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Maritimes Region

Canadian Science Advisory Secretariat
Science Advisory Report 2024/011

POST-RELEASE SURVIVAL OF JUVENILE LOGGERHEAD SEA TURTLES (*CARETTA CARETTA*) INCIDENTALLY HOOKED BY ATLANTIC CANADIAN PELAGIC LONGLINE GEAR

Photo credit: Fisheries and Oceans Canada.

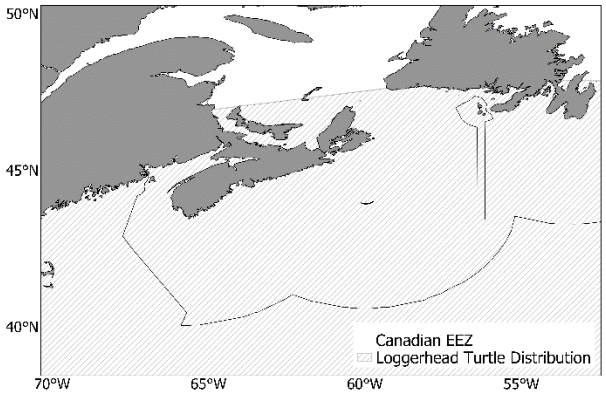

Figure 1. Estimated distribution of Loggerhead Sea Turtle in Atlantic Canada (hashed lines). Black line delimits the Canadian Exclusive Economic Zone (EEZ).

Context:

*The Loggerhead Sea Turtle (*Caretta caretta*) was listed as Endangered under Canada's Species at Risk Act (SARA) in 2017. Incidental capture of Loggerhead Sea Turtles in pelagic longline gear has been documented in all of the major ocean basins (DFO 2010). In Atlantic Canada, this threat is the only documented source of human-induced harm or mortality for Loggerhead Sea Turtles (DFO 2010). The Fisheries and Oceans Canada Species at Risk Program requested an estimation of post-release survival for Loggerhead Sea Turtles hooked by pelagic longline gear based on telemetry data. Estimates of post-release survival will help increase understanding of the threat of pelagic longline gear to Loggerhead Sea Turtles in Atlantic Canadian waters and will inform management and recovery of this species.*

*This Science Advisory Report is from the October 19–20, 2021 regional advisory meeting on Post-release Survival of Loggerhead Sea Turtles (*Caretta caretta*) in the Atlantic Canadian Pelagic Longline Fishery. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.*

February 2024

Canada

SUMMARY

- Estimating post-release survival is essential to understand how bycatch may impact sea turtle populations.
- Pelagic longline gear is the only documented source of anthropogenic harm and mortality to Loggerhead Sea Turtles in Atlantic Canadian waters.
- Mortality affecting juvenile Loggerhead Sea Turtles in Atlantic Canadian waters may ultimately translate to population-level impacts for the Loggerhead Sea Turtle population in the northwest Atlantic.
- Pop-up satellite archival tags (PSATs) were attached to 62 juvenile Loggerhead Sea Turtles incidentally hooked by Atlantic Canadian pelagic longline gear (2012–2018) to estimate associated post-release survival.
- Analysis of diving behaviour, ocean temperature, and ambient light level was used to assign fates to hooked Loggerhead Sea Turtles.
- Application of the Kaplan-Meier estimator with right censoring indicated that the annual probability of an individual hooked Loggerhead surviving post-release was 87.7%.
- There was no significant difference in probability of survival between shallow-hooked and deep-hooked Loggerhead Sea Turtles.
- PSATs are valuable tools to investigate post-release survival of a variety of marine animals, however, there are some limitations associated with tag performance and acquisition of tag data via satellite.

BACKGROUND

Juvenile Loggerhead Sea Turtles (*Caretta caretta*; herein referred to as Loggerheads) forage in waters off Atlantic Canada in summer through fall (Brazner and McMillan 2008, Gardner et al. 2008, COSEWIC 2010). Pelagic longlines have been identified as a primary threat to the recovery of Loggerheads populations (Wallace et al. 2010, COSEWIC 2010, Wallace et al. 2013, Lewison et al. 2013), and the only documented source of anthropogenic harm and mortality in Atlantic Canadian waters (DFO 2017).

Estimating post-release survival is essential to understand how bycatch may impact sea turtle populations, but survival rate estimations are few for Loggerheads (Sasso and Epperly 2007, Alvarez de Quevedo et al. 2013, Swimmer et al. 2013). Clarifying post-release survival is critical for conservation and management because, in the absence of this information, true bycatch mortality may be greatly underestimated (Molina and Cooke 2012). Estimating post-release survival can be challenging because delayed mortality following live release may result from impaired movement, fatal infections, exertional myopathy, and reduced feeding efficiency (Innis et al. 2010, Cassoff et al. 2011, Phillips et al. 2015). Pop-up satellite archival tags (PSATs) provide a way of determining fates of individuals. The PSATs archive depth, temperature and light level data while attached to their hosts and subsequently transmit summaries of these data through Argos at the time of release (“pop-up”).

In the present study we deployed PSATs to assess the post-release survival of juvenile Loggerheads incidentally hooked by Atlantic Canadian pelagic longline gear.

ANALYSIS

Tagging

Over the course of five tagging seasons (2012, 2014–2015, 2017–2018), PSATs (PAT-Mk10, Mini-PAT, or SPLASH323-B; Wildlife Computers, Redmond, WA) were deployed on 62 juvenile Loggerheads incidentally hooked by Atlantic Canadian pelagic longline gear targeting tuna and swordfish. Loggerheads were boarded with a dip-net, and trained commercial fishermen, fishery observers, and biologists attached PSATs to them using the method described by Epperly et al. (2007). Loggerhead mean curved carapace length was 65.4 ± 5.62 cm (range: 54.5 to 75.0 cm) and mean curved carapace width was 63.7 ± 6.57 cm (range: 42.0–76.5 cm; Table A1). A total of 23 Loggerheads were hooked in the mouth or the jaw and were classified as shallow-hooked (Figure 2A–C), and 39 Loggerheads swallowed the hook and were classified as deep-hooked (Figure 2D, Table A1). Hooks (circle, size 16) were not removed. Removal of monofilament fishing line and the length of line remaining attached to the hook/Loggerhead was inconsistently recorded in this study, and thus, was not incorporated into the analysis. Therefore, as is the case for sea turtles released during regular fishing operations, the amount of line removed was variable.

