—	2,951,576	610	—	—	40,175	106,990
2017	—	1,150,707	253	—	—	4,173	236,080
2018	—	3,793,992	896	—	—	149,315	67,380
2019	—	2,515,559	534	—	—	110,976	160,211
2020	—	—	—	—	—	—	—
2021	—	2,071,555	463	—	—	—	—
2022	—	7,273,401	1,610	—	—	—	—

Table 13. Summary of available annual elver abundances scaled to the catchment area (km^2) of the receiving waterbody. The daily catch of elvers at East River-Chester (ER-C) is estimated by weight (kg) and subsampled to estimate number of elvers (n). The estimates for Eel Pond Brook (EPB) and West Harbor Pond (WHP) were reported as number of elvers. The estimates reported below as kg/km^2 for these indices assume 5,000 elvers per kg, a typical annual aggregated estimate for ER-C. SE=standard error. CI 2.5 and CI 97.5 are the lower and upper bounds of the 95 percentile confidence interval.

Years	System	Units	Nominal Mean	Nominal Median	Mean	Median	SE	CI 2.5	CI 97.5
1996-2002, 2008-2018	ER-C	kg	2.58	2.33	2.64	2.55	0.89	1.09	4.58
1996-2002, 2008-2018	ER-C	n	12,991	12,107	13,314	13,110	4,073	5,969	21,800
1996-2002, 2008-2022	ER-C	kg	3.12	2.82	3.12	3.09	0.52	2.23	4.25
2001-2021	WHP	kg	0.57	0.79	1.21	1.19	0.28	0.69	1.80
2001-2002, 2008-2022	ER-C	kg	2.77	3.34	3.10	3.09	0.35	2.41	3.80
2001-2002, 2008-2021	WHP	kg	0.95	1.24	1.49	1.48	0.33	0.91	2.20
1996-2002, 2008-2022	ER-C	n	15,258	14,387	15,258	15,090	2,289	11,312	20,239
2001-2021	WHP	n	2,789	3,958	6,032	5,959	1,387	2,584	8,967
2001-2002, 2008-2022	ER-C	n	13,775	16,166	15,262	15,282	1,575	12,204	18,428
2001-2002, 2008-2022	WHP	n	4,767	6,192	7,459	7,402	1,624	4,533	10,620
2014-2019	ER-C	kg	3.4	3.77	3.73	3.73	0.65	2.53	5.00
2014-2019	EPB	kg	3.12	1.81	3.12	3.10	1.19	1.03	5.58
2014-2019	WHP	kg	1.55	1.86	1.86	1.86	0.40	1.11	2.66
2014-2019	ER-C	n	16,373	19,211	17,750	17,749	2,688	12,635	22,922
2014-2019	EPB	n	15,624	9,035	15,624	15,529	5,808	4,797	27,580
2014-2019	WHP	n	7,767	9,311	9,311	9,286	2,010	5,561	13,246

Table 14a. Results of analysis of variance among elver abundance indices scaled to number of elvers per km² of receiving habitat for East River-Chester, Eel Pond Brook, and West Harbor Pond. 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 14b. Results of t-test between East River-Chester and West Harbor Pond 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 14c. 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

*Table 15. Model selection for the standardized abundance indices for LaHave (LH), Nashwaak River (NW) and St. Mary's River (SM) electrofishing eel data series using generalized linear models: distributions (D) are either zero-inflated (ZINB) or negative binomial (NB). Delta corrected Akaike Information Criterion (ΔAICc), Kolmogorov-Smirnov test (KS), Dispersion test (Disp), df = degrees of freedom, root mean square error (rmse), variance statistical significance of the variables tested *p<0.05, **p=0.01, ***p<0.01. Subset 1 is all datasets that have area and location data available for each site. Subset 2 data is all data sets that have area, location and flow data available for each site. Subset 3 is all datasets that have area, location, flow and water temperature data available for each site.*

River	Subset	Conditional Model	D	ΔAICc	df	KS	Disp p value	rmse
LH	**3**	**Catch~offset(log(Area))+ fYear*+Flow***+fMonth*** +fBranch***+WaterT*** **	**NB**	**0**	**29**	**0.84**	**0.36**	**10.22**
LH	3	Catch~offset(log(Area))+fYear* +Flow***+fMonth***+fBranch*** +WaterT***	ZINB	2.8	30	0.98	0.34	10.22
LH	3	Catch~offset(log(Area))+fYear* +l.Flow***+fMonth*** +fBranch***+WaterT***	NB	4	29	0.96	0.37	10.45
LH	3	Catch~offset(log(Area))+fYear* +l.Flow***+fMonth*** +fBranch***+WaterT***	ZINB	6.8	3	0.90	0.37	10.45
LH	2	Catch~offset(log(Area))+fYear* +Flow***+fMonth*** +fBranch***	NB	0	28	0.73	0.08	10.14
LH	2	Catch~offset(log(Area))+fYear* +Flow***+fMonth* +fBranch***	ZINB	1.4	29	0.77	0.14	9.86
LH	2	Catch~offset(log(Area))+fYear* +l.Flow*+fMonth** +fBranch***	NB	5.1	28	0.97	0.24	10.19
LH	2	Catch~offset(log(Area))+fYear* +l.Flow*+fMonth* +fBranch***	ZINB	7.5	29	0.97	0.18	10.05
LH	1	Catch~offset(log(Area))+fYear* +fMonth**+fBranch***	NB	0	27	0.95	0.18	10.67
LH	1	Catch~offset(log(Area))+fYear* +fMonth*+fBranch***	NB	1.8	28	0.94	0.14	10.42
LH	1	Catch~offset(log(Area))+Year** *+fMonth***+Branch***	NB	22.2	6	0.89	0.21	13.81
LH	1	Catch~offset(log(Area))+fYear* +fMonth**	NB	29	26	0.43	0.33	11.53
SM	**3**	**Catch~offset(log(Area))+fYear *+l.Flow+fMonth* +fBranch***+WaterT*** **	**ZINB**	**0.0**	**26**	**0.82**	**0.78**	**11.45**
SM	3	Catch~offset(log(Area))+fYear* +Flow+fMonth*+fBranch*** +WaterT***	NB	0.1	26	0.59	0.74	11.32
SM	3	Catch~offset(log(Area))+fYear* +Flow+fMonth*+fBranch*** +WaterT***	NB	2.7	27	0.65	0.80	11.45
SM	3	Catch~offset(log(Area))+fYear* +l.Flow+fMonth+fBranch*** +WaterT***	ZINB	2.7	27	0.97	0.75	11.32
SM	2	Catch~offset(log(Area))+fYear* +Flow+fMonth +fBranch***	NB	0.0	23	0.83	0.224	10.23
SM	2	Catch~offset(log(Area))+fYear* +l.Flow+fMonth +fBranch***	NB	0.2	23	0.75	0.30	10.30
SM	2	Catch~offset(log(Area))+fYear* +Flow+fMonth +fBranch***	ZINB	2.7	24	0.98	0.29	10.22
SM	2	Catch~offset(log(Area))+fYear* +l.Flow+fMonth +fBranch***	ZINB	2.8	24	0.94	0.34	10.30

River	Subset	Conditional Model	D	ΔAICc	df	KS	Disp p value	rmse
SM	**1**	Catch~offset(log(Area))+fYear* +fMonth+fBranch***	NB	0.0	24	0.75	0.36	10.28
SM	**1**	Catch~offset(log(Area))+fYear* +fMonth+fBranch***	ZINB	2.6	25	0.80	0.32	10.28
SM	**1**	Catch~offset(log(Area))+fYear*	NB	8.2	21	0.99	0.91	13.91
SM	**1**	Catch~offset(log(Area))+fYear* +fMonth	NB	11.9	6	0.74	0.98	13.27
NW	**3**	**Catch~offset(log(Area))+fYear* +Flow+fMonth +fBranch**+WaterT****	**ZINB**	**0.0**	**41**	**0.90**	**0.92**	**9.67**
NW	**3**	Catch~offset(log(Area))+fYear* +WaterT**	ZINB	1.9	37	0.95	0.82	9.61
NW	**3**	Catch~offset(log(Area))+fYear* +l.Flow+fMonth +fBranch**+WaterT**	ZINB	3.2	41	0.56	0.98	9.67
NW	**3**	Catch~offset(log(Area))+fYear* +Flow+fMonth+WaterT**	ZINB	4.1	40	0.76	0.87	9.62
NW	**2**	Catch~offset(log(Area))+fYear* +Flow+fMonth +fBranch**	ZINB	0.0	40	0.60	0.93	9.66
NW	**2**	Catch~offset(log(Area))+fYear* +Flow	ZINB	1.4	37	0.90	0.85	9.62
NW	**2**	Catch~offset(log(Area))+fYear* +l.Flow+fMonth +fBranch**	ZINB	2.5	40	0.85	1.00	9.65
NW	**2**	Catch~offset(log(Area))+fYear* +l.Flow	ZINB	3.5	37	0.94	0.90	9.62
NW	**1**	Catch~offset(log(Area))+fYear* +fMonth+fBranch**	ZINB	0.0	39	0.77	0.97	9.67
NW	**1**	Catch~offset(log(Area))+Year*** +fMonth+fBranch	ZINB	43.8	7	0.89	0.86	10.83
NW	**1**	Catch~offset(log(Area))+fYear* +fMonth+fBranch**	NB	45.8	38	0.74	0.024*	9.59
NW	**1**	Catch~offset(log(Area))+fYear**	NB	48.6	35	0.32	0.08	9.48

Table 16. Abundance indices calculated using zero-inflated negative binomial models (ZINB) and nominal abundance indices for electrofishing surveys (eels per 100 m²) in the LaHave River. Den=density, SE=standard error of the mean, n=number of survey sites.

Year	n*	Den *	SE *	n**	Den**	SE**	n***	Den***	SE***	Nominal Index	Nominal SE
1995	28	1.22	0.32	28	1.27	0.33	26	1.24	0.33	1.11	0.15
1997	13	1.14	0.42	13	1.12	0.39	11	1.51	0.55	0.87	0.23
2002	14	0.62	0.19	14	0.62	0.18	14	0.66	0.19	0.8	0.25
2003	11	0.37	0.13	11	0.36	0.12	10	0.33	0.11	0.36	0.1
2004	12	0.12	0.05	12	0.12	0.05	12	0.11	0.04	0.11	0.06
2005	15	0.19	0.07	15	0.19	0.07	15	0.18	0.07	0.21	0.08
2006	10	0.31	0.11	10	0.3	0.11	9	0.19	0.07	0.4	0.2
2007	7	0.01	0.01	7	0.01	0.01	7	0.01	0.01	0.01	0.01
2008	6	0.06	0.04	6	0.06	0.04	5	0.07	0.04	0.06	0.03
2009	9	0.25	0.09	9	0.25	0.09	9	0.25	0.09	0.27	0.11
2010	9	0.74	0.29	9	0.74	0.28	9	0.78	0.28	0.86	0.36
2011	4	0.28	0.16	4	0.27	0.15	3	0.46	0.3	0.32	0.21
2012	8	0.38	0.16	8	0.43	0.22	8	0.42	0.21	0.4	0.16
2013	8	0.69	0.31	8	0.49	0.21	8	0.47	0.19	0.51	0.32
2014	10	0.46	0.18	10	0.5	0.19	10	0.41	0.15	0.48	0.16
2015	9	0.59	0.22	9	0.65	0.23	9	0.68	0.23	0.71	0.37
2016	5	1.39	0.68	5	1.32	0.62	5	1.73	0.86	1.33	0.42
2017	11	0.54	0.2	11	0.51	0.19	11	0.53	0.19	0.54	0.26
2018	7	0.78	0.33	7	0.73	0.29	7	0.72	0.29	0.96	0.46
2019	2	0.89	0.66	2	0.68	0.49	2	0.65	0.44	0.91	0.83
2020	2	0.26	0.22	2	0.26	0.22	2	0.26	0.2	0.27	0.16
2021	5	0.51	0.26	5	0.54	0.27	5	0.49	0.23	0.49	0.24
2022	6	0.79	0.34	6	0.79	0.34	6	0.85	0.36	0.91	0.35

**Model 1: Includes data subset 1 – Area, Location -full dataset (n=211)*
***Model 2: Includes data subset 2- Area, Location, Flow – full dataset (n=211)*
****Model 3: Includes data subset 3- Area, Location, Water temp -reduced dataset (n=203)*

Table 17. Abundance indices calculated using zero-inflated negative binomial models (ZINB) and nominal abundance indices for electrofishing surveys (eels per 100 m^2) in the St. Mary's River. Den=density, SE=standard error of the mean, n=number of survey sites.

Year	n *	Den *	SE *	n**	Den**	SE**	n***	Den***	SE***	Nominal Index	Nominal SE
1995	28	1.22	0.32	28	1.27	0.33	26	1.24	0.33	1.11	0.15
1997	13	1.14	0.42	13	1.12	0.39	11	1.51	0.55	0.87	0.23
2002	14	0.62	0.19	14	0.62	0.18	14	0.66	0.19	0.8	0.25
2003	11	0.37	0.13	11	0.36	0.12	10	0.33	0.11	0.36	0.1
2004	12	0.12	0.05	12	0.12	0.05	12	0.11	0.04	0.11	0.06
2005	15	0.19	0.07	15	0.19	0.07	15	0.18	0.07	0.21	0.08
2006	10	0.31	0.11	10	0.3	0.11	9	0.19	0.07	0.4	0.2
2007	7	0.01	0.01	7	0.01	0.01	7	0.01	0.01	0.01	0.01
2008	6	0.06	0.04	6	0.06	0.04	5	0.07	0.04	0.06	0.03
2009	9	0.25	0.09	9	0.25	0.09	9	0.25	0.09	0.27	0.11
2010	9	0.74	0.29	9	0.74	0.28	9	0.78	0.28	0.86	0.36
2011	4	0.28	0.16	4	0.27	0.15	3	0.46	0.3	0.32	0.21
2012	8	0.38	0.16	8	0.43	0.22	8	0.42	0.21	0.4	0.16
2013	8	0.69	0.31	8	0.49	0.21	8	0.47	0.19	0.51	0.32
2014	10	0.46	0.18	10	0.5	0.19	10	0.41	0.15	0.48	0.16
2015	9	0.59	0.22	9	0.65	0.23	9	0.68	0.23	0.71	0.37
2016	5	1.39	0.68	5	1.32	0.62	5	1.73	0.86	1.33	0.42
2017	11	0.54	0.2	11	0.51	0.19	11	0.53	0.19	0.54	0.26
2018	7	0.78	0.33	7	0.73	0.29	7	0.72	0.29	0.96	0.46
2019	2	0.89	0.66	2	0.68	0.49	2	0.65	0.44	0.91	0.83
2020	2	0.26	0.22	2	0.26	0.22	2	0.26	0.2	0.27	0.16
2021	5	0.51	0.26	5	0.54	0.27	5	0.49	0.23	0.49	0.24
2022	6	0.79	0.34	6	0.79	0.34	6	0.85	0.36	0.91	0.35

**Model 1: Includes data subset 1 – Area, Location -full dataset (n=202)*
***Model 2: Includes data subset 2- Area, Location, Flow – full dataset (n=202)*
****Model 3: Includes data subset 3- Area, Location, Water temp -reduced dataset (n=201)*

Table 18. *Abundance indices calculated using zero-inflated negative binomial models (ZINB) and nominal abundance indices for electrofishing surveys (eels per 100 m^2) in the Nashwaak River. Den=density, SE=standard error of the mean, n=number of survey sites.*

