Methods

Over the course of 4 tagging seasons, 79 pop-up satellite archival tags were deployed by researchers, commercial fishermen and fishery observers. The tags were programmed to release after a set period (between 150–500 days after deployment), after a prolonged period (4–8 days) at a constant depth or reaching a maximum depth threshold of 1700 meters. A range of Wildlife Computing PAT, SPLASH 323-B and MinPAT tags were used (Table 1).

	2011	2012	2014	2015
MinPAT	0	0	0	20
PAT	1	36	2	2
SPLASH 323-B	0	0	17	1

Table 1: The types of tags deployed over the 4 tagging seasons

Tag data was downloaded from Wildlife Computers and processed using WC-DAP v3.0.369. These data were then analyzed using R v3.3.2.

Tags often transmitted for a long period after releasing from turtles and the start of transmission could be delayed from the time of release. To infer the final time that the tag was clearly on the turtle, data was censored back from the first time the tag indicated release (or last transmission for lost tags) to the last time point where the maximum depth exceeded 10 m.

Turtle fate was determined based on the tag release condition. Tags released due to extreme depth or constant depth were counted as mortalities and all other releases counted as a turtle which was alive at the time of release (Figure 2. A limitation with all such data is that there is little opportunity to identify a sudden mortality event, e.g. a large shark bite or propeller strike, which both kills the turtle and releases the tag. However, we believe that most premature releases and tag losses are due to tag or attachment failure as exemplified in a particularly loss-prone batch of PAT tags in 2012 and release-prone SPLASH tags in 2014 (Table 2).

	2011	2012	2014	2015
Broken	0	4	0	1
ConstantDepth	0	2	0	0
Float	0	4	18	5
Lost	1	14	0	3
Scheduled	0	8	1	12
TooDeep	0	2	0	2
Unknown	0	2	0	0

Table 2: Inferred fate of tags deployed over the 4 tagging seasons

We estimated survival rates using Kaplan-Meier estimates (Kaplan and Meier, 1958) and compared between conditions using Cox proportional hazards models (Cox, 1972).

Results

Mortalities

Over the 4 tagging-seasons, tags were deployed on 79 turtles giving 9,419 turtle-days of information (Figure 1, Table S1). We observed 6 inferred mortalilities, 4 inferred from maximum depth dives and 2 from constant depth (Figure 2).

Over all the data, 98.4% (95% confidence interval (CI): 89.1–99.8%) of turtles survived at least 30 days after tagging, 94.1% (95% CI: 82.5–98.1%) of turtles survived at least 90 days after tagging and 87% (95% CI: 73.1–94%) of turtles survived at least 360 days after tagging (Figure 3A).

Hooking location did not appear to have a significant effect on mortalities (Cox proportional hazards model score test: $p = 0.46$). No mortalities were observed in turtles captured without hooking (Figure 3B) but with only 8 unhooked turtles, this difference did not reach significance ($p = 0.5$).

Turtle selection and tagging by either observer/researcher or fishing boat crew did not have a significant effect on mortality ($p = 0.96$) (Figure 3C).

There were hints that the length of monofilament left on the hook could have an effect on mortality, with shorter lengths potentially linked to mortality (Figure 3D). However, the length of monofilament was known for only 15 turtles and the difference was not significant ($p = 0.4$).

Tag failures

There were several difficulties in tag retention in this study. Over all the data, 28% (95% CI: 19.4–39.3%) of tags detached or failed within 30 days of tagging. Further, 56.4% (95% CI: 45.6–67.9%) of tags detached or failed within 150 days of tagging and only 20.3% (95% CI: 10.1–32.9%) lasted to 360 days (Figure 4A).

Turtle selection and tagging by either observer/researcher or fishing boat crew did not have a significant effect on tag drop rate ($p = 0.27$) (Figure 4B).

Tag type and tagging year were highly correlated (Table 1) so precisely defining which variable is affecting performance is difficult but SPLASH tags deployed in 2014 had a very high drop off rate (Figure 4C, 4D). SPLASH tags had a 100% failure rate with 77.8% (95% CI: 57.1–93.1%) of SPLASH tags failing within 30 days of deployment.