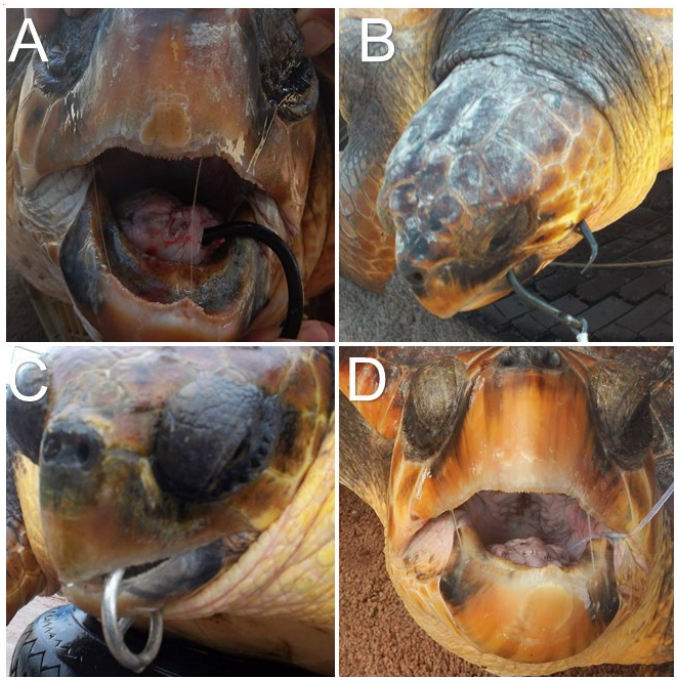

Figure 2. Hooking locations on Loggerhead Sea Turtles incidentally-captured by Atlantic Canadian pelagic longline gear. (A) mouth, (B) jaw, (C) beak, and (D) swallowed. Photo credit: Fisheries and Oceans Canada.

Tag Programming

PSATs were programmed to release after a set period (120–365 days after deployment; “scheduled” release type), or after a prolonged period (4–8 days) at a constant depth (± 1 m) (“premature” release type). They were also programmed to release if a maximum depth threshold was reached (1800 m; “too deep” release type). If the tag’s pressure sensor failed to

initiate release of the tag at maximum depth, a mechanical release was triggered ("too deep" release type).

Of the 62 deployed tags, 22 released as programmed (scheduled), 27 released prematurely, and 13 did not report release (but opportunistically transmitted on the first of each month during deployment; Table A1). Nineteen percent (n=12) of tags prematurely released or did not report release within 30 days of tagging. Fifty percent (n=31) of tags detached or did not report release within 120 days of tagging. Fifty percent (n=31) of tags logged data for at least 120 days. When tags released prematurely and the sea turtle was suspected to be alive at the end of tracking, release was attributed to hardware malfunction (two tags; Table A1).

Time at depth and time at temperature data were collected by PSATs in 6-hour periods and compiled in either 12 or 14 histogram bins ranging from 0 to greater than 200 m and 8 to greater than 32 °C. The tags also recorded depth-temperature profiles, from which daily minimum and maximum dive depths were extracted. A sample of tags were programmed to transmit opportunistically on the first day of each month enabling confirmation that they remained attached to the sea turtle and were operating as expected. Otherwise, data were archived and batch transmitted upon tag release. Argos data were decoded and exported using the Wildlife Computers Data Analysis Program (DAP).

Tag Data

For all Loggerheads, raw dive data were used to calculate the average daily percentage of time spent at the surface (0–1 m) and the maximum dive depth (deepest daily dive). When tag release was triggered (either scheduled or premature), the four to eight days spent at surface after release were excluded from analyses. These parameters were examined throughout the tracking duration for each Loggerhead to check for potential changes in dive patterns indicative of a mortality event (such as a marked increase in time spent at surface and/or tags reaching depths beyond what is biologically feasible for a living turtle). Mortality events were evident upon investigation of these parameters (e.g., Figure A3). Argos locations were also used to identify the location of tag release. For PSATs that did not transmit upon release, the end of the deployment was assigned to the first day of whichever month marked the final receipt of opportunistically transmitted data.

Loggerhead Fate

Data from PSATs provided insight into 4 possible Loggerhead fates: (1) survival assumed - full programmed deployment duration achieved and Loggerhead appeared to be diving normally prior to tag pop-up; (2) survival suspected – the Loggerhead appeared to be diving normally but the tag detached for an unknown reason, tag remained at the surface for four to eight days and released prematurely, or the tag did not report release, but the Loggerhead appeared to be diving normally until last data transmission; (3) mortality assumed – the Loggerhead exhibited a change in diving behavior indicative of compromised health until it sank and tag remained at constant depth for four to eight days, or tag sank below 1,800 m followed by tag releasing and remaining at the surface for four to eight days; and (4) inconclusive - tag did not transmit upon release or insufficient dive data were received.

Twenty-two Loggerheads were classified as 'survival assumed', 21 as 'survival suspected', five as 'mortality assumed', and 14 as 'inconclusive' (Table A1). Locations of Loggerheads at the time their fates were assumed are presented in Figure 3.