Year	n *	Den *	SE *	n**	Den**	SE**	n***	Den***	SE***	Nominal Index	Nominal SE
1988	7	1.95	0.55	7	1.95	0.54	7	1.96	0.56	1.62	0.52
1989	8	3.35	0.72	8	3.35	0.72	8	3.38	0.73	3.62	0.41
1990	5	2.88	0.77	5	2.88	0.77	5	2.89	0.77	3.16	0.67
1991	8	2.12	0.47	8	2.12	0.47	8	2.11	0.47	2.35	0.52
1992	6	0.66	0.19	6	0.67	0.19	6	0.67	0.2	0.63	0.29
1993	10	1.96	0.44	10	1.96	0.44	10	1.98	0.44	1.47	0.44
1994	12	1.12	0.33	12	1.13	0.33	12	1.15	0.33	0.54	0.24
1995	8	0.92	0.31	8	0.92	0.31	8	0.9	0.31	0.62	0.32
1996	9	1.32	0.28	9	1.33	0.28	9	1.35	0.29	1.39	0.22
1997	9	0.96	0.2	9	0.96	0.2	9	0.97	0.2	1.04	0.23
1998	13	1.39	0.27	13	1.41	0.27	13	1.4	0.27	1.22	0.26
1999	9	0.88	0.23	9	0.89	0.24	9	0.86	0.23	0.73	0.25
2000	12	1.22	0.23	12	1.22	0.23	12	1.23	0.24	1.26	0.27
2001	15	1.57	0.27	15	1.57	0.27	15	1.59	0.27	1.72	0.29
2002	9	1.29	0.27	9	1.3	0.27	9	1.3	0.27	1.36	0.35
2003	14	0.72	0.17	14	0.72	0.17	14	0.71	0.17	0.54	0.14
2004	25	1.56	0.2	24	1.58	0.21	24	1.6	0.22	1.71	0.18
2005	25	1.35	0.18	25	1.35	0.18	25	1.36	0.19	1.47	0.24
2006	25	0.84	0.13	25	0.84	0.13	25	0.83	0.13	0.85	0.15
2007	26	1.37	0.19	26	1.37	0.19	26	1.36	0.2	1.43	0.19
2008	16	1.19	0.19	16	1.16	0.21	16	1.16	0.21	1.27	0.28
2009	8	1.22	0.27	8	1.21	0.27	8	1.22	0.27	1.34	0.3
2010	10	1.01	0.2	10	1.01	0.2	10	1.04	0.21	1.08	0.3
2011	10	0.61	0.14	10	0.61	0.14	10	0.62	0.14	0.62	0.11
2012	10	1.56	0.29	10	1.56	0.29	10	1.57	0.29	1.73	0.34
2013	22	0.23	0.06	22	0.22	0.06	22	0.21	0.05	0.19	0.06
2014	27	0.69	0.09	27	0.7	0.11	27	0.71	0.12	0.75	0.06
2015	10	1.29	0.25	10	1.3	0.25	10	1.29	0.25	1.38	0.24
2016	10	1.69	0.32	10	1.7	0.33	10	1.69	0.32	1.8	0.41
2017	10	1.16	0.23	10	1.16	0.23	10	1.17	0.23	1.24	0.23
2018	10	1.31	0.26	9	1.19	0.25	9	1.19	0.25	1.29	0.24
2019	10	0.93	0.19	10	0.94	0.19	10	0.95	0.19	1	0.21
2021	14	1.01	0.19	14	1	0.19	14	1.01	0.19	1.07	0.23
2022	20	1.22	0.19	20	1.22	0.19	20	1.21	0.19	1.33	0.16

**Model 1: Includes data subset 1 – Area, Location -full dataset (n=442)*
***Model 2: Includes data subset 2- Area, Location, Flow – reduced dataset (n=440)*
****Model 3: Includes data subset 3- Area, Location, Water temp -reduced dataset (n=440)*

Table 19. 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 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	0.926	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

Table 20. 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	0.1	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	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	0.1
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	0.1
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	0.1	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	0.06
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	0.2	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.*

FIGURES

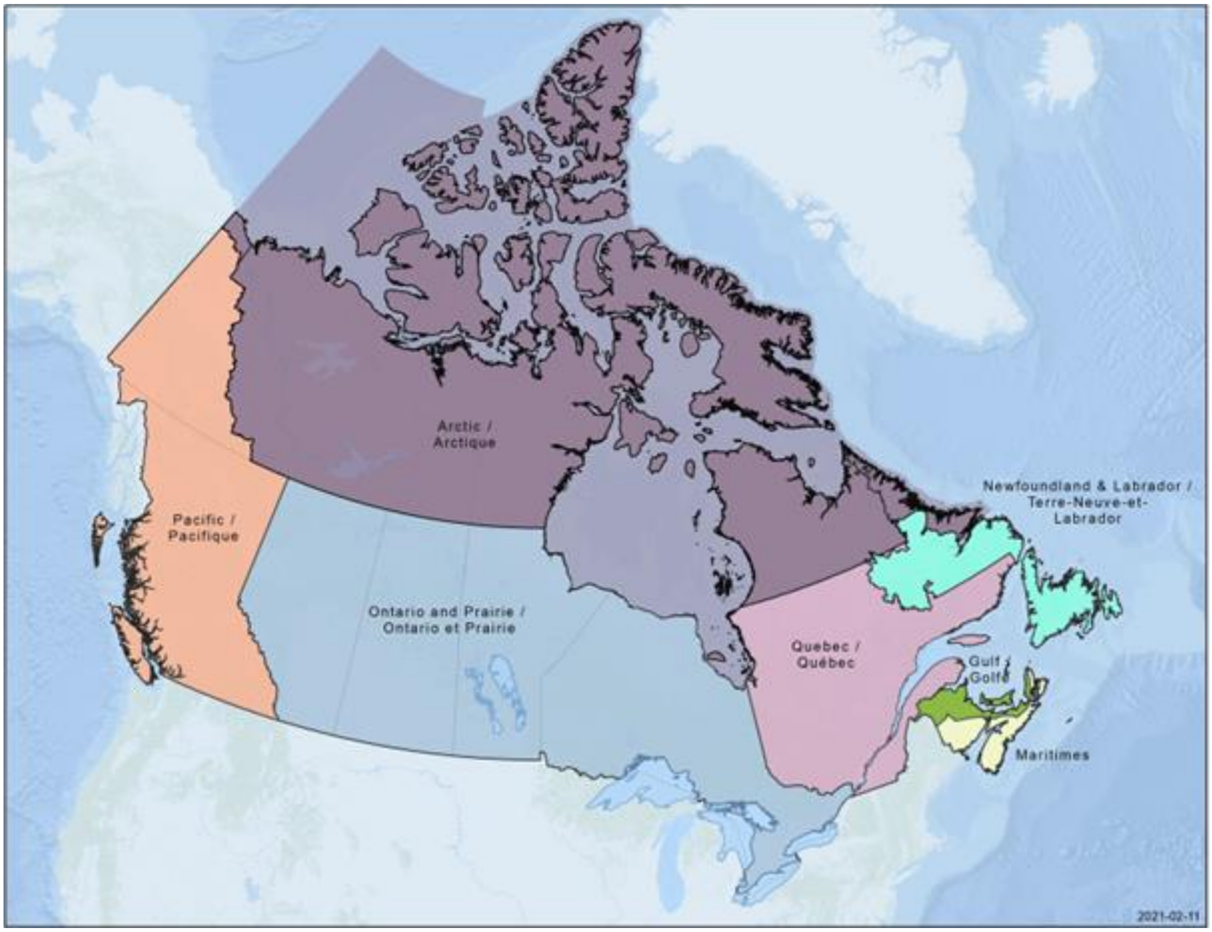

Figure 1. Map of Fisheries and Oceans Canada (DFO) administrative regions.

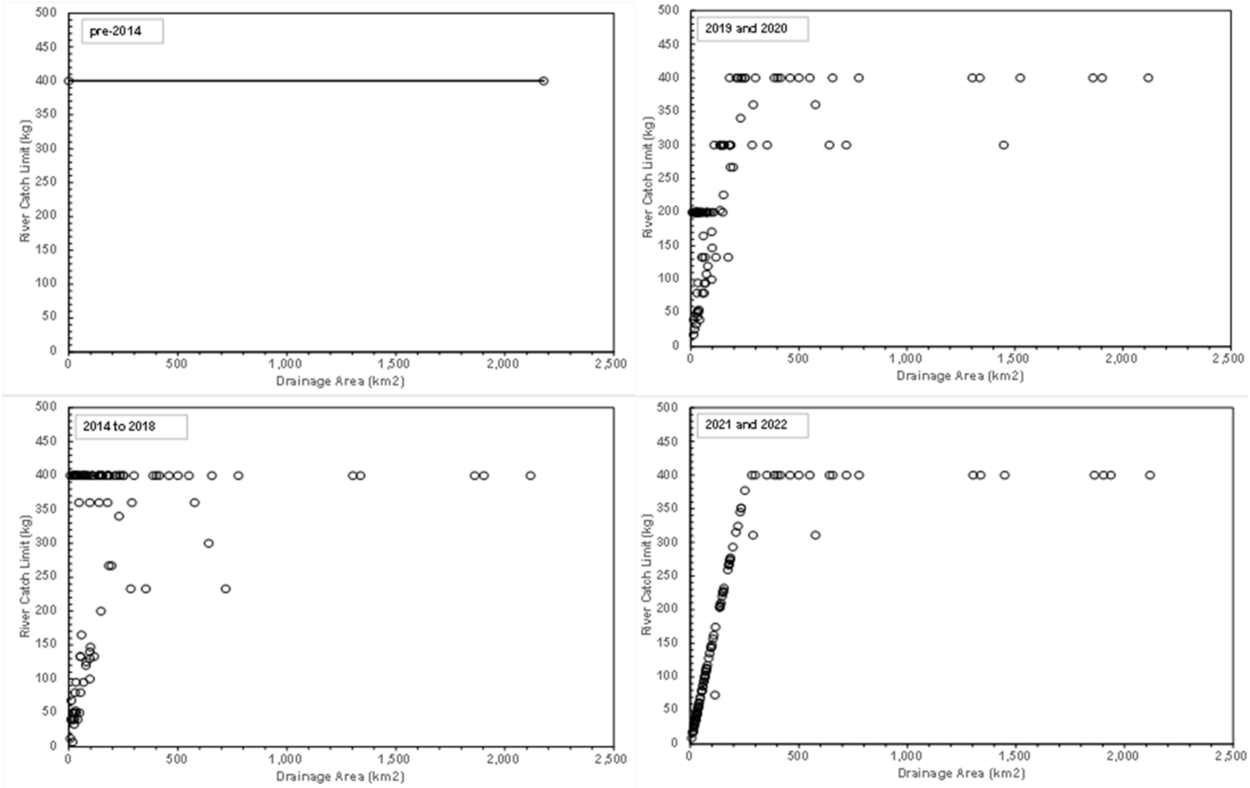

Figure 2. River catch limits (kg) versus drainage area (km²) scenarios that have been in effect since the inception of the commercial elver fishery in 1996 through to 2022.

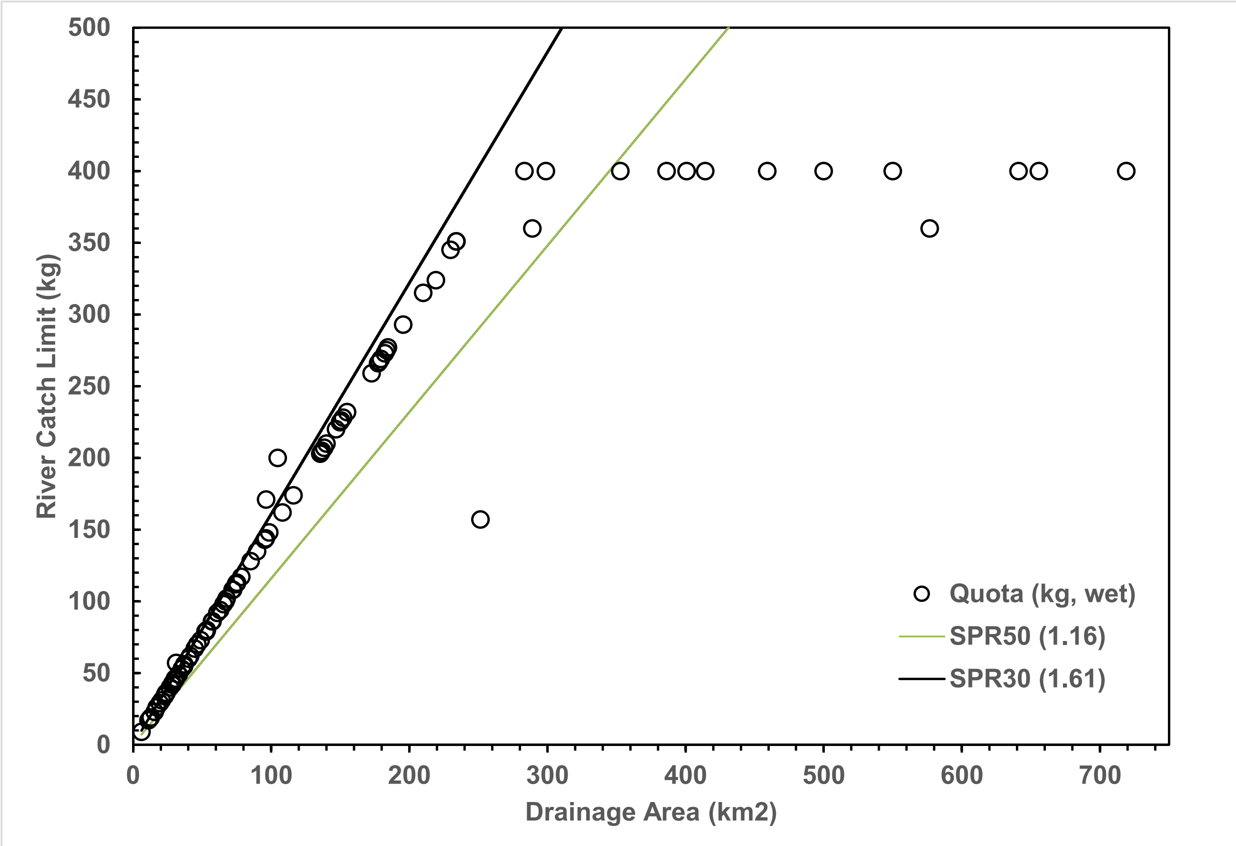

Figure 3. River catch limits (kg) for drainage areas less than 750 km² in area that have been in effect since 2021 relative to the mortality limit (SPR30) and target (SPR50) reference levels for the Maritimes Region elver fishery.

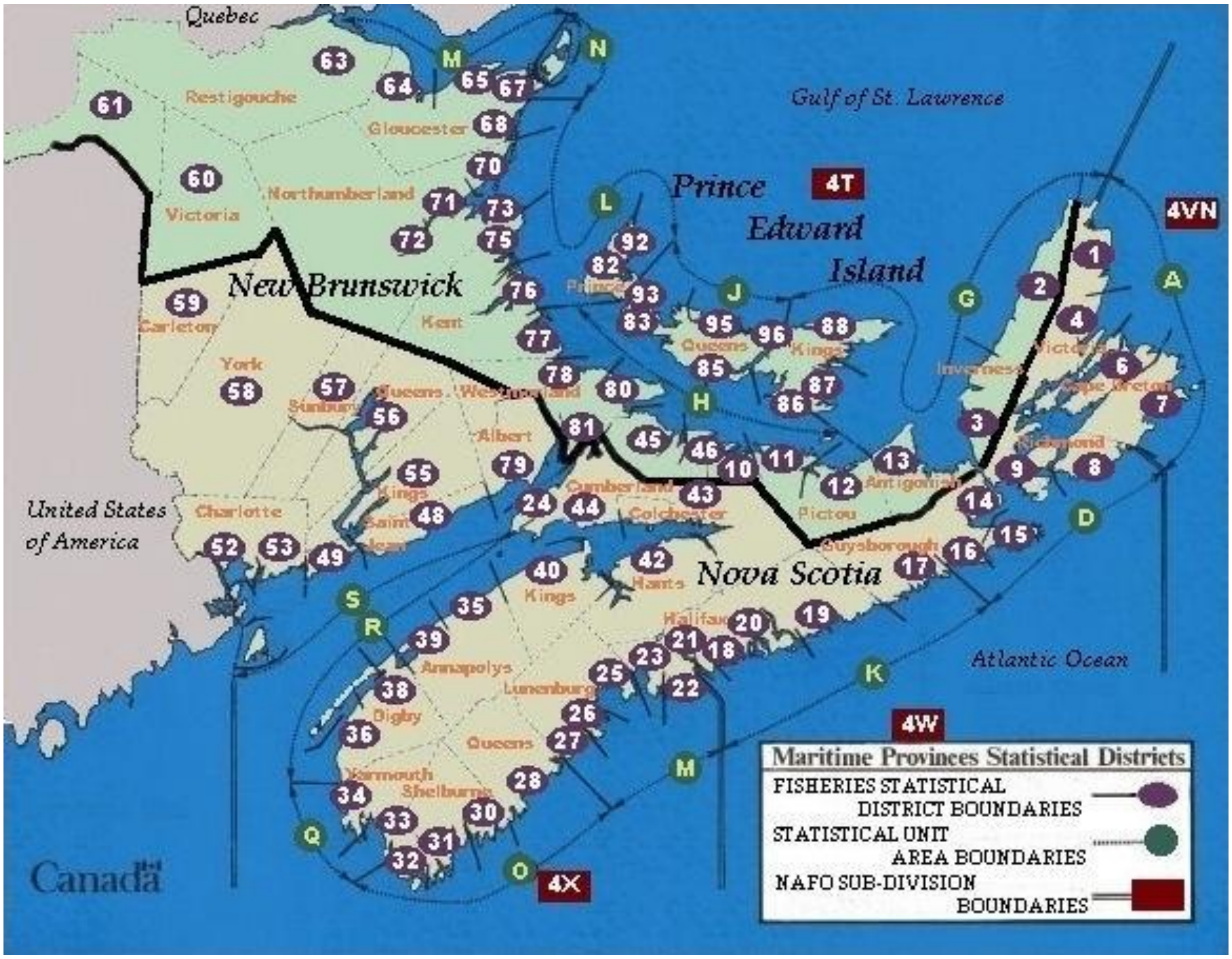

Figure 4. Map of the Maritime provinces showing the portions of southwest New Brunswick, Bay of Fundy Nova Scotia and Atlantic Coastal Nova Scotia that lie within the Maritimes Region. County boundaries, which define the geographic bounds for individual large eel licences, are shown. The fisheries statistical district boundaries (blue circles with white numbers) lying within the region represent the conventional basis for the reporting of eel landings for the years prior to 2015.