Complete tag loss with no terminal transmission of archived data is a particular problem for PAT tags. Here, we did not receive terminal transmissions from 18 tags (Figure 5A). These losses were largely from PAT type tags (Figure 5B) but the rate of loss was not significantly different between tag types ($p = 0.16$).

Conclusions

In this population of turtles, the mortality rate after hooking appears relatively low. We estimate that 87% of turtles survive at least 150 days after tagging. The survival rate does not appear to be related to the location of the hook in the turtle. The data hints that there

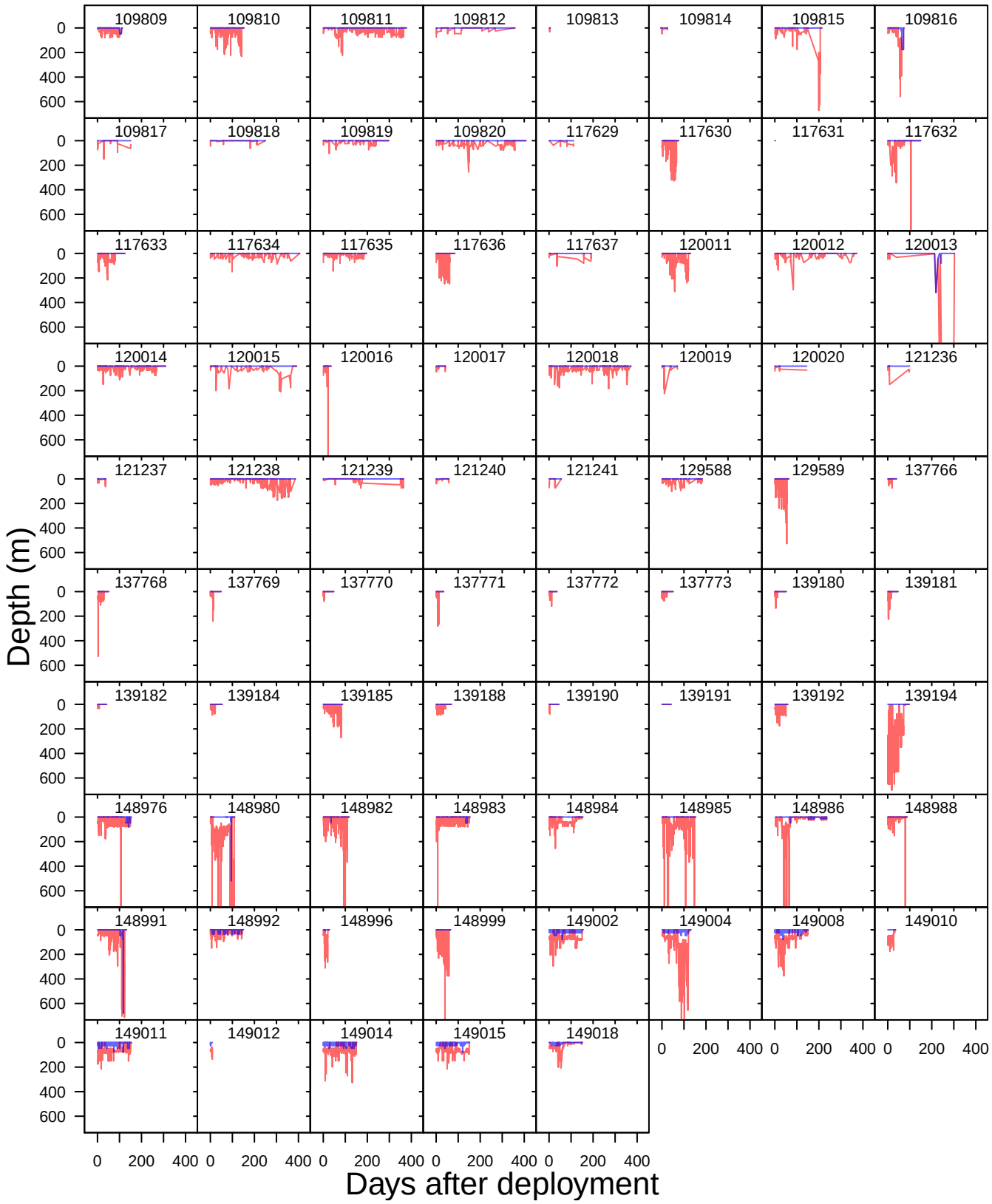

Figure 1: Minimum (blue) and maximum (red) depth reports extracted from all available tag sensors for all turtles with any records in the study.