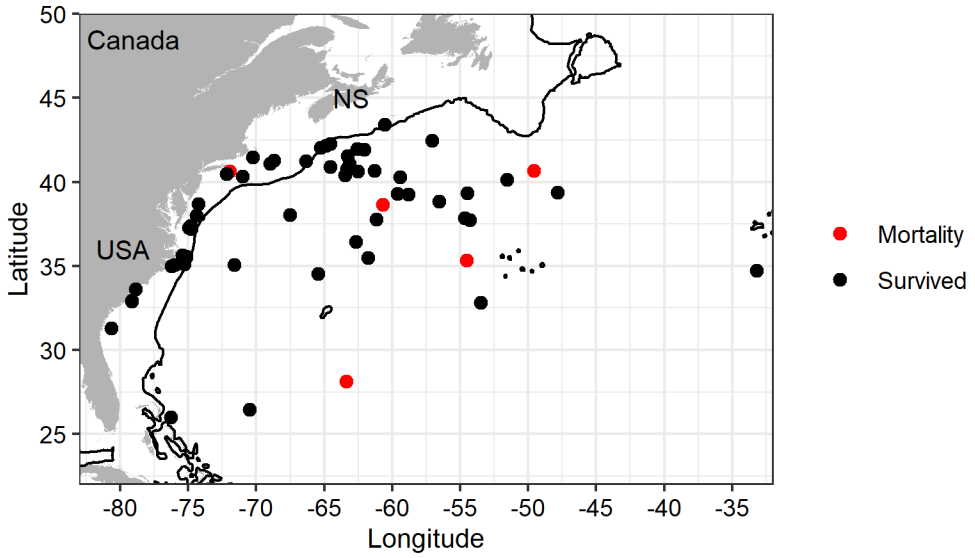

Figure 3. Post-release locations of 49 juvenile Loggerhead Sea Turtles incidentally hooked by Atlantic Canadian pelagic longline gear, colored by fate: red = mortality, black = survived. Note: tags that did not report a release location are not included (n=13).

Among the 21 'survival suspected' Loggerheads, PSATs prematurely released for eight and did not report release for 13. For tags that did not report release type, large data gaps prevented the classification of Loggerhead fate.

For the 'mortality assumed' Loggerheads, all sank to the bottom at the time of inferred death, triggering PSAT release. Two Loggerheads sank below the tag release threshold depth.

Survival Estimation

All statistical analyses were conducted using R 3.6.1 (R Core Team 2019).

Based on the four possible fates, we estimated post-release survival. Loggerheads with an inconclusive fate (tags did not transmit upon release) were included as censored results (i.e., alive until last observation). The fates of 62 individual Loggerheads contributed to the calculation of post-release survival.

Survival was estimated using the Kaplan-Meier estimator with right censoring using the survival package in R (Kaplan and Meier 1958, R Core Team 2019, Therneau 2019). This method makes no assumptions about the fate of Loggerheads without inferred mortalities. This allows for estimates of the probability of survival even if tracking duration was shorter than the programmed PSAT deployment length and no time of death was determined. Survived Loggerheads and those with an inconclusive fate are treated equally (considered alive at last observation when no further data are available; censored). A Kaplan-Meier survival model was run to determine if annual survival varied according to hooking location (i.e., hooking location was included in the model as an explicative variable).

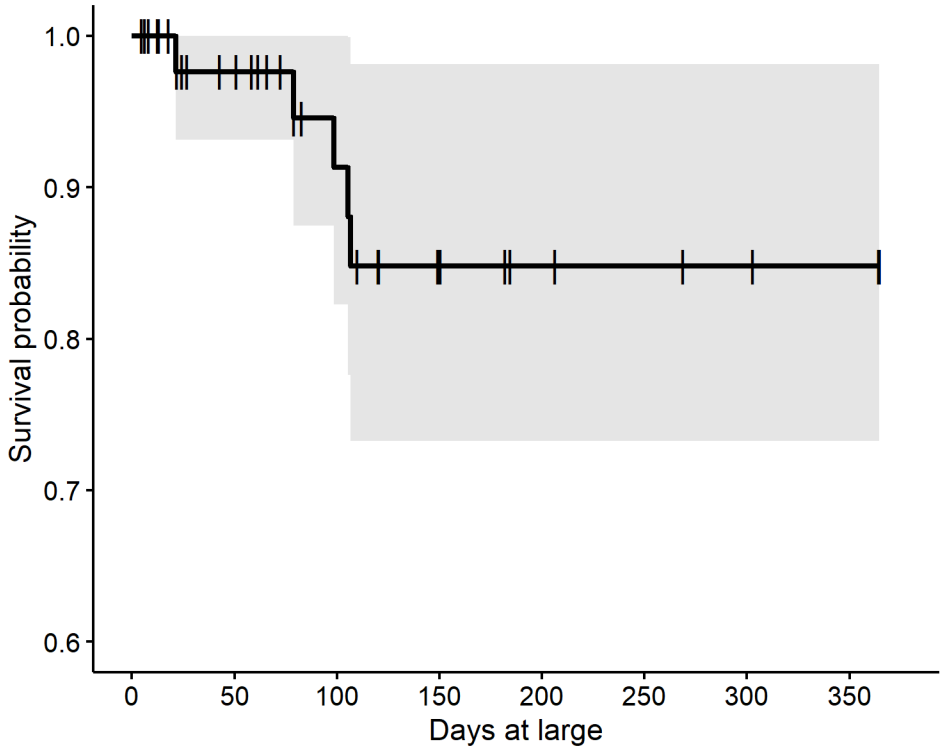

Figure 4. Kaplan-Meier annual post-release survival probability of juvenile Loggerhead Sea Turtles incidentally hooked by Atlantic Canadian pelagic longline gear. Solid line is the survivorship curve, with shaded 95% confidence intervals. Hashed lines are censored results. Each step is a mortality.