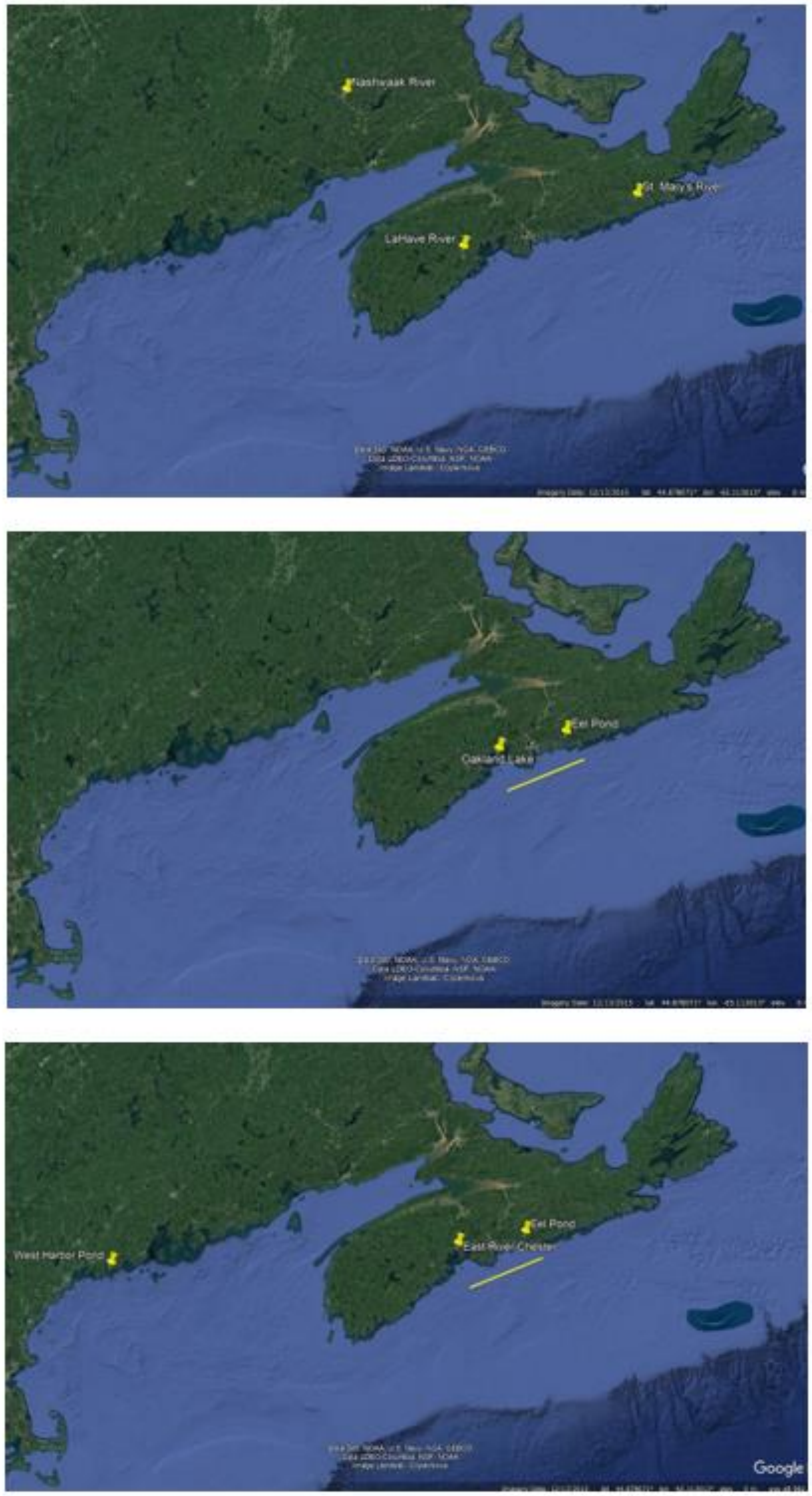

Figure 5. Locations of electrofishing-based eel abundance information (upper panel), silver eel run-size monitoring (middle panel), and elver monitoring (lower panel) sites referred to in the text.

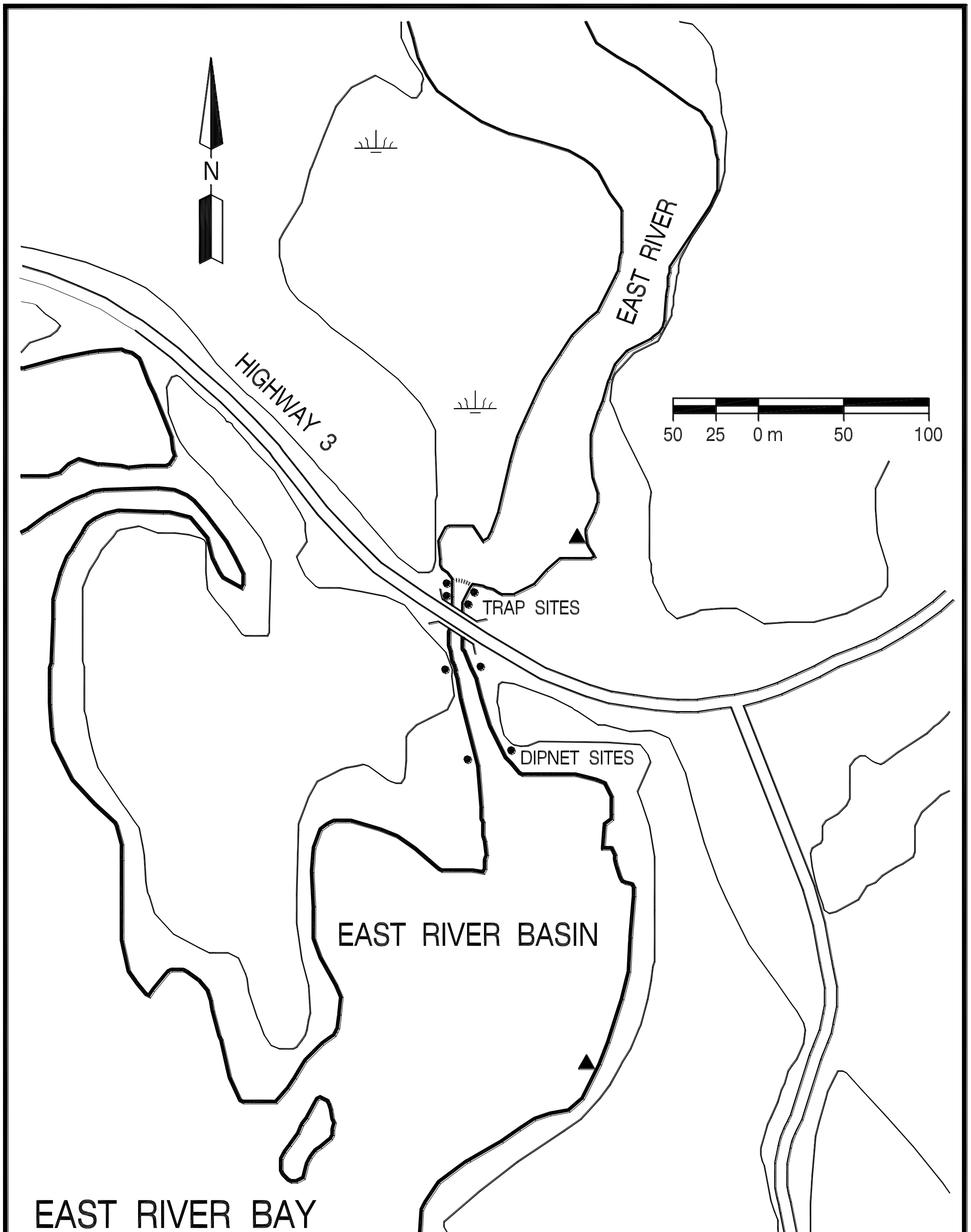

Figure 6. Elver trap and dip net fishing locations on the East River, Chester, Nova Scotia indicated by solid circles. Solid triangles indicate thermograph sites.

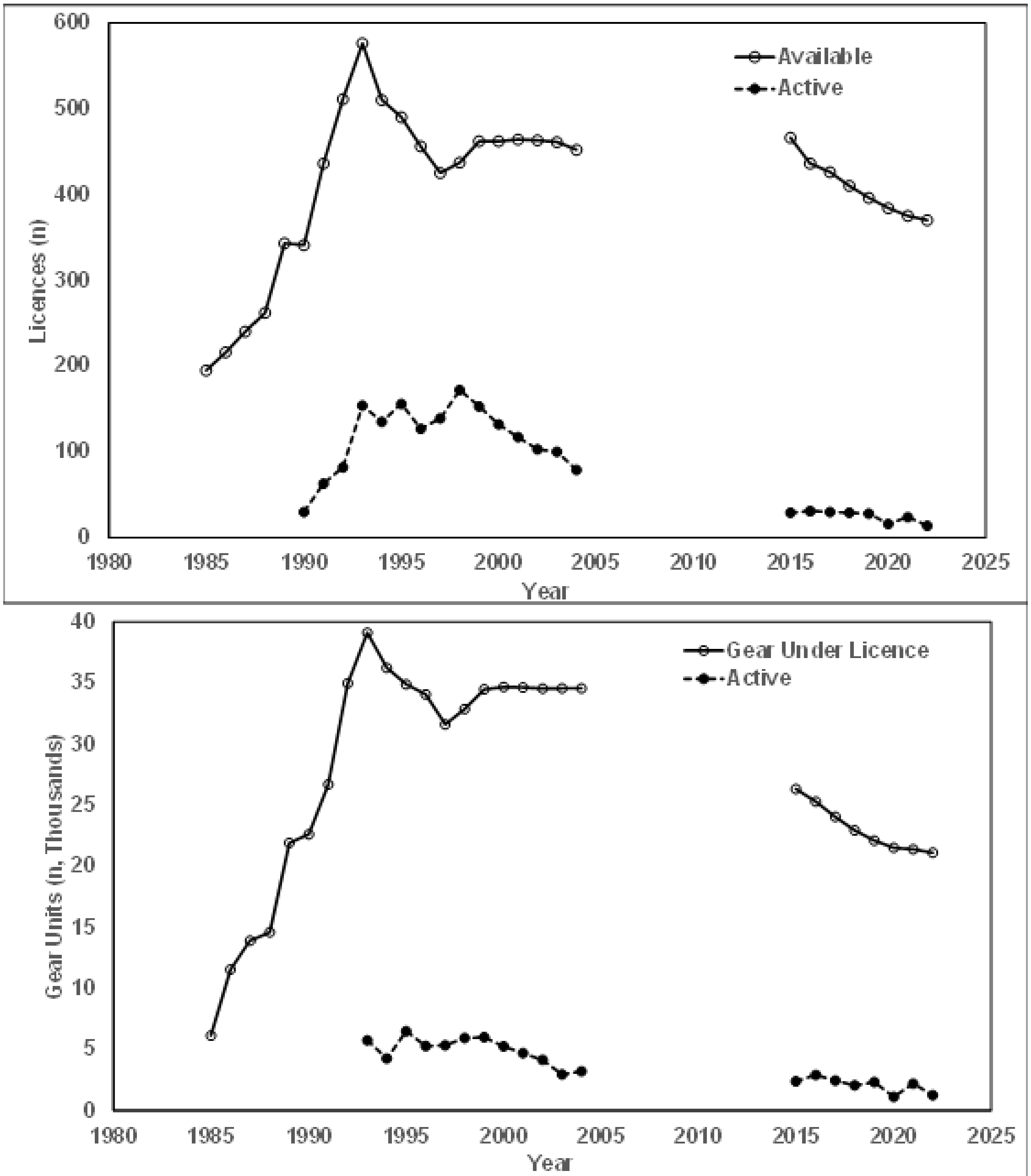

Figure 7. Top panel: Number of commercial eel licences (solid line with open circles) and active commercial licences reporting catches of eels (dashed line with solid circles) by year. Bottom panel: Quantities (thousands) of gear units under licence to fish eels (solid line with open circles) and gear associated with licences reporting having caught eels (dashed line with solid circles) by year.

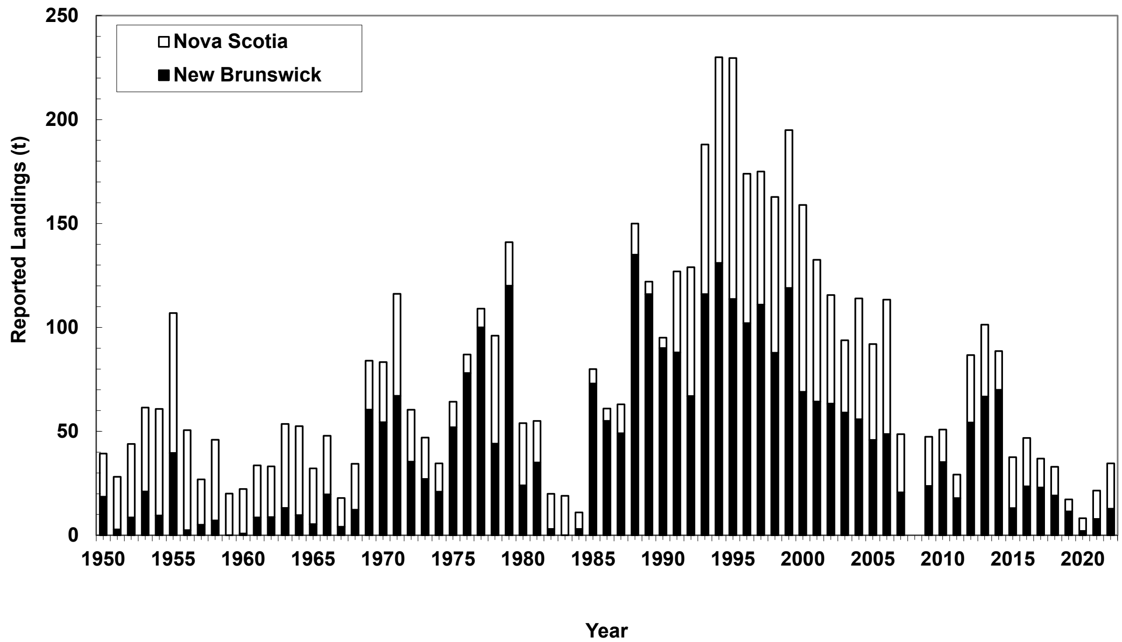

Figure 8. Annual reported commercial landings (t) of American Eel (large eel only) for the years 1950 to 2022 by province by year (open bars: Nova Scotia, solid bars: New Brunswick).

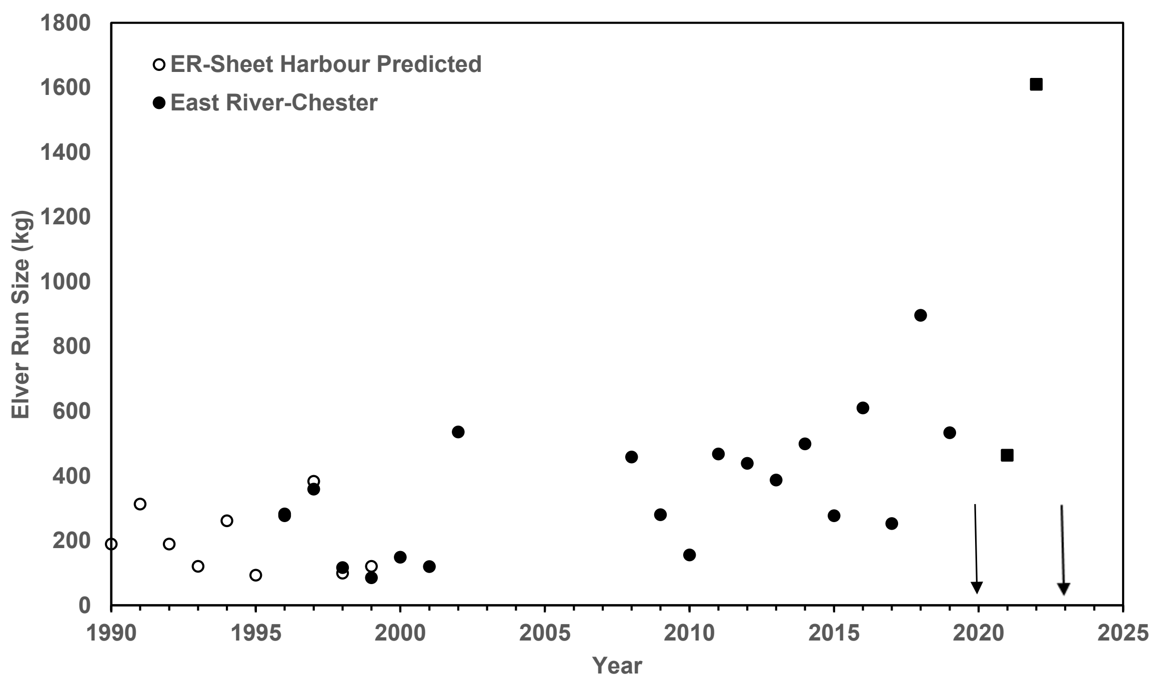

Figure 9. East River-Chester elver index (closed circles, kg) by year. Open circles represent predicted run sizes from regression of the time series against the East River-Sheet Harbour index. Arrows indicate years since 2018 when there was no East River survey. Solid squares indicate years since 2018 when the index likely underestimated total run size.