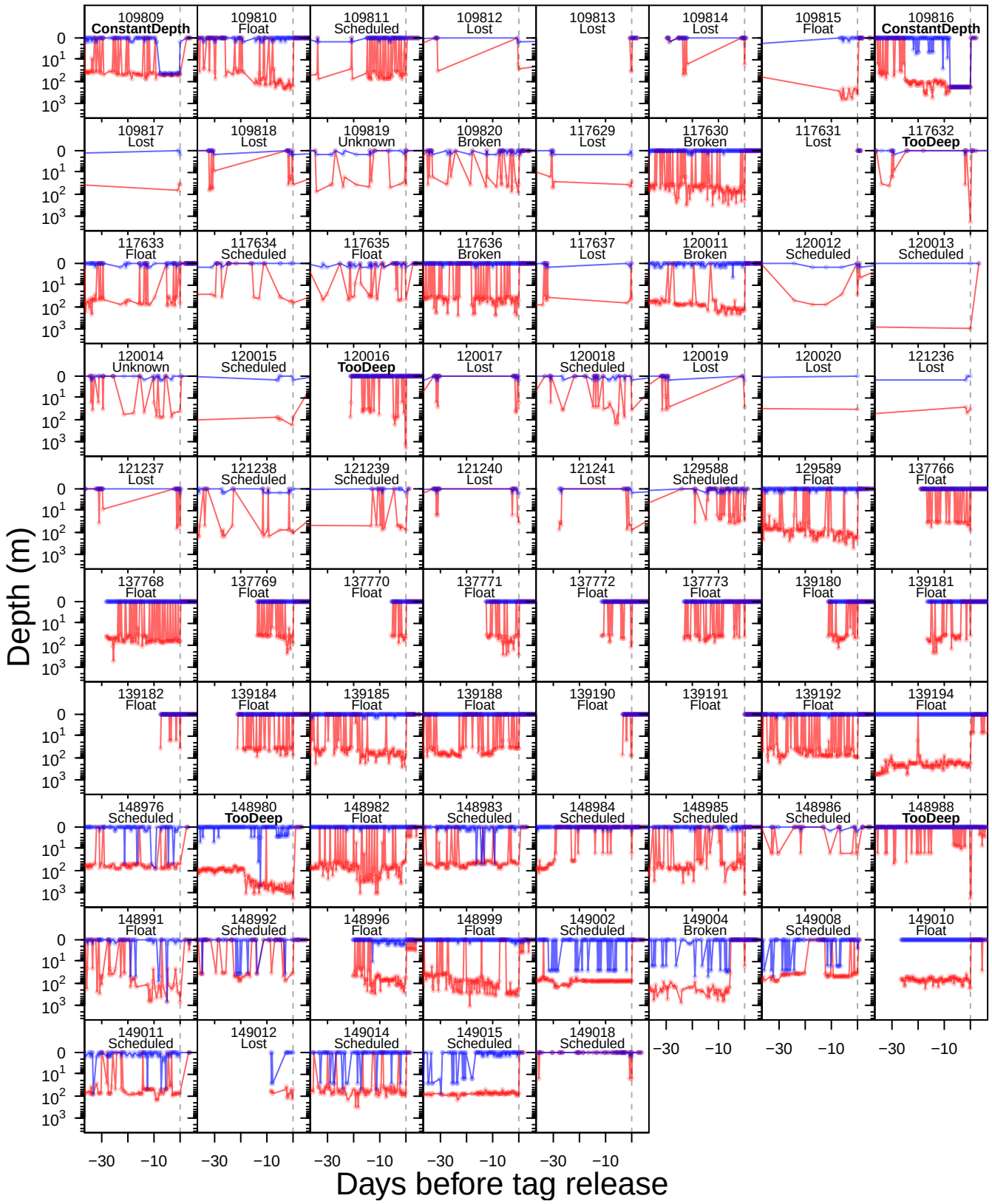

Figure 2: Minimum (blue) and maximum (red) depth reports extracted from all available tag sensors for all turtles with any records in the study in the month prior to release. Dashed line indicates inferred release time. The inferred fate for each turtle based on its tag's communications and depth profiles is indicated for each subplot. Note the log scaling on the y-axis.