Application of the Kaplan-Meier estimator with right censoring indicated that the annual probability of an individual hooked Loggerhead surviving post-release was 87.7%. There was no significant difference in probability of survival between shallow-hooked and deep-hooked Loggerheads (Kaplan-Meier, p=0.20). Figure 4 shows the final model selected, with each step of the curve indicative of a mortality event. Annual survival probability decreased at day 21.3 (survival was 0.982 ± 0.0180), day 78.9 (survival was 0.957 ± 0.0299), day 98.6 (survival was 0.931 ± 0.0392), day 105.4 (survival was 0.904 ± 0.0462), and at day 106.6 (survival was 0.877 ± 0.0519) (Figure 4; Table 1).

Table 1. Summary of Kaplan-Meier estimator results: annual probability of post-release survival for an individual Loggerhead Sea Turtle incidentally hooked by Atlantic Canadian pelagic longline gear.

Time (days)	Number of turtles at risk at time	Number of mortality events occurring at time	Survival Probability ± Standard Error	Lower 95% Confidence Interval	Upper 95% Confidence Interval
21.3	42	1	0.982 ± 0.0180	0.947	1.000
78.9	32	1	0.957 ± 0.0299	0.900	1.000
98.6	29	1	0.931 ± 0.0392	0.857	1.000
105.4	28	1	0.904 ± 0.0462	0.818	0.999
106.6	27	1	0.877 ± 0.0519	0.781	0.985

Sources of Uncertainty

Post-release mortality can occur beyond the time frame of PSAT deployments. With increased time post-release, Loggerheads may experience additional threats (natural or anthropogenic) that make it difficult to attribute the cause of mortality, or chronic debilitation affecting fitness and survival, to the initial fishery interaction. Such considerations were beyond the scope of this study.

PSATs are valuable tools to investigate post-release survival of a variety of marine animals; however, there are some limitations associated with tag performance. In the present study, 21 tags (excluding mortality tags) released prematurely even though Loggerheads appeared to dive normally, and 13 tags did not report release.

Incomplete receipt of transmitted archival datasets from PSATs was apparent in the current study; data gaps were associated with many tags. The amount of recovered dive data varied widely among individuals, and was highest in PSATs that released at their scheduled pop-off date. Beyond issues related to detection of and receipt of data from PSATs by the Argos satellite system, biofouling of a tag's wet/dry sensor and/or the antenna, or damage to the antenna can also impede transmission and/or successful data transfer.

Recognizing the caveats regarding tag performance and data interpretation, PSATs are the best available tool to remotely assess the post-release survival of sea turtles incidentally-hooked in fisheries. Further communication between tag users and manufacturers is expected to lead to continuous improvements in PSAT technology, allowing users to optimize the quantity and quality of data collected.

CONCLUSIONS

The Kaplan-Meier survival model with right censoring resulted in an individual annual post-release survival probability of 0.877 ± 0.0519 for Loggerheads hooked by Atlantic Canadian pelagic longline gear. Mortality occurred after 21.3 days, 78.9 days, 98.6 days, 105.4 days, and 106.6 days.

Post-release survival did not vary between deep-hooked and shallow-hooked sea turtles. Hook removal from shallow-hooked sea turtles may increase survival probability following release (Swimmer et al. 2006, Sasso and Epperly 2007).However, in deep-hooked turtles, hooks may be lodged in the gastrointestinal tract or may have perforated large vessels or organs; therefore, attempts to remove them may aggravate injuries and potentially cause lethal damage (Parga 2012). It is important to note that cutting the remaining monofilament line before sea turtles are released can help prevent more serious or lethal injuries caused by constriction, tractions, lesions, or perforations in the gastrointestinal tract or adjacent organs (Work and Balazs 2010, Parga 2012). Therefore, following safe-handling recommendations for incidentally-captured sea turtles is important and may play a critical role in enhancing post-release survival (Parga et al. 2015).

Mortality affecting juvenile Loggerheads in Atlantic Canadian waters may ultimately translate to population-level impacts for the Loggerheads in the northwest Atlantic. The present results will hopefully contribute to a better understanding of the impact pelagic longline fisheries have on recovery of the Loggerhead population in the northwest Atlantic.

OTHER CONSIDERATIONS

This Science Advisory Report contains unpublished data that should not be cited outside the context of this regional advisory process.

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SOURCES OF INFORMATION

This Science Advisory Report is from the October 19-20, 2021 regional advisory meeting on Post-release Survival of Loggerhead Sea Turtles (*Caretta caretta*) in the Atlantic Canadian Pelagic Longline Fishery. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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APPENDIX

Table A1. Details from 62 juvenile Loggerhead Sea Turtles incidentally hooked by Atlantic Canadian pelagic longline gear. CCL=Curve Carapace Length; CCW=Curve Carapace Width. N/A means data is not available. A dash (-) indicates there is no additional detail to infer.