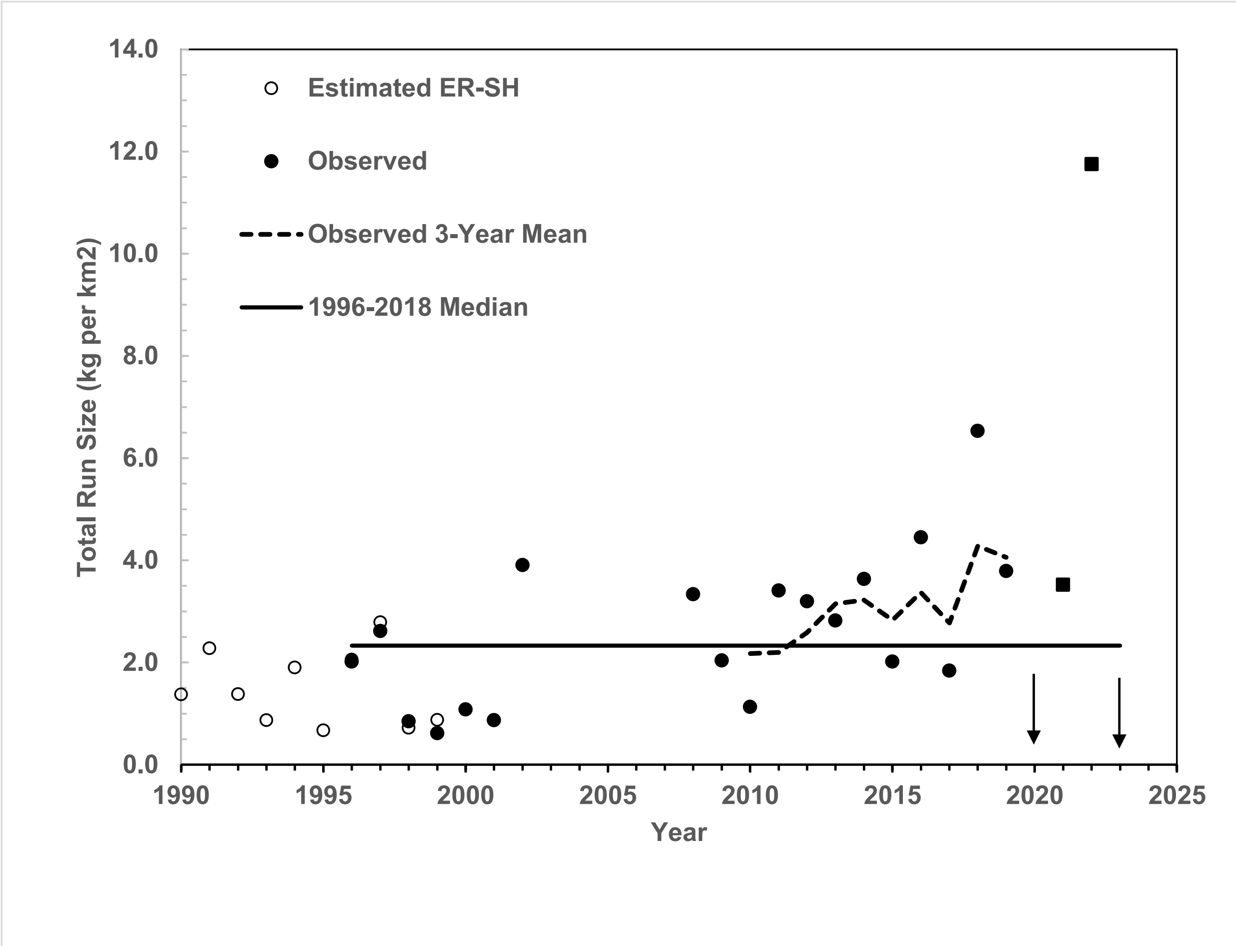

Figure 10. The East River-Chester (ER-C) elver abundance index expressed in terms of elver weight (kg) per km² of receiving habitat. Open circles represent predicted values estimated from the regression of ER-C run size with East River-Sheet Harbour (ER-SH) run size for the years 1996 to 1999. The closed 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 there was no East River-Chester survey. Solid squares indicate years since 2018 when the index likely underestimated total run size.

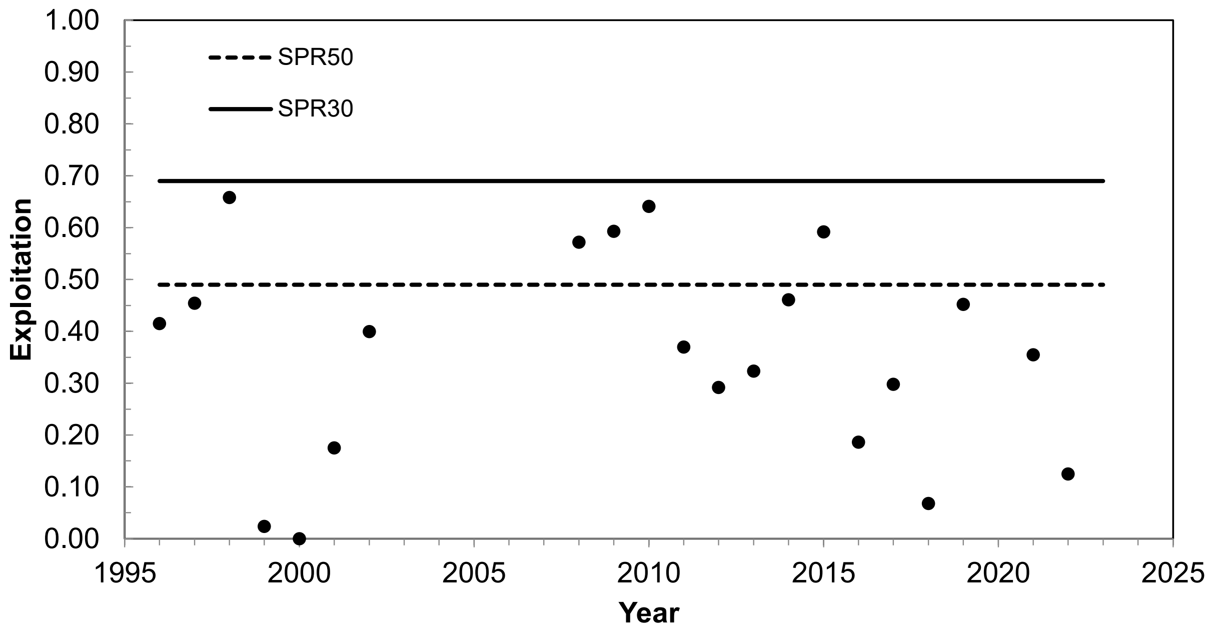

Figure 11. Elver exploitation rate estimates by year on East River-Chester relative to 30% spawner per recruit (SPR30; 0.69) and SPR50 (0.49) reference levels.

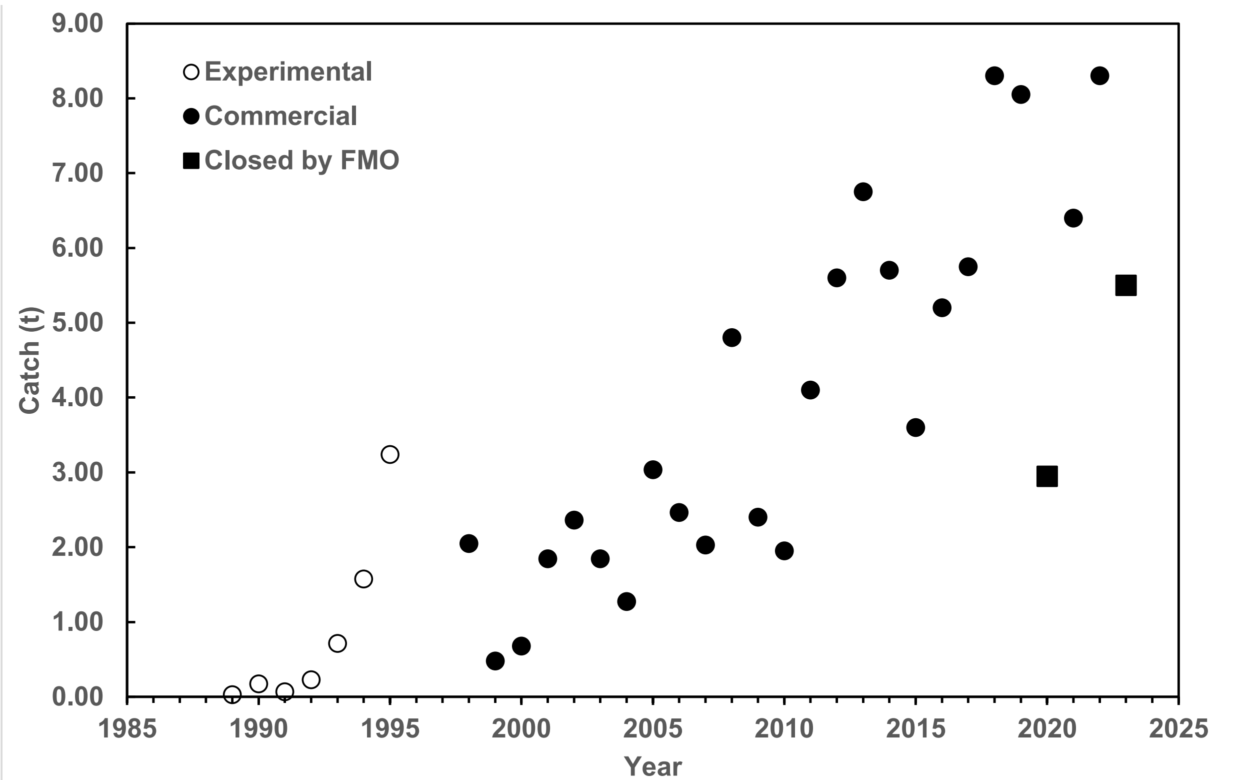

Figure 12. Elver landings (t) versus time (years). Estimates for the years 2008 to 2018 have been revised from those reported previously in DFO (2018) and Bradford et al. (2022). Open and closed circles represent years of experimental and commercial fishing respectively. Closed squares indicate the years that the fishery was closed by fishery management order for conservation and public safety reasons shortly after the start of the commercial fishing season.

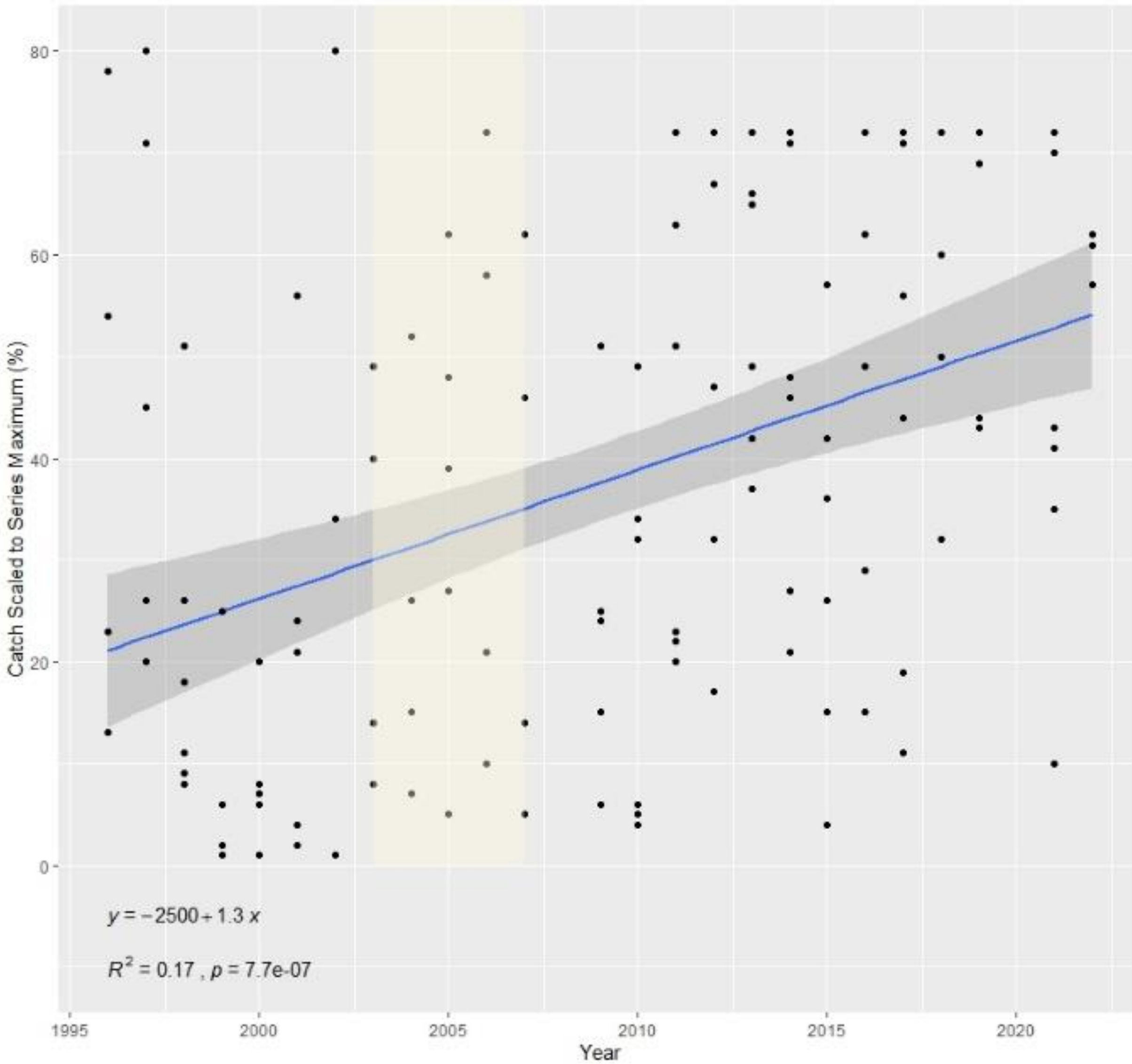

Figure 13. Reported annual catch (y-axis) versus year (x-axis, 1996 to 2022) for six licensed elver fisheries. Catches are expressed as a percentage of the maximum reported annual catch and are capped at the individual quota for a given year. The light shaded area (2003 to 2007) identifies the block of years that the East River-Chester elver index was not conducted. The 2020 fishery year is excluded.

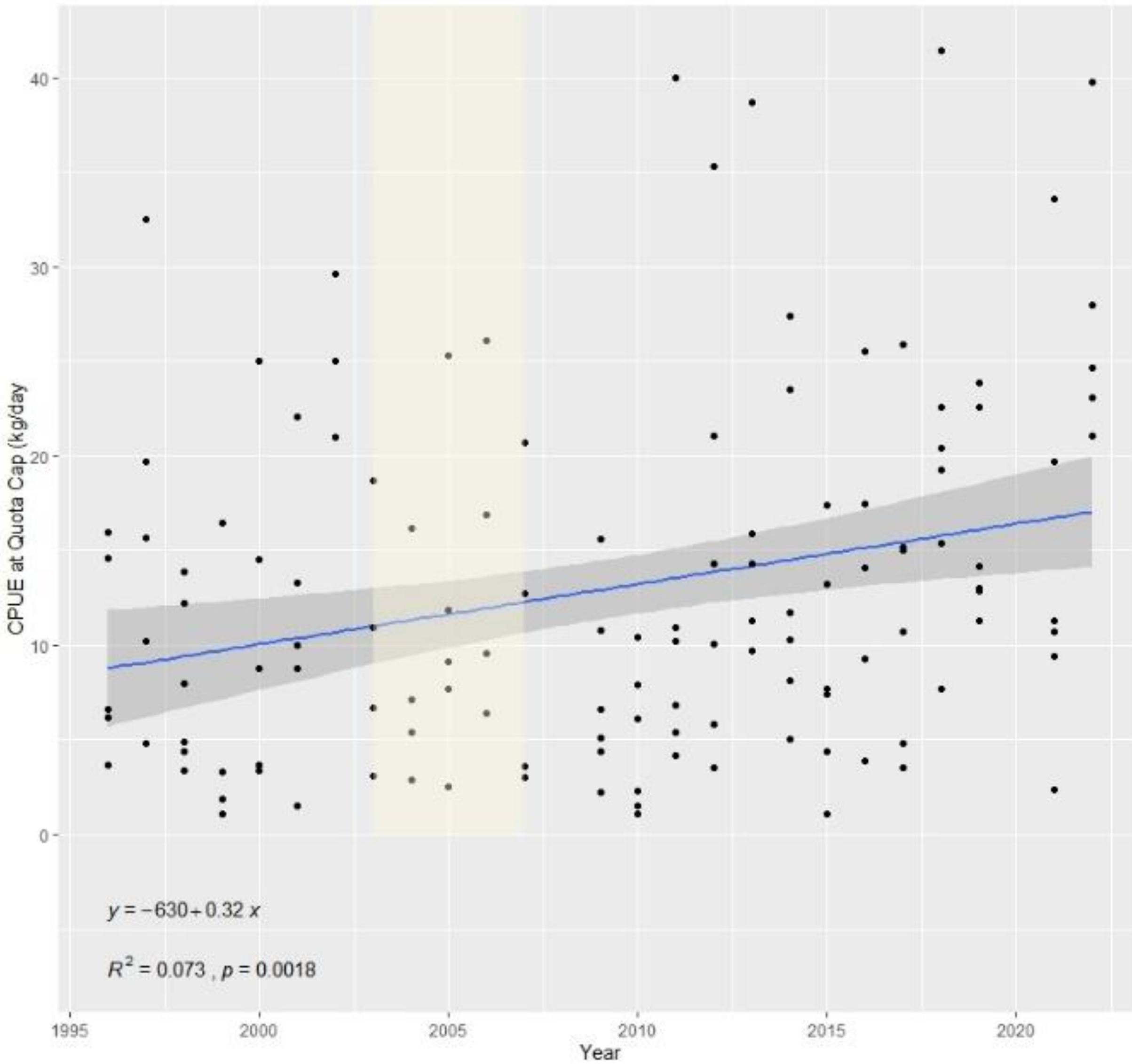

Figure 14. Catch per effort (CPUE; y-axis, kg/day) versus year (x-axis, 1996 to 2022) for six licensed elver fisheries. Both catch and days fished are truncated where relevant at the individual quota for a given year. The light shaded area (2003 to 2007) identifies the block of years that the East River-Chester elver index was not conducted. The 2020 fishery year is excluded.