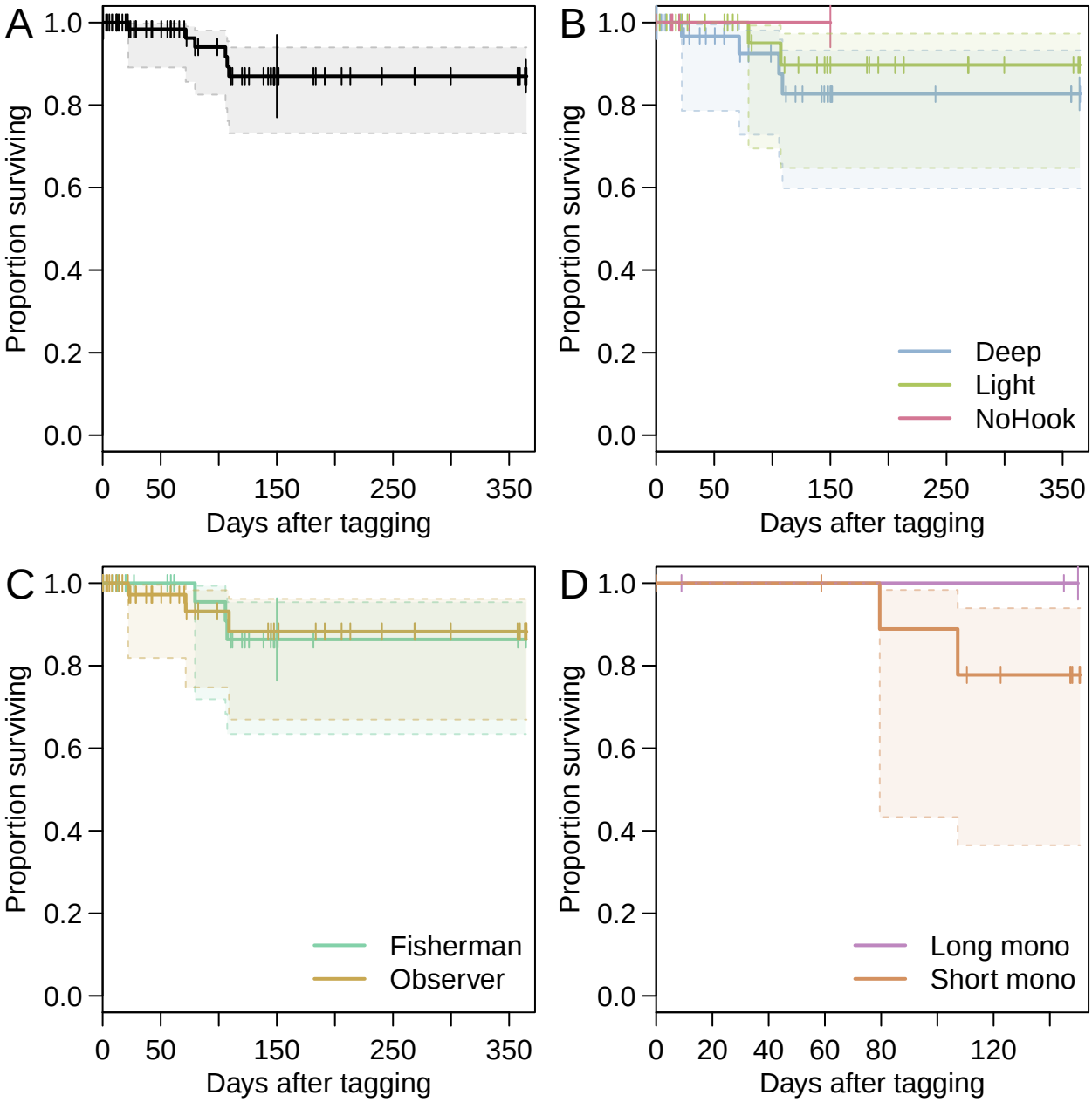

Figure 3: Kaplan-Meier curves showing the estimated proportion of turtles surviving over time for all turtles (A), deep, light or no hook turtles (B), observer or fisherman tagged turtles (C) and turtles with long (> 30 cm) or short pieces of monofilament left attached to hooks (D). Shaded regions indicate 95% confidence intervals. Lost tags, scheduled releases and tags prematurely released without dives to maximum depth or a period of constant depth are counted as censored observations (vertical dashes, scaled by the number of tags censored on that day).