PTT #	CCL (cm)	CCW (cm)	Hooking type	Hooking location details	Deployment date dd/mm/yyyy	Interval to release	Release type	Days at Large	Fate	Fate details (dates as dd/mm/yyyy)
109820	73.0	72.0	Deep	Swallowed, not visible	01/05/2012	365	Scheduled	364.6	Survival assumed	Hardware malfunction
109809	72.0	71.0	Deep	Swallowed, not visible	02/05/2012	365	Premature	98.6	Mortality assumed	Turtle died and sank inshore (48m depth)
109818	66.0	68.0	Shallow	Mouth, lower jaw	02/05/2012	365	Non-reported	249.4	Inconclusive	Assumed alive until 07/01/2013
109819	69.0	67.0	Deep	Swallowed, not visible	04/05/2012	365	Premature	240.4	Inconclusive	Assumed alive until 08/01/2013; cause of release unknown
109814	71.0	69.5	Deep	Swallowed, visible to insertion point	07/05/2012	365	Non-reported	23.9	Inconclusive	Assumed alive until 31/05/2013
109811	63.0	64.5	Shallow	Beak	08/05/2012	365	Scheduled	364.5	Survival assumed	-
109812	60.5	58.0	Shallow	Mouth, tongue	08/05/2012	365	Non-reported	268.1	Inconclusive	Assumed alive until 31/01/2013
117631	64.0	62.0	Deep	Swallowed	14/06/2012	365	Non-reported	0.9	Inconclusive	Assumed alive until 15/06/2012
120012	60.0	61.0	Deep	Swallowed	14/06/2012	365	Scheduled	364.3	Survival assumed	-
117637	65.0	65.5	Shallow	Mouth, lower jaw	24/06/2012	365	Non-reported	190.9	Inconclusive	Assumed alive until 01/01/2013
117636	60.0	60.0	Shallow	Mouth, lower jaw	09/07/2012	365	Premature	61.3	Survival suspected	Assumed alive until 08/09/12; hardware malfunction
109815	68.5	65.5	Shallow	Mouth, jaw joint, lower jaw	27/07/2012	365	Premature	206.3	Survival suspected	Assumed alive until 18/02/2013; cause of release unknown

PTT #	CCL (cm)	CCW (cm)	Hooking type	Hooking location details	Deployment date dd/mm/yyyy	Interval to release	Release type	Days at Large	Fate	Fate details (dates as dd/mm/yyyy)
120015	65.5	66.5	Deep	Swallowed, not visible	30/07/2012	365	Scheduled	364.7	Survival assumed	-
117633	55.5	52.0	Deep	Swallowed, not visible	01/08/2012	365	Premature	79.0	Survival suspected	Assumed alive until 19/10/2012; cause of release unknown
117630	71.0	72.0	Shallow	Mouth, jaw joint, lower jaw	01/08/2012	365	Premature	65.6	Survival suspected	Assumed alive until 06/10/2012; hardware malfunction
120020	63.0	62.0	Deep	Swallowed, partial hook	09/08/2012	365	Non-reported	144.2	Inconclusive	Assumed alive until 31/12/2012
117635	63.0	62.0	Shallow	Mouth, tongue	09/08/2012	365	Premature	184.5	Survival suspected	Assumed alive until 10/02/13; cause of release unknown
117629	62.5	58.5	Deep	Swallowed, not visible	10/08/2012	365	Non-reported	111.1	Inconclusive	Assumed alive until 29/11/2012
120013	58.0	59.0	Shallow	Mouth, lower	21/08/2012	365	Scheduled	302.8	Survival assumed	-
120018	N/A	N/A	Shallow	Mouth, side	21/08/2012	365	Scheduled	364.6	Survival assumed	-
120014	71.0	68.0	Shallow	Mouth	22/08/2012	365	Premature	268.6	Survival suspected	Assumed alive until 19/05/2013; cause of release unknown
117632	63.0	59.0	Deep	Swallowed, not visible	22/08/2012	365	Premature	105.4	Mortality assumed	Turtle died and sank (> 1800m)
120016	71.6	69.0	Deep	Swallowed, visible to insertion point	22/08/2012	365	Premature	21.3	Mortality assumed	Turtle died and sank (> 1800m)
117634	65.0	63.0	Deep	Swallowed, partial hook visible	23/08/2012	365	Scheduled	364.3	Survival assumed	-
121236	66.0	65.0	Deep	Swallowed, not visible	24/08/2012	365	Non-reported	98.3	Inconclusive	Assumed alive until 30/11/2012
121237	64.0	61.0	Deep	Swallowed, not visible	24/08/2012	365	Non-reported	37.5	Inconclusive	Assumed alive until 30/09/2012

PTT #	CCL (cm)	CCW (cm)	Hooking type	Hooking location details	Deployment date dd/mm/yyyy	Interval to release	Release type	Days at Large	Fate	Fate details (dates as dd/mm/yyyy)
121240	55.0	55.0	Deep	Swallowed, not visible	04/10/2012	365	Non-reported	58.5	Inconclusive	Assumed alive until 01/12/2012
121241	67.0	64.0	Deep	Swallowed, not visible	04/10/2012	365	Non-reported	55.1	Inconclusive	Assumed alive until 28/11/2012
121238	61.0	59.0	Deep	Swallowed, not visible	06/10/2012	365	Scheduled	364.5	Survival assumed	-
121239	64.0	61.0	Shallow	Mouth, lower	06/10/2012	365	Scheduled	364.5	Survival assumed	-
139184	57.0	58.0	Deep	Swallowed, not visible	09/07/2014	182	Premature	21.8	Survival suspected	Assumed alive until 30/09/2014
139182	70.0	70.0	Deep	Swallowed, visible to insertion	10/07/2014	182	Premature	8.0	Survival suspected	Assumed alive until 18/07/2014
139194	62.5	61.0	Deep	Swallowed, visible to insertion	12/07/2014	182	Premature	72.3	Survival suspected	Assumed alive until 22/09/2014
139180	73.0	69.0	Deep	Swallowed, not visible	13/07/2014	182	Premature	12.3	Survival suspected	Assumed alive until 25/07/2014
139191	71.0	70.0	Deep	Swallowed, not visible	13/07/2014	182	Premature	4.5	Survival suspected	Assumed alive until 17/07/2014
139188	75.0	76.5	Deep	Swallowed, not visible	14/07/2014	182	Premature	42.8	Survival suspected	Assumed alive until 25/08/2014
139185	62.0	63.0	Shallow	Mouth, tongue	17/07/2014	182	Premature	82.5	Survival suspected	Assumed alive until 25/08/2014
139181	73.0	72.0	Shallow	Mouth, lower	19/07/2014	182	Premature	17.8	Survival suspected	Assumed alive until 05/08/2014
139190	58.0	59.5	Deep	Swallowed, not visible	19/07/2014	182	Premature	6.3	Survival suspected	Assumed alive until 25/07/2014
139192	58.0	57.0	Deep	Swallowed, not visible	20/07/2014	182	Premature	50.8	Survival suspected	Assumed alive until 08/09/2014
137772	74.5	72.0	Deep	Swallowed, not visible	08/08/2014	365	Premature	13.0	Survival suspected	Assumed alive until 21/08/2014
129588	67.0	65.0	Deep	Swallowed, partially visible	25/08/2014	182	Scheduled	182.0	Survival assumed	-