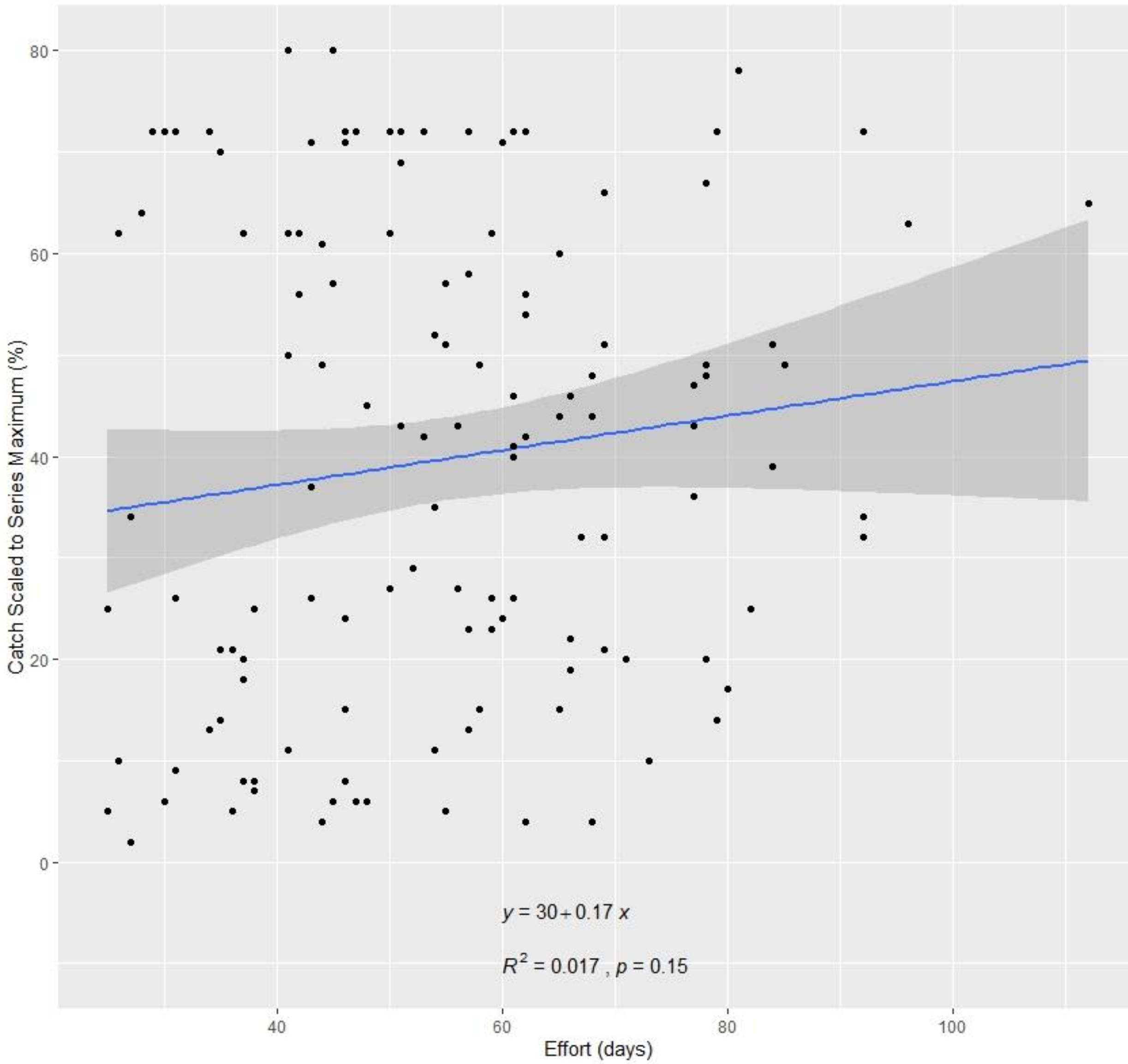

Figure 15. Annual commercial catch (y-axis) versus effort (x-axis, days) reported by six licence holders between 1996 and 2022. Catches are expressed as a percentage of the maximum reported annual catch and are capped at the individual quota for a given year.

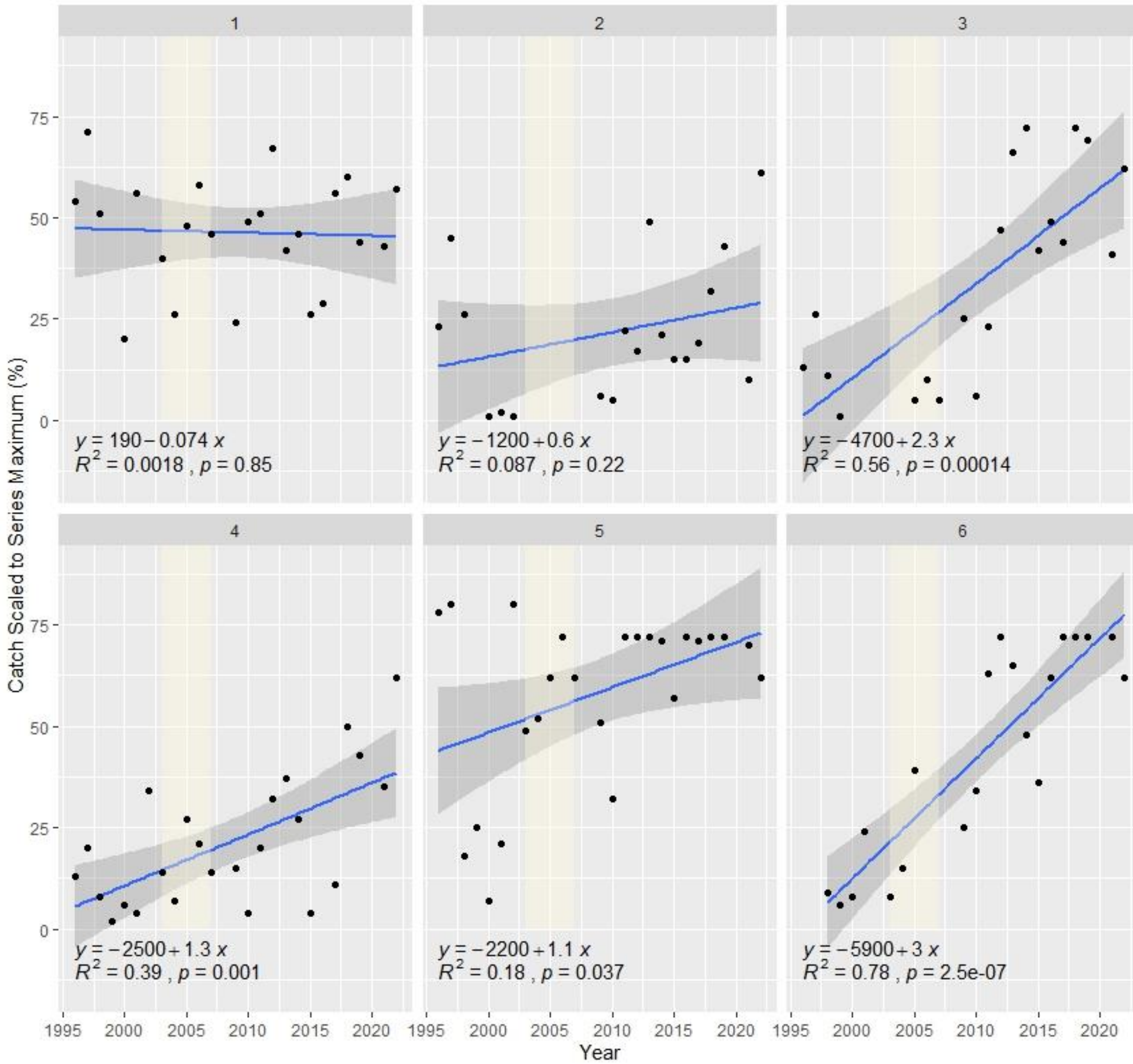

Figure 16. Reported annual catches (y-axis) compared by year (x-axis, 1996 to 2022) by licence. Catches are expressed as a percentage of the maximum reported annual catch and are capped at the individual quota for a given year. The light shaded area (2003 to 2007) identifies the block of years that the East River-Chester elver index was not conducted. The 2020 fishery year is excluded.

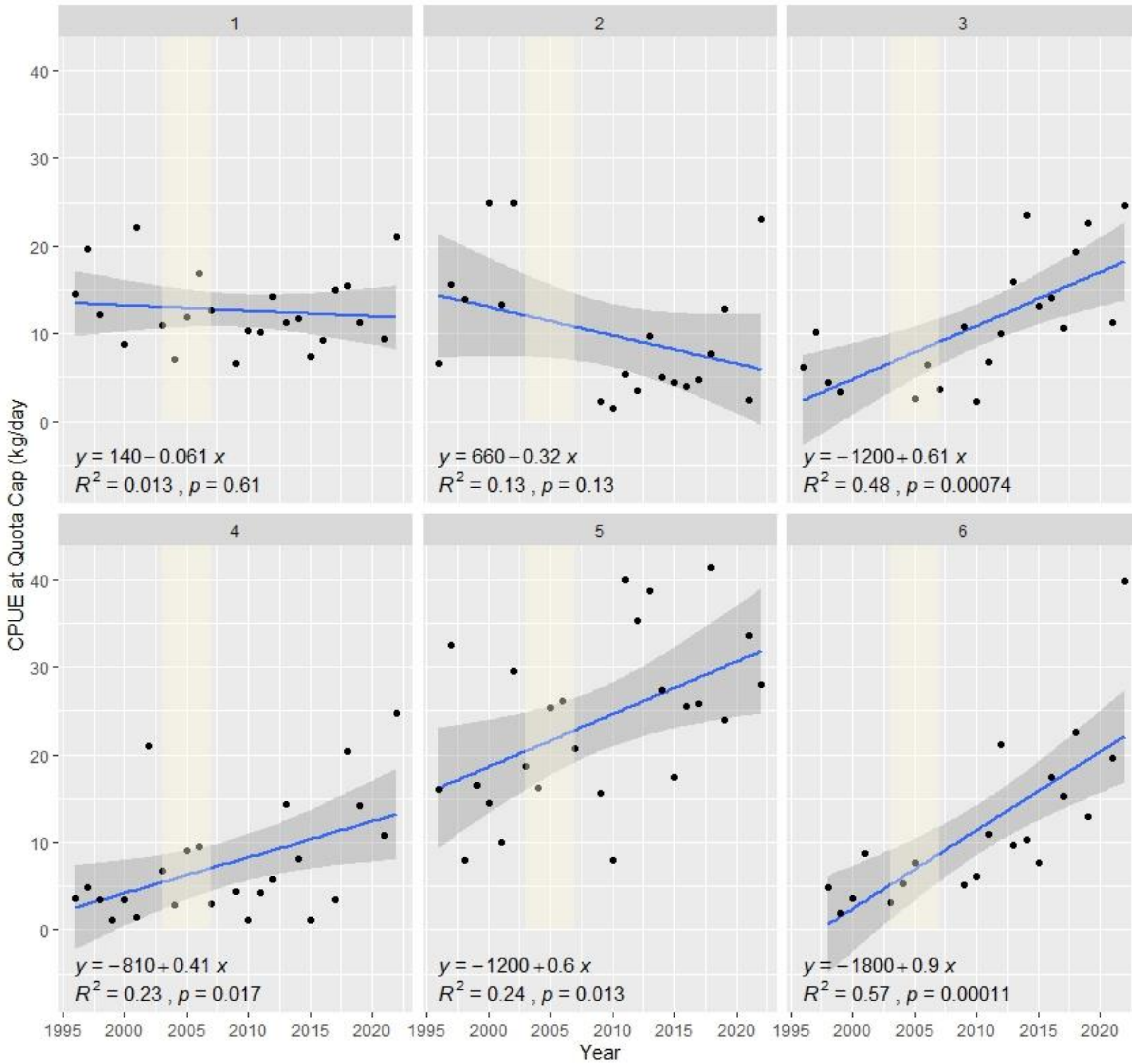

Figure 17. Catch per unit effort (y-axis, CPUE, kg/day) by year (x-axis, 1996 to 2022) by individual licence. The CPUE is calculated from catch and days fished both truncated where relevant at the individual quota for a given year. The light shaded area (2003 to 2007) identifies the block of years that the East River-Chester elver index was not conducted. The 2020 fishery year is excluded.

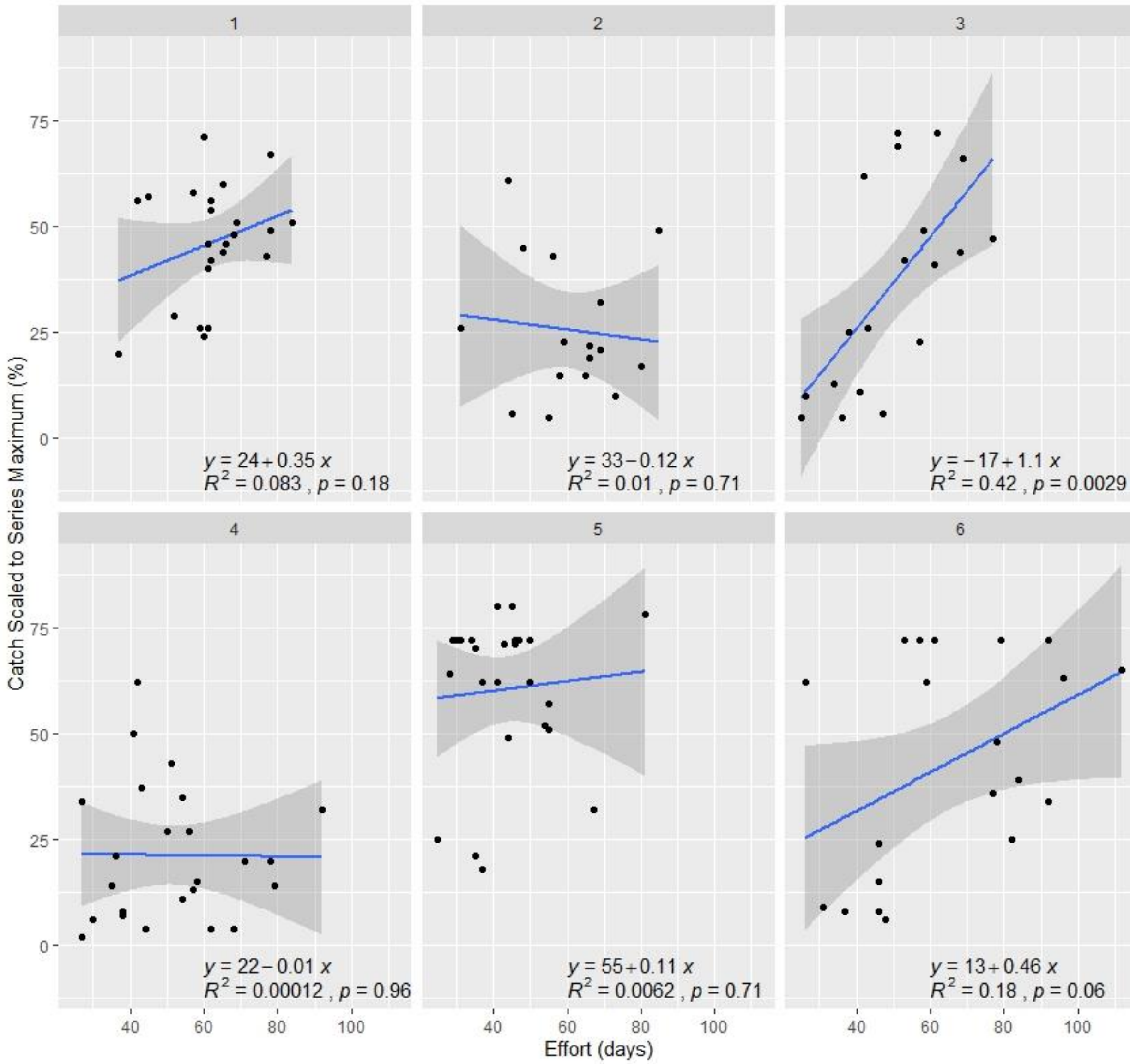

Figure 18. Annual commercial catches (y-axis) compared to effort (x-axis, days) by licence. Catches are expressed as a percentage of the maximum reported annual catch and are capped at the individual quota for a given year.