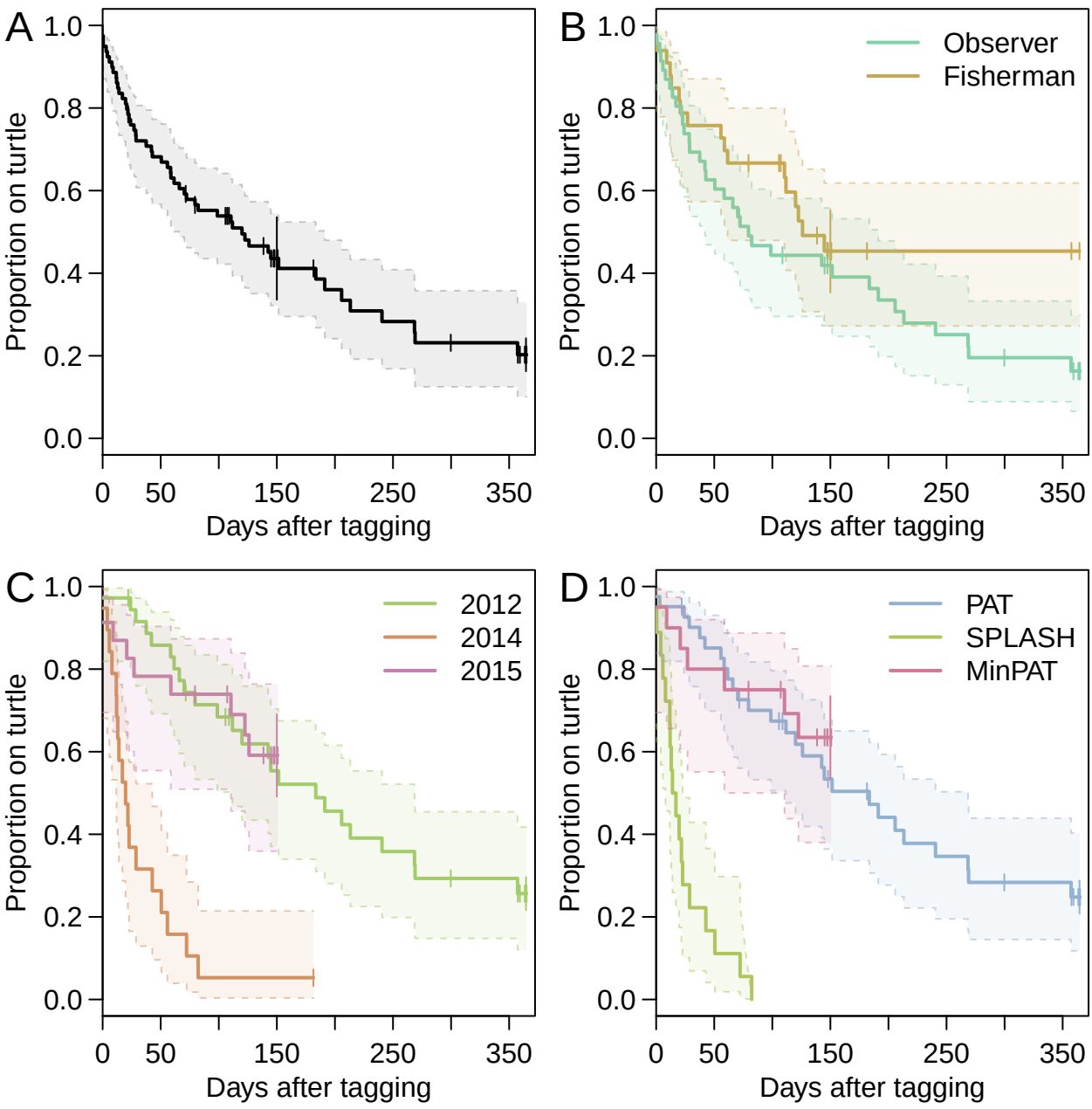

Figure 4: Kaplan-Meier curves showing the estimated proportion of tags remaining on turtles for all turtles (A), turtles split by tagging by an observer/researcher or a fisherman (B), turtles split by tagging year (C) and turtles split by tag type (D). Note that tagging year and tag type are highly correlated (Table 1. A single tag deployed in 2011 is not shown in (C). Maximum depth, constant depth and scheduled released are counted as censored observations (vertical dashes, scaled by the number of tags censored on that day).