PTT #	CCL (cm)	CCW (cm)	Hooking type	Hooking location details	Deployment date dd/mm/yyyy	Interval to release	Release type	Days at Large	Fate	Fate details (dates as dd/mm/yyyy)
148986	55.0	51.2	Shallow	Beak, lower	24/06/2015	150	Interval	150.0	Survival assumed	-
148988	71.0	68.0	Deep	Swallowed, partially visible	25/06/2015	150	Too deep	78.9	Mortality assumed	-
148976	73.5	71.5	Shallow	Mouth	25/06/2015	150	Interval	150.0	Survival assumed	-
148980	54.5	49.0	Shallow	Mouth, jaw joint, side	25/06/2015	150	Too deep	106.6	Mortality assumed	-
148985	72.0	70.0	Shallow	Mouth, lower	25/06/2015	150	Interval	150.0	Survival assumed	-
148999	68.0	64.0	Shallow	Mouth, tongue	26/06/2015	150	Floater	58.3	Survival suspected	Assumed alive until 23/08/2015; cause of release unknown
148982	55.5	42.0	Shallow	Mouth, lower	26/06/2015	150	Premature	109.8	Survival suspected	Assumed alive until 14/10/2015; cause of release unknown
148983	70.0	70.5	Deep	Swallowed, not visible	26/06/2015	150	Interval	150.1	Survival assumed	-
149015	70.5	66.0	Deep	Swallowed, partially visible	23/07/2015	150	Scheduled	149.2	Survival assumed	-
148984	61.5	56.0	Deep	Swallowed, partially visible	08/08/2015	150	Interval	150.2	Survival assumed	-
149002	67.0	57.0	Shallow	Mouth, tongue	20/08/2015	150	Scheduled	150.0	Survival assumed	-
149018	65.0	66.0	Shallow	Mouth, lower	21/08/2015	150	Scheduled	150.0	Survival assumed	-
149012	70.0	73.0	Deep	Swallowed, partially visible	23/08/2015	150	Non-reported	39.0	Survival suspected	Assumed alive until 01/10/2015
149010	66.0	65.0	Deep	Swallowed, not visible	30/08/2015	150	Premature	26.8	Survival suspected	Assumed alive 26/09/2015; cause of release unknown
148992	59.0	56.4	Shallow	Mouth, jaw joint	06/09/2015	150	Interval	150.3	Survival assumed	-

PTT #	CCL (cm)	CCW (cm)	Hooking type	Hooking location details	Deployment date dd/mm/yyyy	Interval to release	Release type	Days at Large	Fate	Fate details (dates as dd/mm/yyyy)
168162	71.4	67.7	Deep	Swallowed, not visible	02/08/2017	120	Interval	120.1	Survival assumed	-
148981	60.0	60.0	Deep	Swallowed, not visible	17/08/2017	120	Interval	120.2	Survival assumed	-
100926	66.6	63.2	Deep	Swallowed, not visible	25/08/2017	120	Interval	120.3	Survival assumed	-
149021	67.0	N/A	Deep	Swallowed, partially visible	26/07/2018	120	Premature	24.3	Survival suspected	Assumed alive until 20/08/2018; cause of release unknown