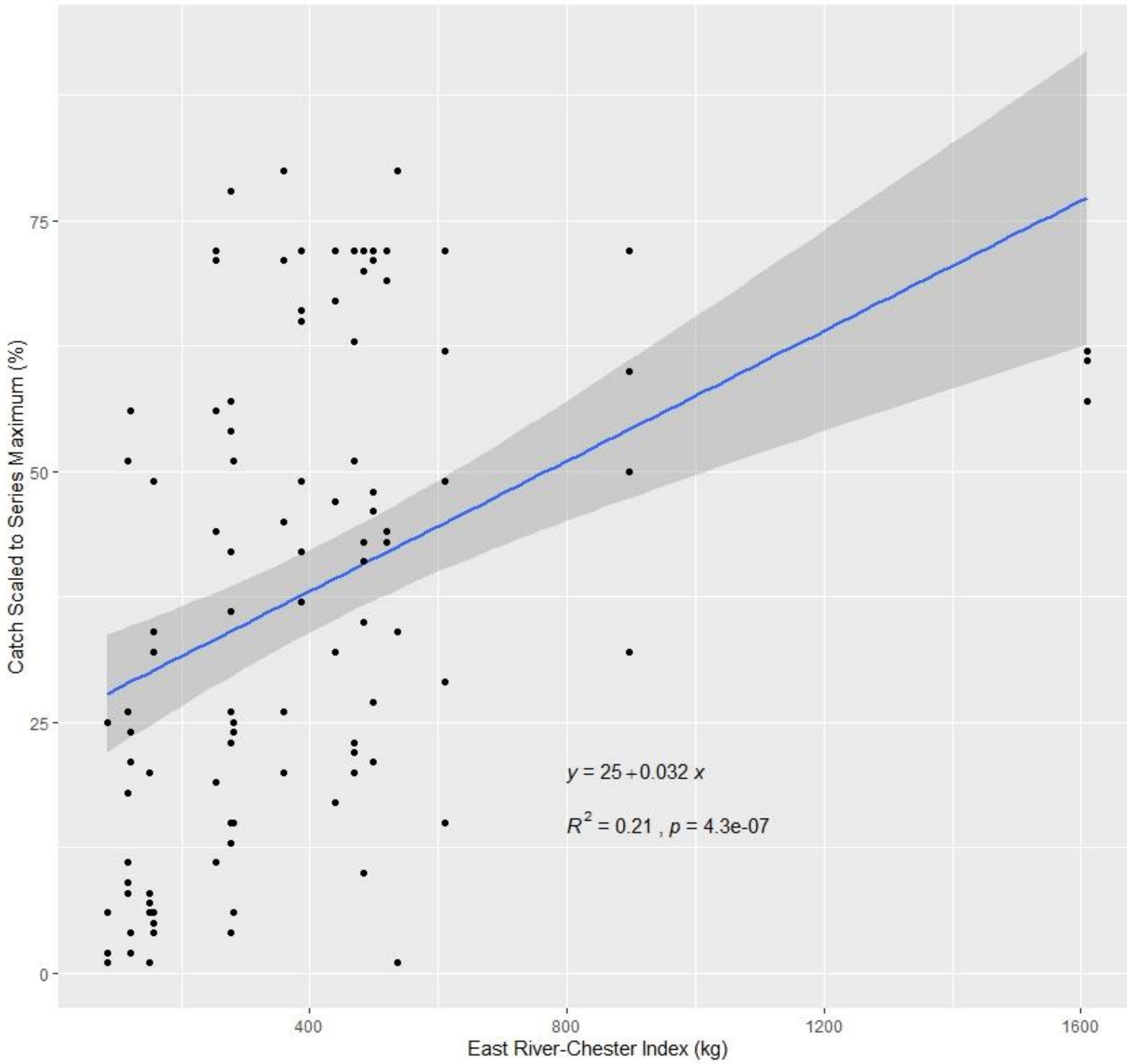

Figure 19. Reported annual catch (y-axis) compared to the East River-Chester elver index (x-axis, kg). Catches are expressed as a percentage of the maximum reported annual catch and are capped at the individual quota for a given year.

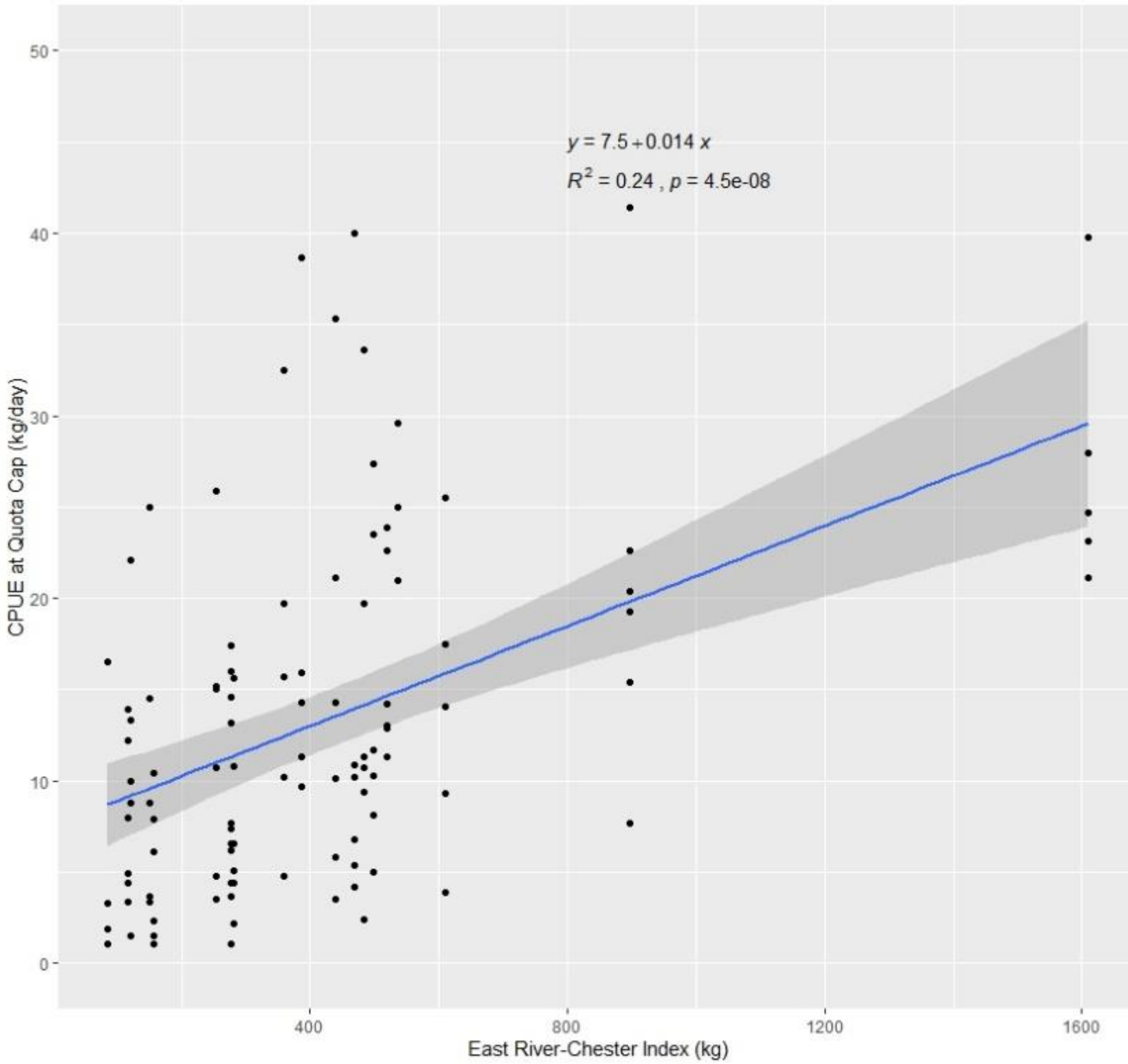

Figure 20. Catch per unit effort (CPUE; y-axis, kg/day) compared to the East River-Chester elver index (x-axis, kg). Both catch and days fished were truncated where relevant at the individual quota for a given year.

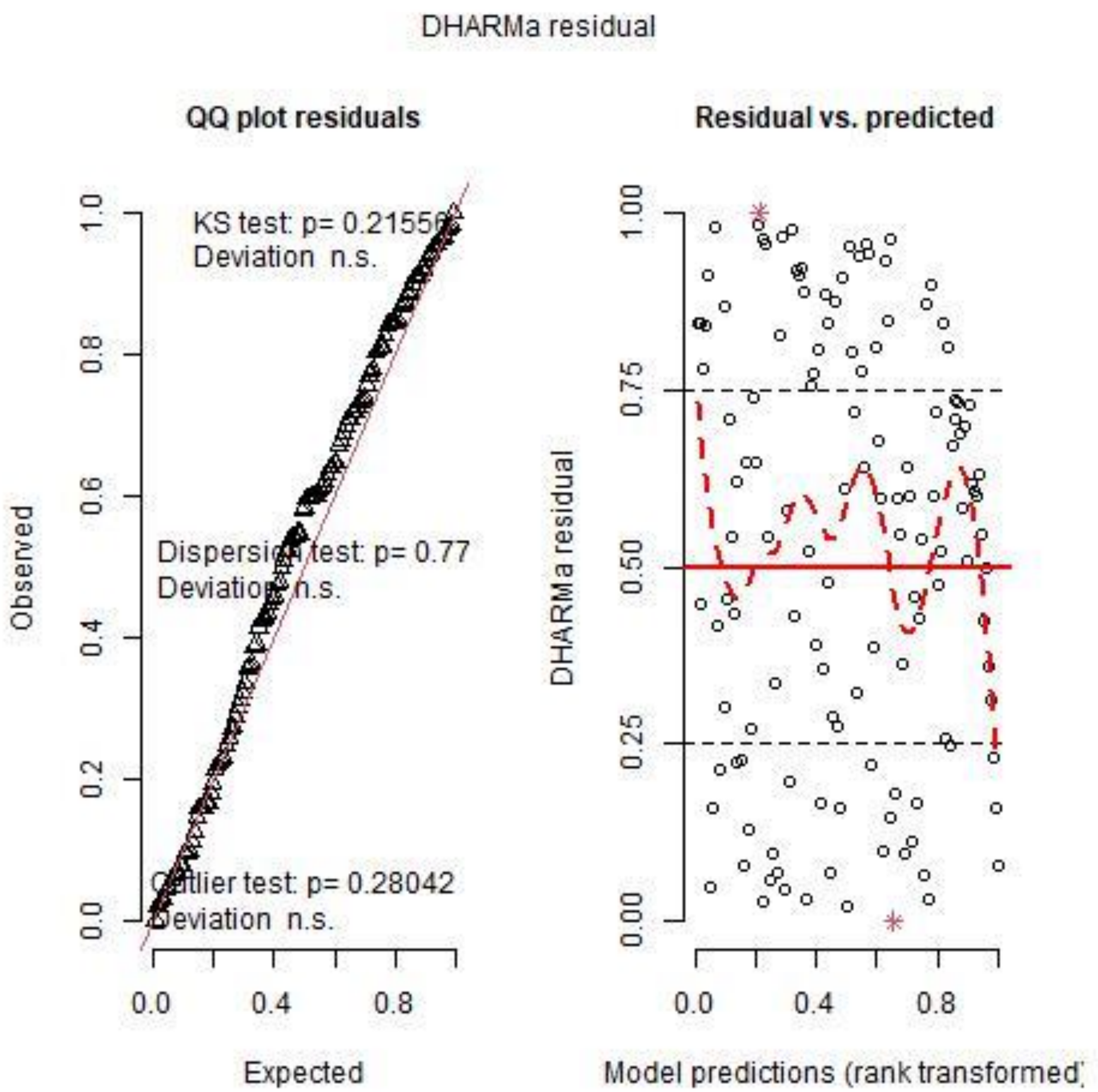

Figure 21. Goodness of fit plots of the final model retained to standardize commercial elver catch by year. DHARMa R-package used for residual diagnostics for hierarchical (multi-level/mixed) regression models.

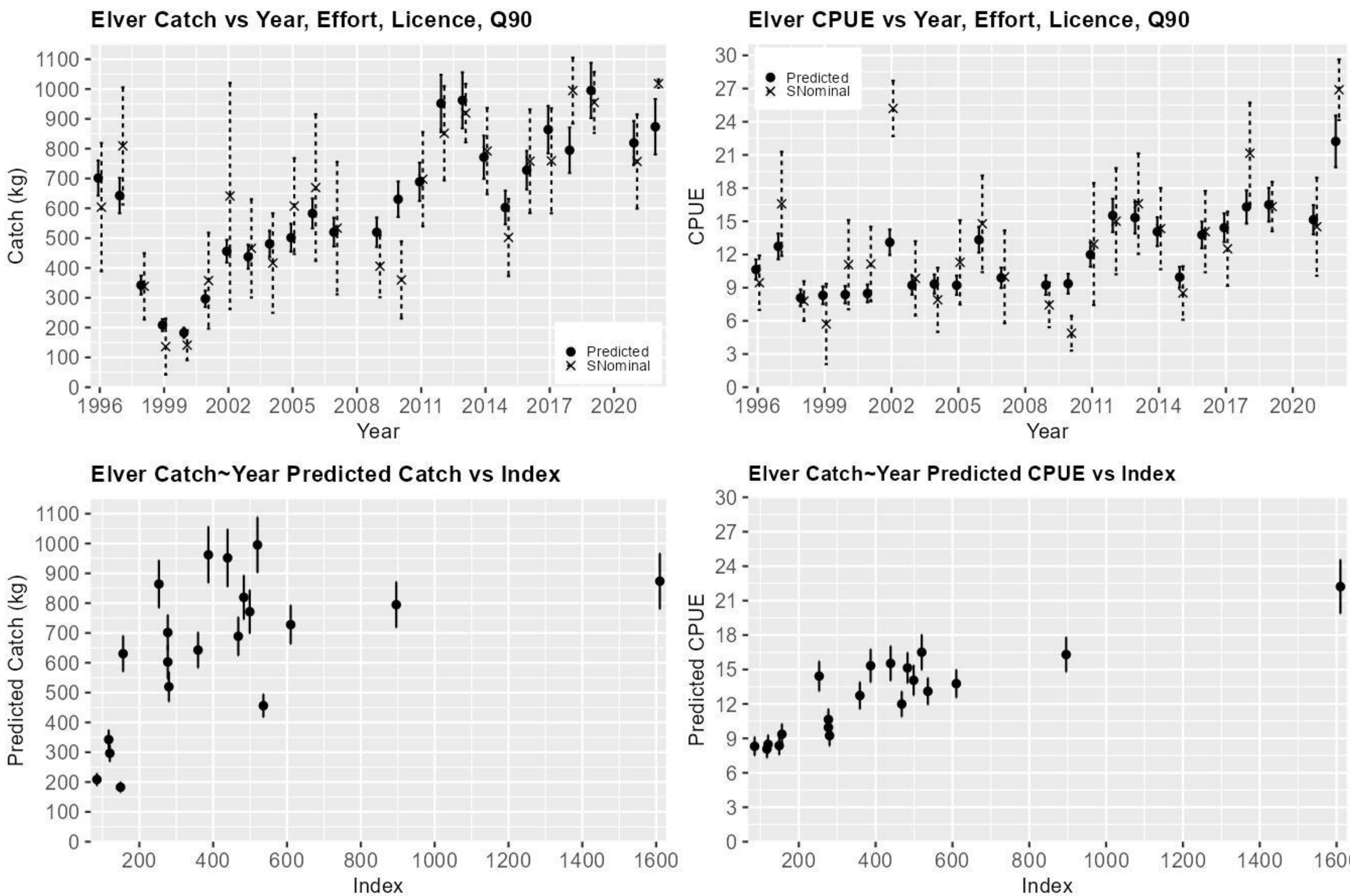

Figure 22. Predicted and nominal relative elver catch weight (top left) and elver catch per unit effort (CPUE; top right) by year. The lower left and lower right panels show the predicted catch and predicted CPUE, respectively, versus the East River-Chester elver index. Vertical lines represent the standard error ranges of the estimates.