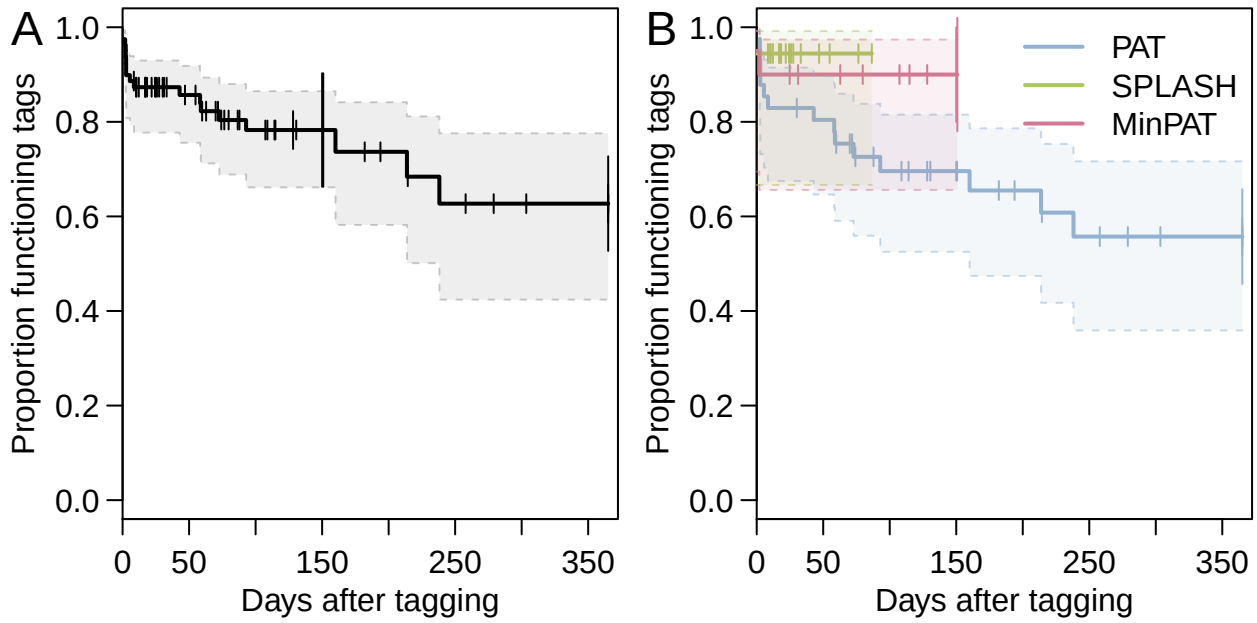

Figure 5: Kaplan-Meier curves showing the estimated proportion of tags not lost for all turtles (A) and turtles split by tag type (B). All fates other than tag loss are counted as censored observations (vertical dashes, scaled by the number of tags censored on that day). Tags were considered lost on the last day a status message was received.

could be an association between mortalities and monofilament clipped at shorter lengths but no conclusions can be drawn from the current data. Since censored observations do not contribute to the statistical power to detect differential mortality (Hsieh and Lavori, 2000), the low mortality rates observed in this study suggest that further tagging is necessary if we wish to determine variables correlated with mortality.

References

Cox, D. R. (1972). Regression models and life tables. *Journal of the Royal Statistical Society: Series B*, 34:187–220.

Hsieh, F. and Lavori, P. W. (2000). Sample-size calculations for the cox proportional hazards regression model with nonbinary covariates. *Controlled Clinical Trials*, 21(6):552–560.

Kaplan, E. L. and Meier, P. (1958). Nonparametric estimation from incomplete observations. *Journal of the American Statistical Association*, 53(282):457–481.