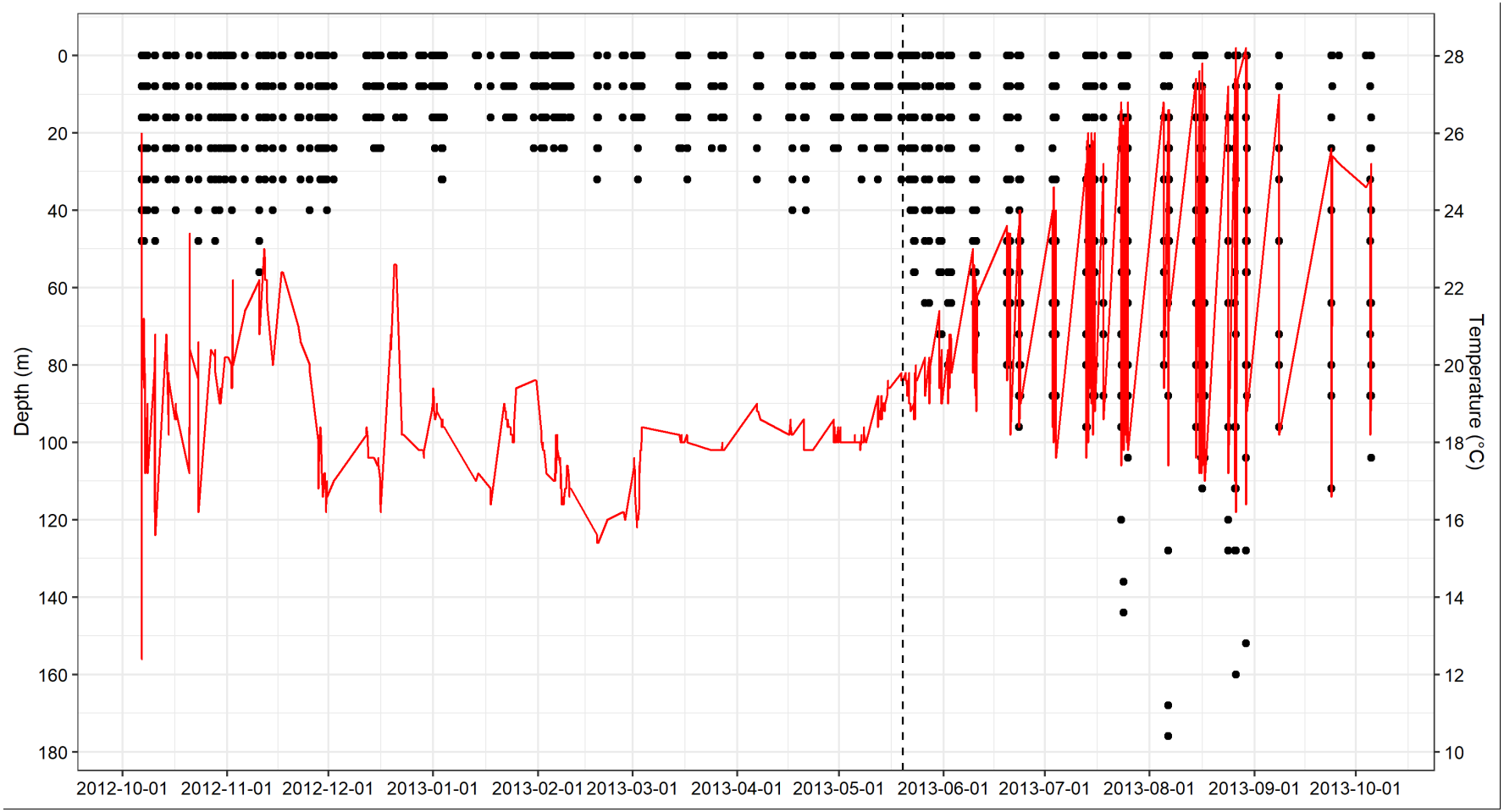

Figure A1. Depth (black points; primary y-axis) and temperature (red line; secondary y-axis) of a 'survival assumed' Loggerhead Sea Turtle throughout pop-up satellite tag deployment. Tag 121238 was deployed on October 6th 2012 and released after 1 year. Change in dive pattern was identified on May 20th 2013 (dashed line).

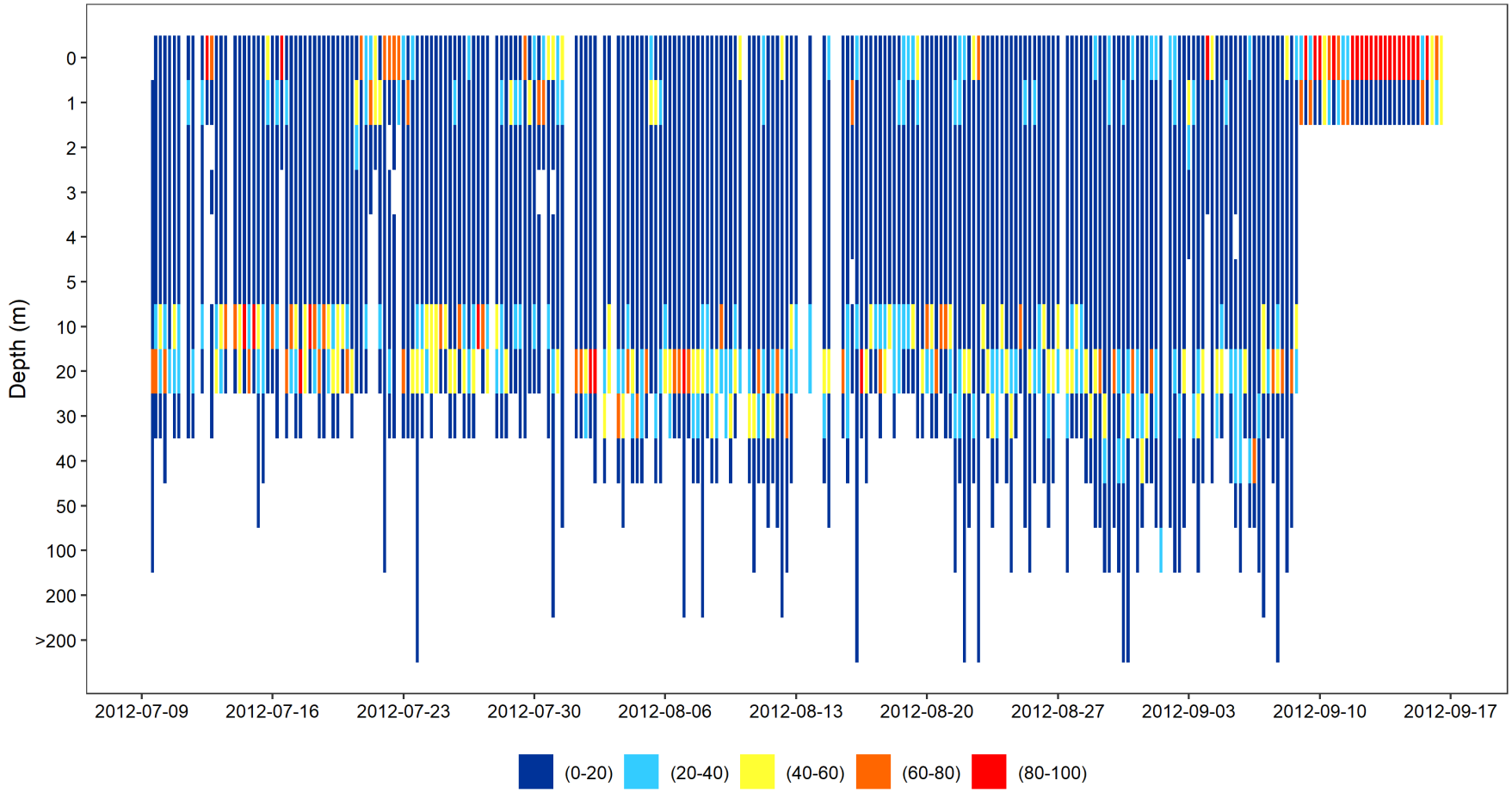

Figure A2. Daily percentage of time (legend) spent at depth (y-axis) of the post-release dive pattern of a 'survival suspected' Loggerhead Sea Turtle throughout pop-up satellite tag deployment. Tag 117636 was deployed on July 9th 2012 and released prematurely on September 16th 2012 after remaining 8 days at the surface (70 day deployment). Turtle was assumed to be alive until September 8th 2012.