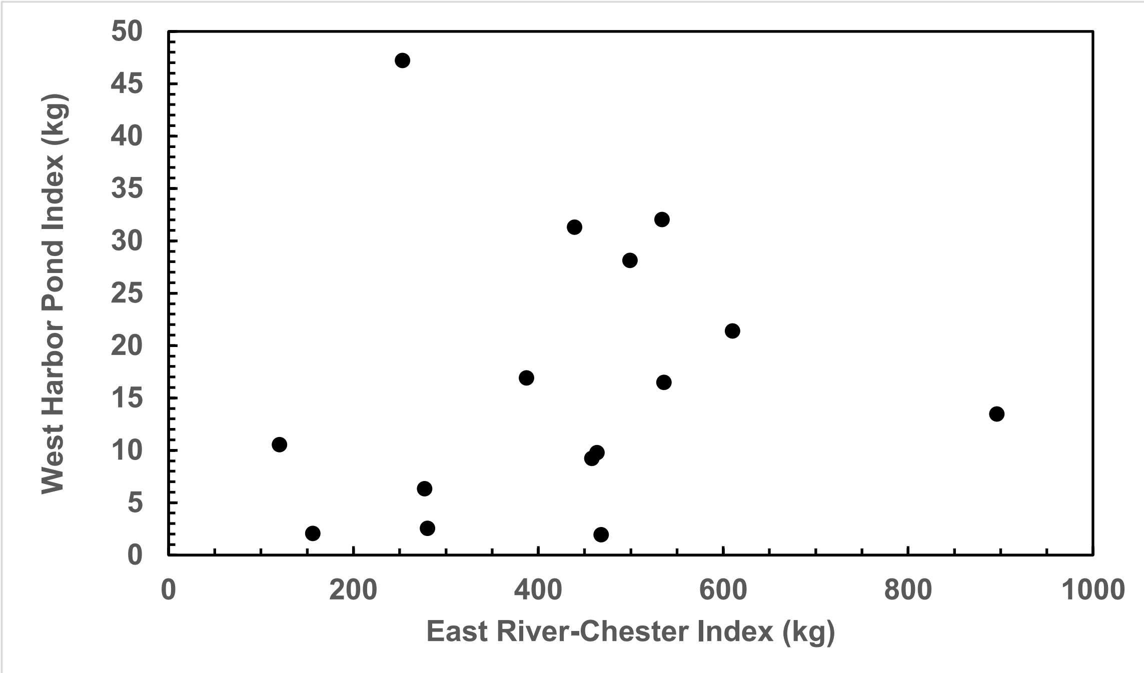

Figure 23. Estimated total annual run size for East River-Chester elver index (kg) compared to the West Harbor Pond elver index (kg) for the years 2001, 2002, 2008–2019, and 2021.

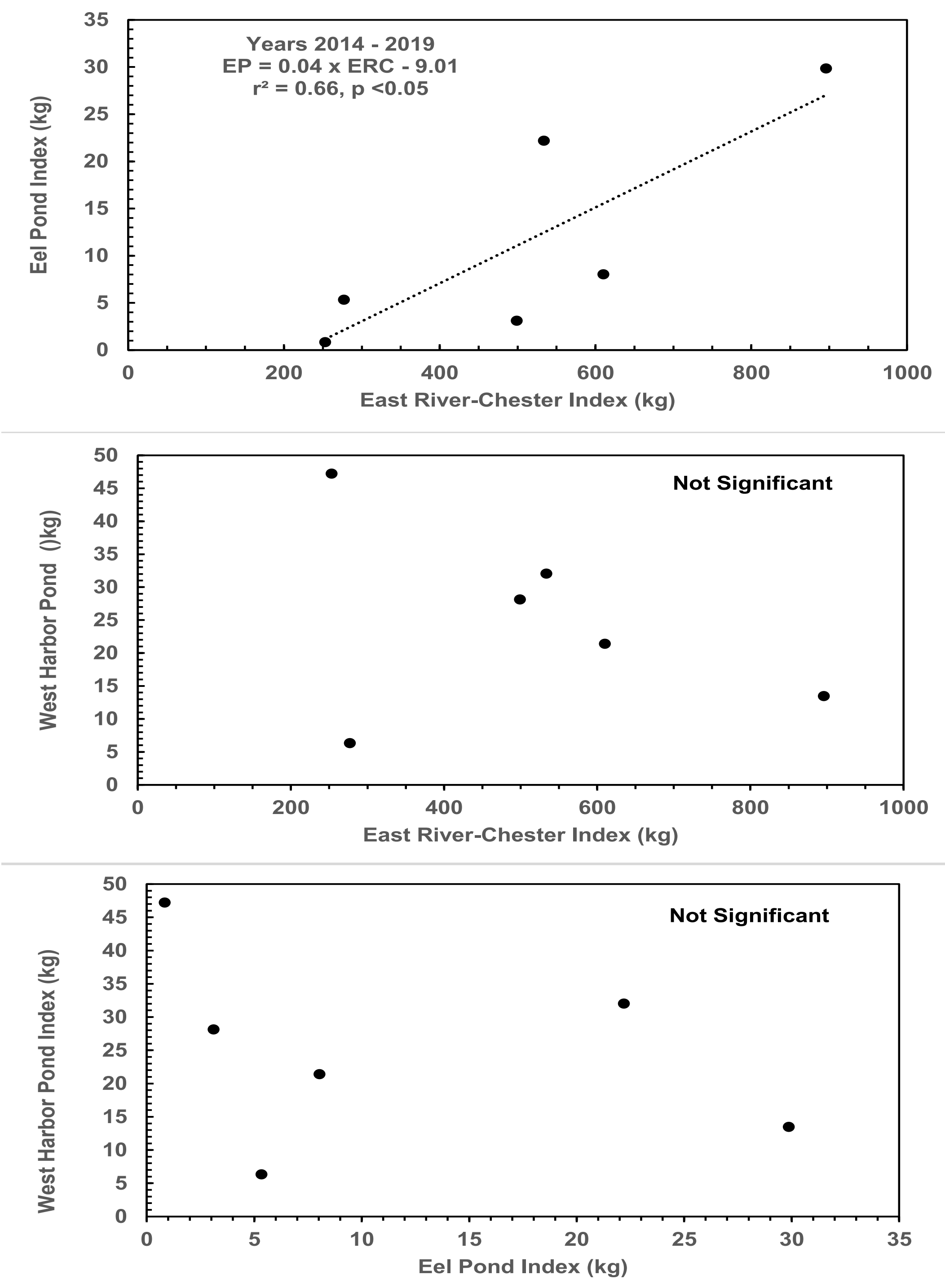

Figure 24. Estimated total annual run size for (upper panel) East River-Chester (kg) versus Eel Pond Brook (kg), (middle panel) East River-Chester (kg) versus West Harbor Pond (kg), and (lower panel) Eel Pond Brook (kg) versus West Harbor Pond (kg) elver run for the years 2014 to 2019.

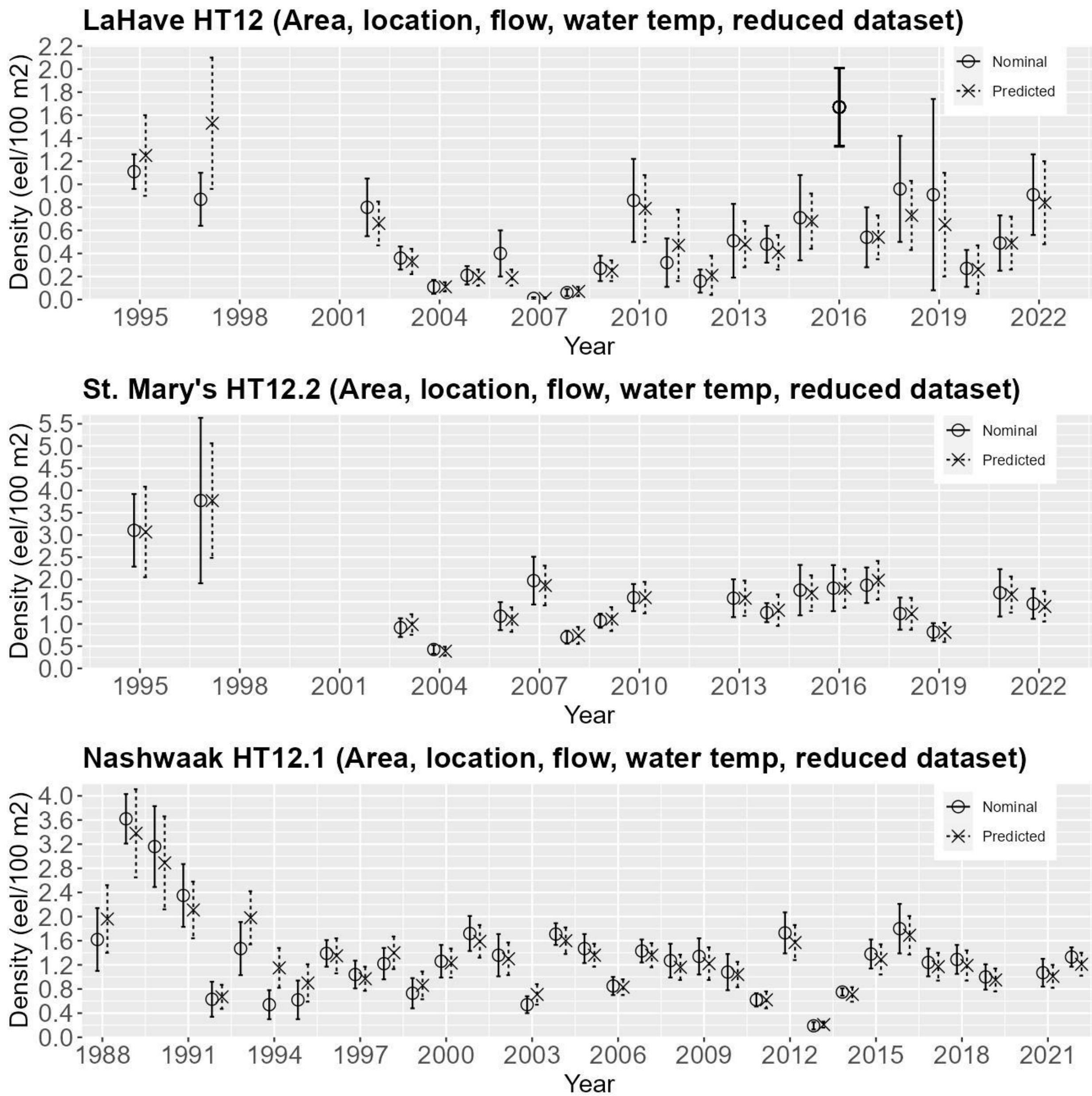

Figure 25. Predicted and nominal abundance indices for American Eel density estimates obtained by electrofishing in the LaHave River (upper panel), St. Mary's River (middle panel), and Nashwaak River (lower panel). The vertical bars represent the standard errors of the estimates.

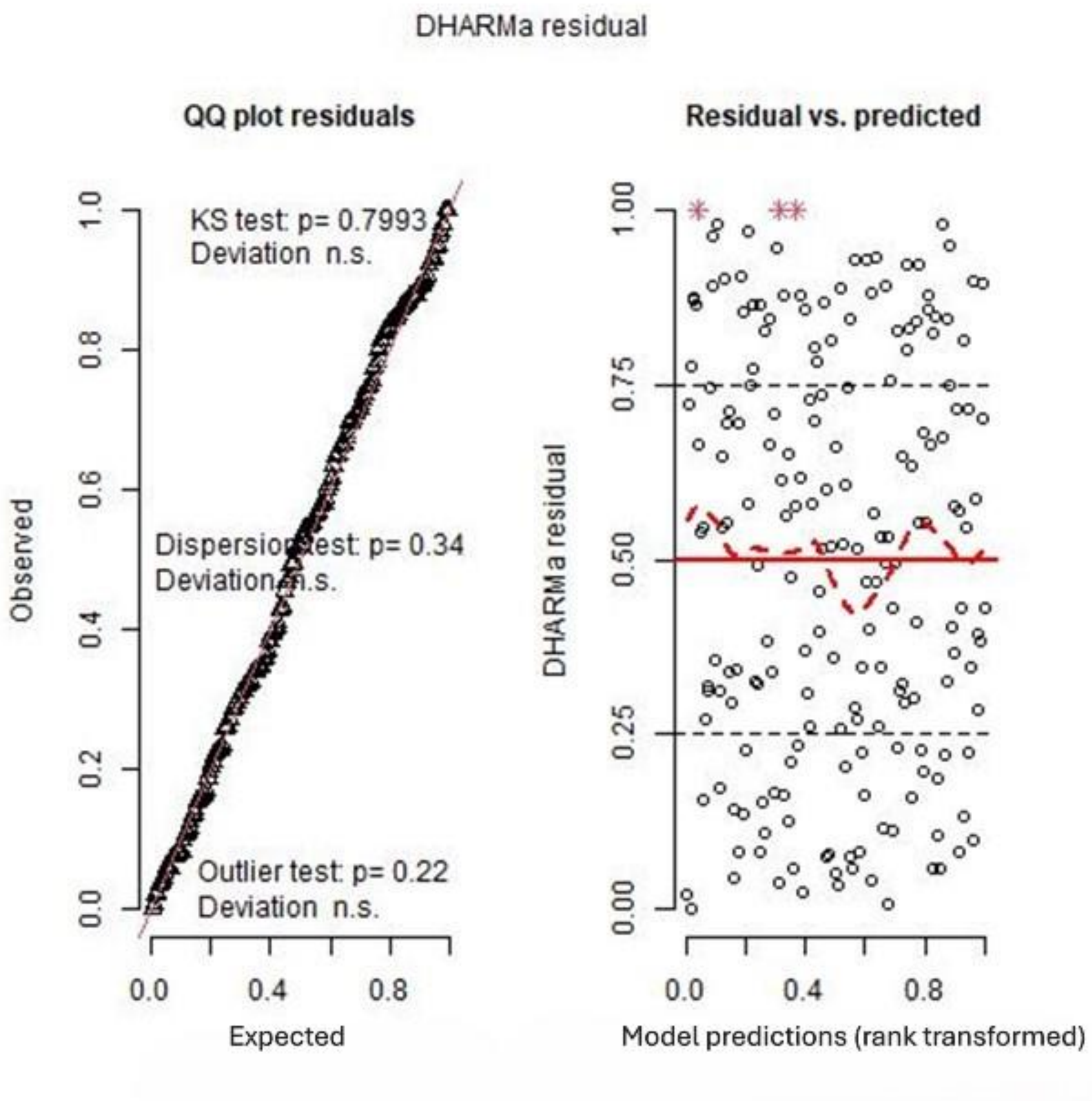

Figure 26. Goodness of fit plots of the final model retained to standardize American Eel density estimates from LaHave River electrofishing surveys. DHARMa R-package used for residual diagnostics for hierarchical (multi-level/mixed) regression models. KS=Kolmogorov-Smirnov test (KS).

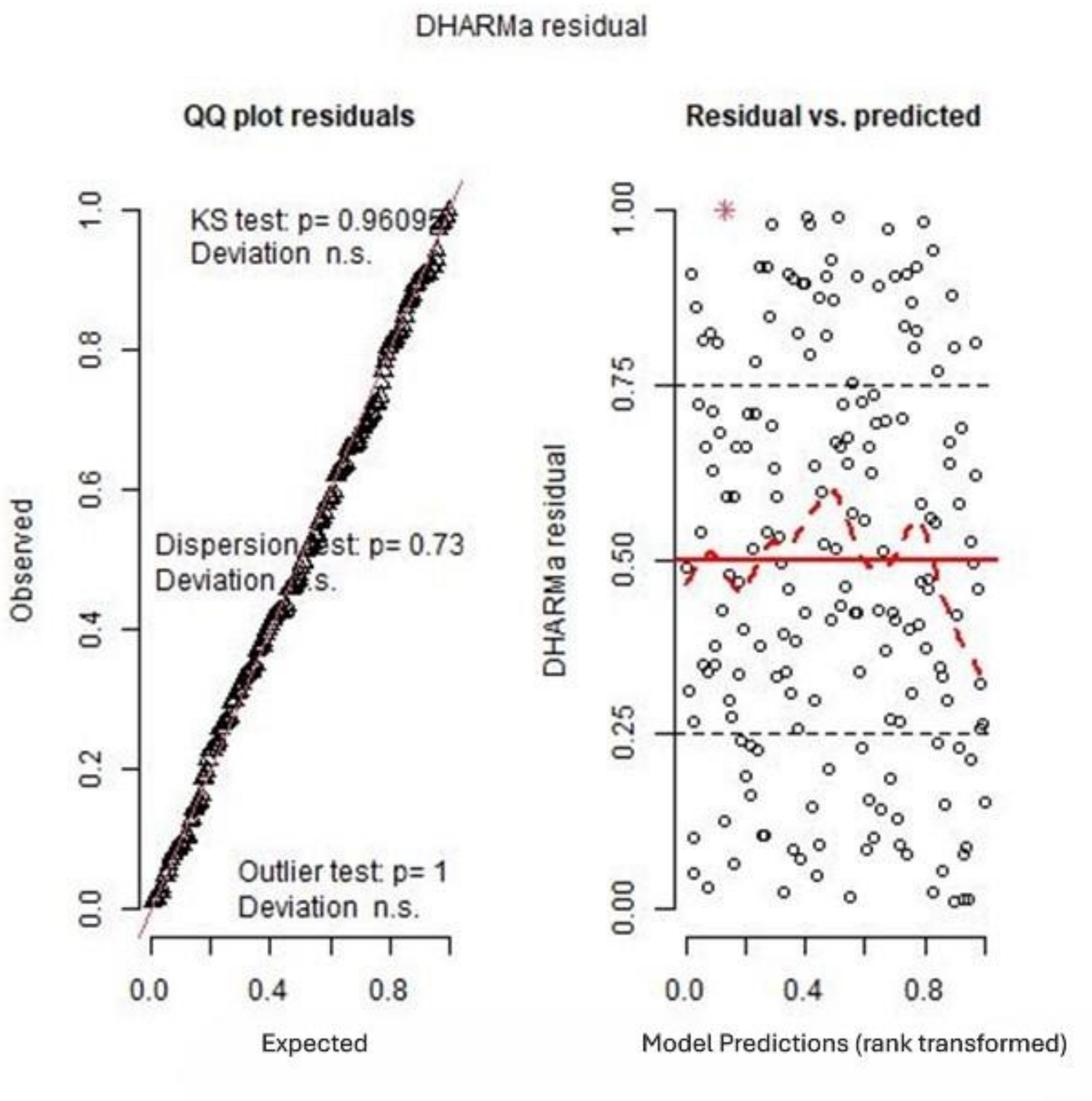

Figure 27. Goodness of fit plots of the final model retained to standardize American Eel density estimates from St. Mary's River electrofishing surveys. DHARMa R-package used for residual diagnostics for hierarchical (multi-level/mixed) regression models.

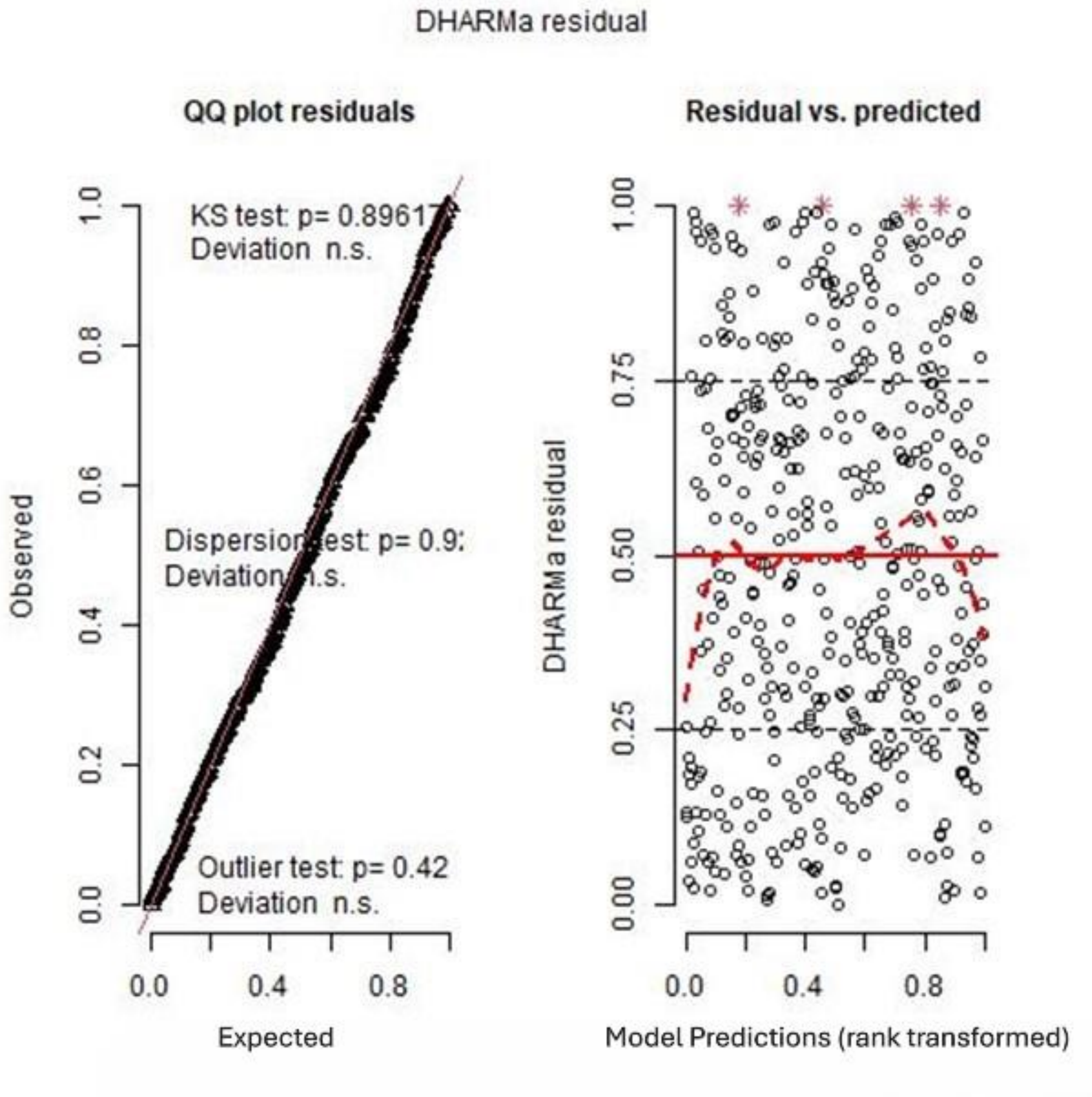

Figure 28. Goodness of fit plots of the final model retained to standardize American Eel density estimates from Nashwaak River electrofishing surveys. DHARMa R-package used for residual diagnostics for hierarchical (multi-level/mixed) regression models.

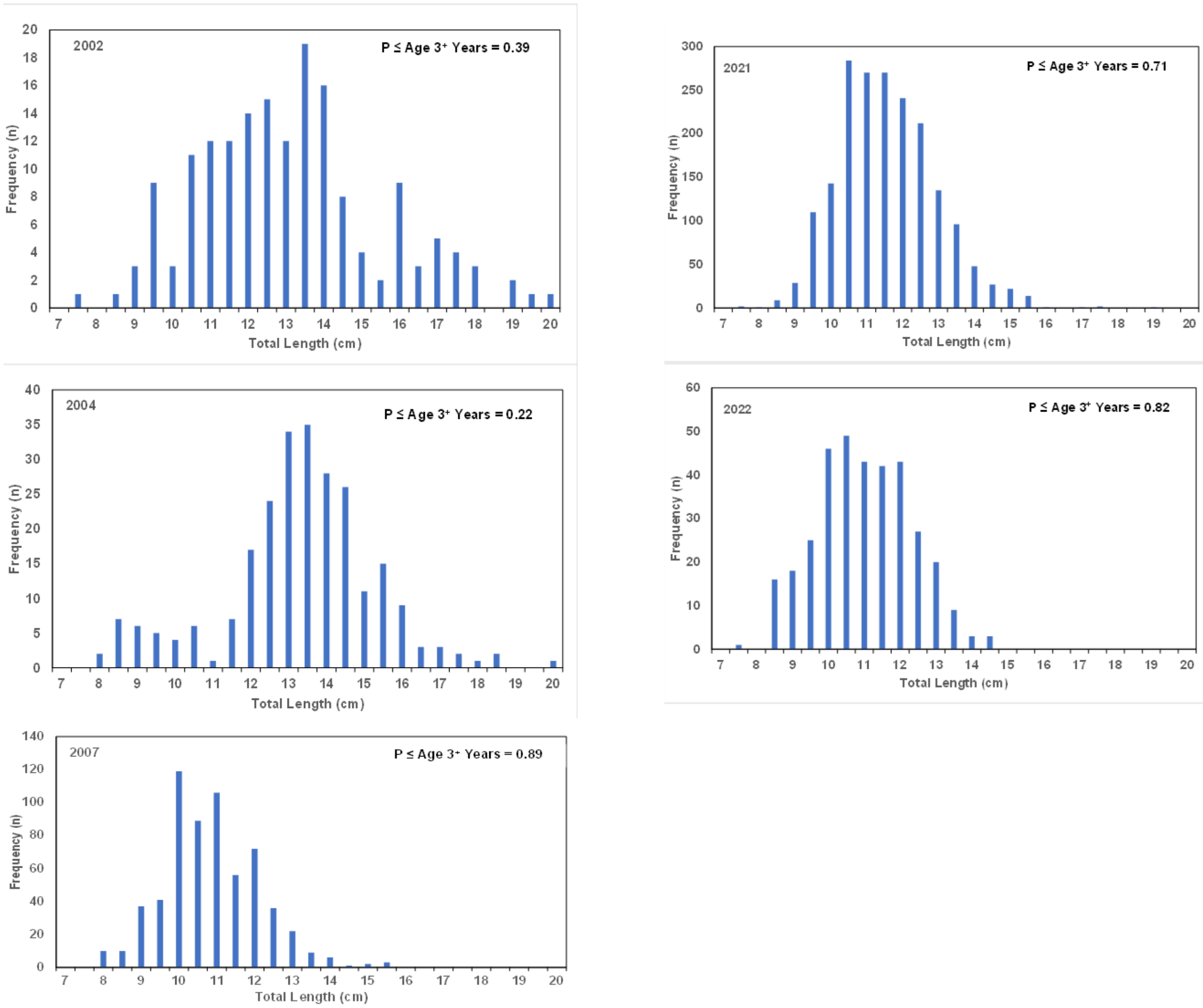

Figure 29. Total length (TL; cm) frequency distributions of yellow eels sampled at Morgan Falls by year. Proportion of eels ≤ 12 cm TL reflects the number of Age 3^{+} and younger eels in the samples.

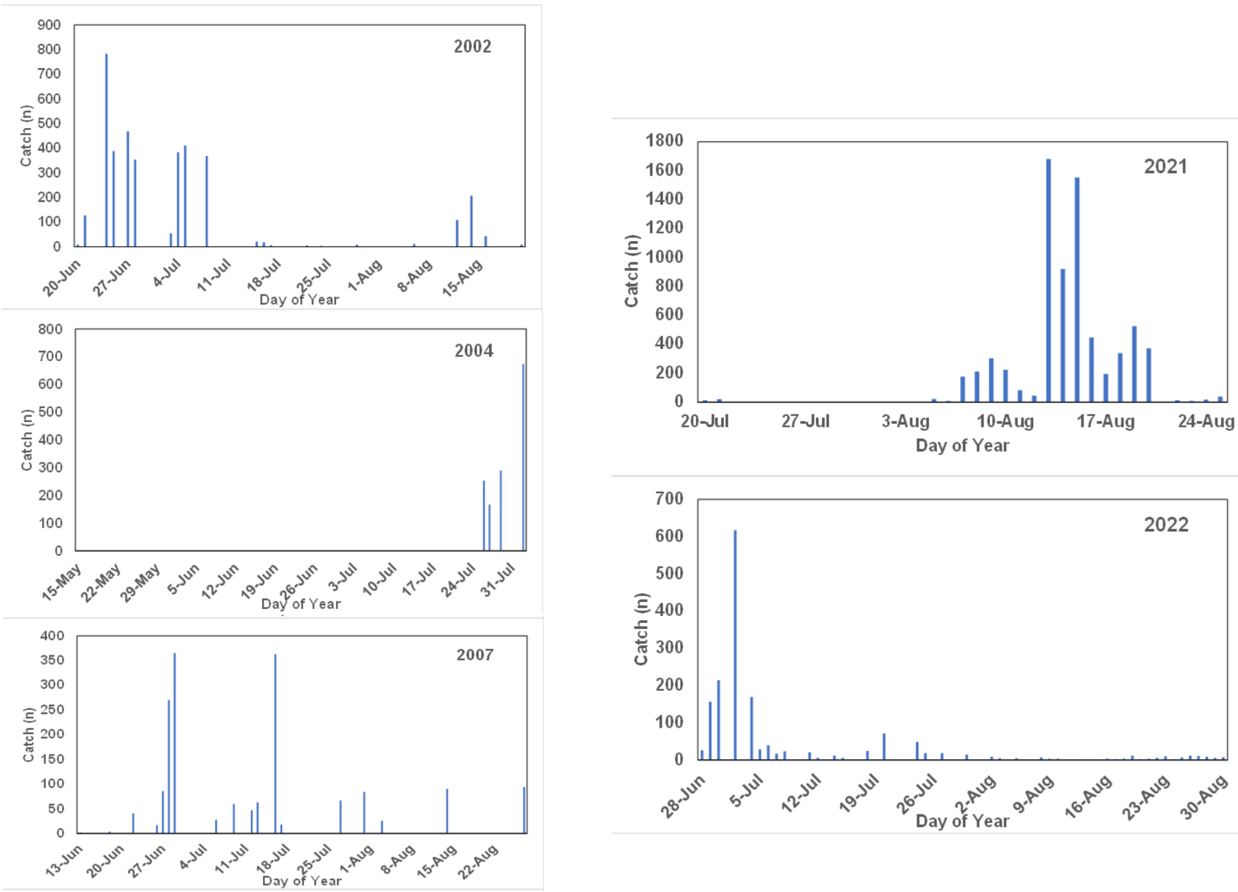

Figure 30. Catch (n=number) of yellow eels by date and year at Morgan Falls. Breadth of dates on the x-axis reflect duration of sampling. Catches were enumerate every few days during 2002, 2004, and 2007 and daily during 2021 and 2022.

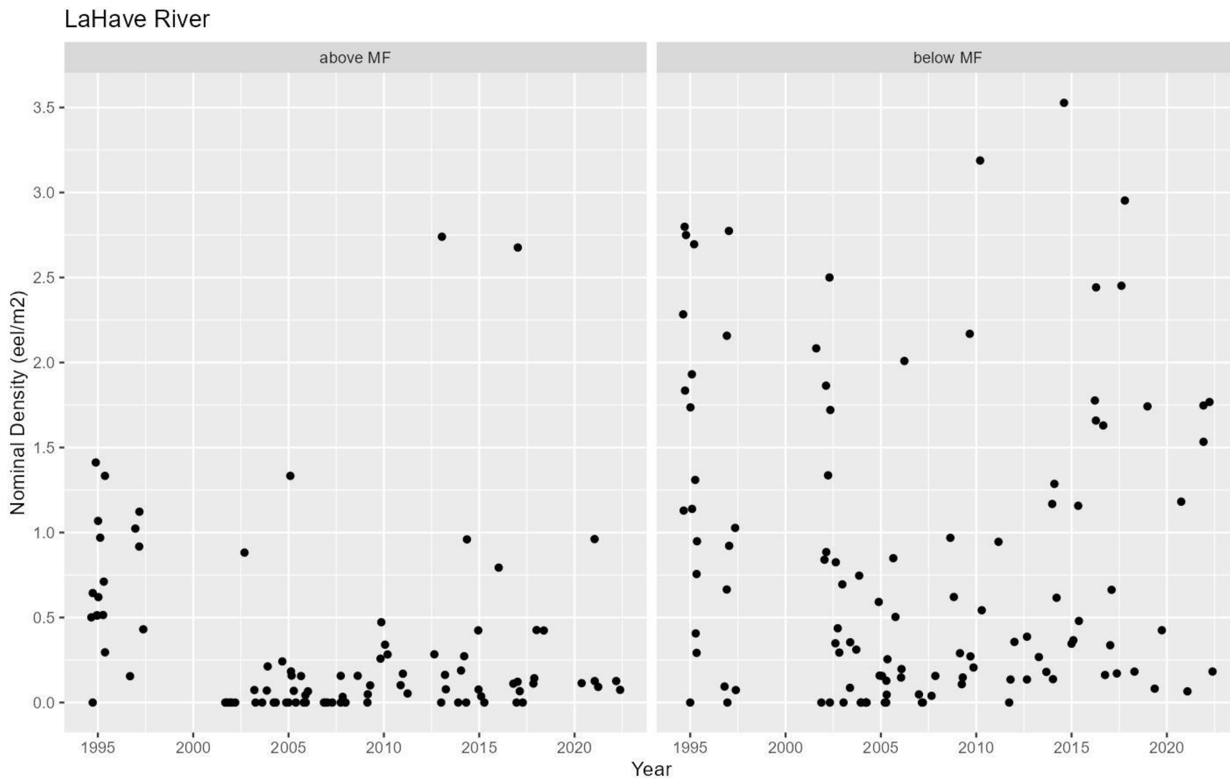

Figure 31. Nominal density (eels per 100 m^2) estimates of eels above (left panel) and below (right panel) Morgan Falls (MF) on LaHave River from 1995–2022.