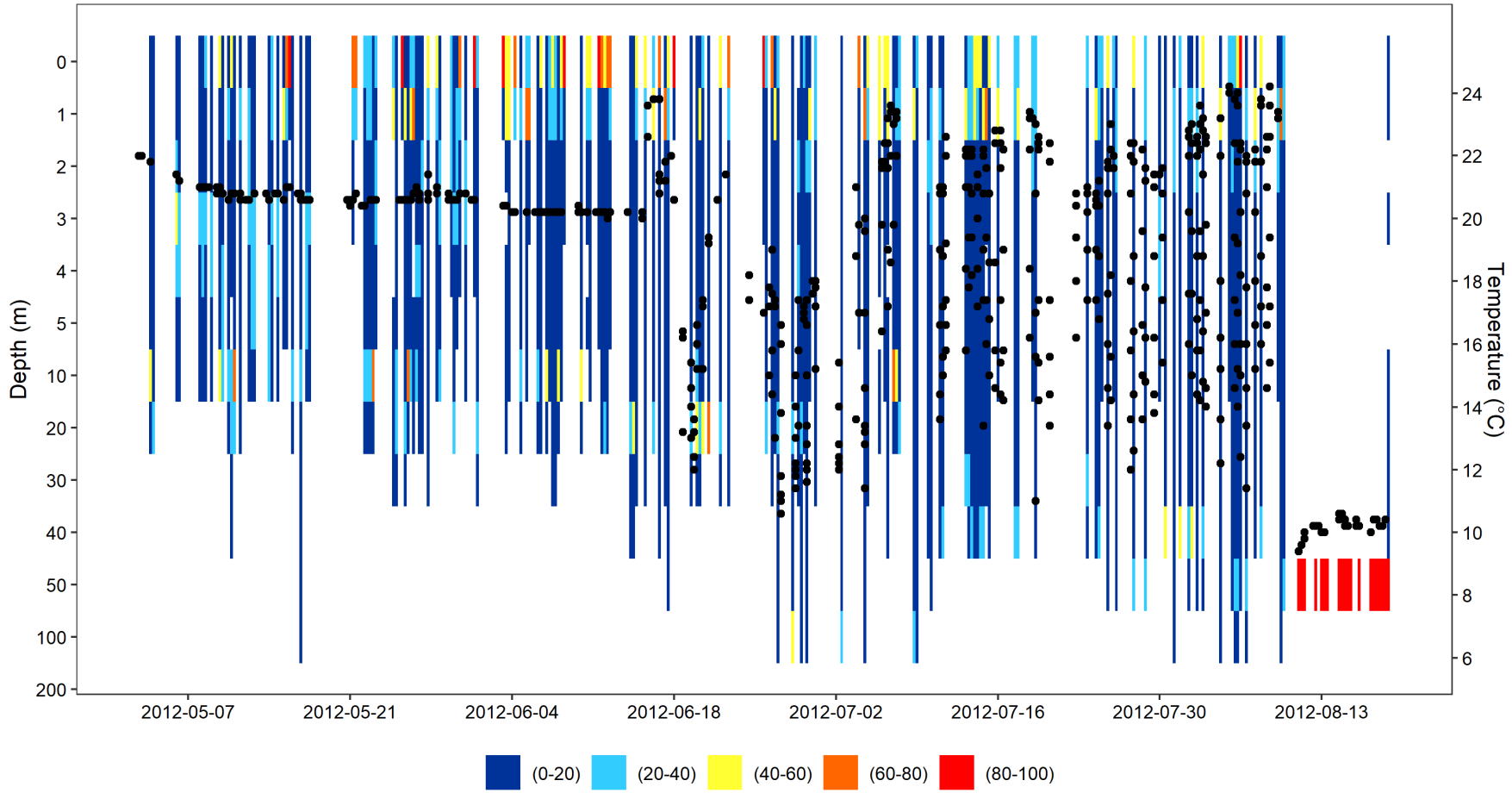

Figure A3. Daily percentage of time (legend) spent at depth (primary y-axis), and temperature (black points; secondary y-axis) of a 'mortality assumed' Loggerhead Sea Turtle throughout pop-up satellite tag deployment. Tag 109809 was deployed on May 2nd 2012 and released prematurely on August 18th 2012. On August 8th 2012, the turtle died and sank to the sea bottom, where tag remained for 8 days before release.

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ISSN 1919-5087
ISBN 978-0-660-70112-7 Cat. No. Fs70-6/2024-011E-PDF

Correct Citation for this Publication:

DFO. 2024. Post-Release Survival of Juvenile Loggerhead Sea Turtles (*Caretta caretta*) Incidentally Hooked by Atlantic Canadian Pelagic Longline Gear. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2024/011.

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*MPO. 2024. Survie des tortues caouannes juvéniles (*Caretta caretta*) remises à l'eau après leur capture accidentelle dans le cadre de la pêche à la palangre pélagique dans les eaux canadiennes de l'Atlantique, Canada. Secr. can. des avis sci. du MPO. Avis. sci. 2024/011.*