Supplementary

PTT	Hook	Deploy date	Deployer	Deploy length	Fate
109813	Light	2011-08-27	Observer/researcher	3.00	Lost
109810	Deep	2012-05-01	Observer/researcher	142.50	Float
109817	Deep	2012-05-01	Observer/researcher	151.50	Lost
109820	Deep	2012-05-01	Observer/researcher	357.25	Broken
109809	Deep	2012-05-02	Observer/researcher	108.75	Constant Depth
109818	Light	2012-05-02	Observer/researcher	213.25	Lost
109819	Deep	2012-05-04	Observer/researcher	240.50	Unknown
109814	Deep	2012-05-07	Observer/researcher	24.00	Lost
109811	Light	2012-05-08	Observer/researcher	364.75	Scheduled
109812	Light	2012-05-08	Observer/researcher	268.50	Lost
120011	Deep	2012-06-14	Fisherman	120.00	Broken
117631	Deep	2012-06-14	Fisherman	0.50	Lost
120012	Deep	2012-06-14	Fisherman	357.50	Scheduled
117637	Light	2012-06-24	Observer/researcher	191.25	Lost
117636	Light	2012-07-09	Fisherman	61.50	Broken
109816	Deep	2012-07-25	Observer/researcher	71.50	Constant Depth
109815	Light	2012-07-27	Observer/researcher	205.75	Float
120015	Deep	2012-07-30	Observer/researcher	365.00	Scheduled
117630	Light	2012-08-01	Observer/researcher	66.00	Broken
117633	Deep	2012-08-01	Observer/researcher	79.50	Float
120020	Deep	2012-08-09	Fisherman	144.75	Lost
117635	Light	2012-08-09	Observer/researcher	183.50	Float
117629	Deep	2012-08-10	Fisherman	111.75	Lost
120017	Light	2012-08-20	Observer/researcher	42.00	Lost
120019	Light	2012-08-21	Observer/researcher	70.25	Lost
120018	Light	2012-08-21	Observer/researcher	359.25	Scheduled
120013	Light	2012-08-21	Observer/researcher	299.75	Scheduled
117632	Deep	2012-08-22	Fisherman	105.75	Too Deep
120014	Light	2012-08-22	Observer/researcher	269.00	Unknown
120016	Deep	2012-08-22	Observer/researcher	22.00	Too Deep
117634	Deep	2012-08-23	Fisherman	364.50	Scheduled
121237	Deep	2012-08-24	Observer/researcher	37.50	Lost
121236	Deep	2012-08-24	Observer/researcher	98.75	Lost
121240	Deep	2012-10-04	Observer/researcher	58.50	Lost
121241	Deep	2012-10-04	Observer/researcher	28.50	Lost
121238	Deep	2012-10-06	Observer/researcher	364.50	Scheduled
121239	Light	2012-10-06	Observer/researcher	363.50	Scheduled
139184	Deep	2014-07-09	Observer/researcher	21.75	Float
139182	Deep	2014-07-10	Observer/researcher	8.00	Float
139194	Deep	2014-07-12	Observer/researcher	72.25	Float
139180	Deep	2014-07-13	Observer/researcher	11.75	Float
139191	Deep	2014-07-13	Observer/researcher	0.50	Float
139188	Deep	2014-07-14	Observer/researcher	42.75	Float

137768	No Hook	2014-07-15	Observer/researcher	28.75	Float
137773	Light	2014-07-16	Observer/researcher	22.75	Float
137769	No Hook	2014-07-17	Observer/researcher	14.00	Float
139185	Light	2014-07-17	Observer/researcher	82.25	Float
137770	Deep	2014-07-18	Observer/researcher	5.75	Float
139190	Deep	2014-07-19	Observer/researcher	4.00	Float
139181	Light	2014-07-19	Observer/researcher	17.00	Float
139192	Deep	2014-07-20	Observer/researcher	50.50	Float
137771	No Hook	2014-08-01	Fisherman	13.00	Float
137766	No Hook	2014-08-03	Fisherman	19.75	Float
137772	Deep	2014-08-08	Fisherman	12.00	Float
129588	Light	2014-08-25	Fisherman	181.50	Scheduled
129589		2014-08-25	Fisherman	55.75	Float
149018	Deep	2015-08-21	Fisherman	148.00	Scheduled
149004	Deep	2015-09-24	Fisherman	126.00	Broken
148992	Light	2015-09-06	Observer/researcher	145.00	Scheduled
148984	Deep	2015-08-08	Observer/researcher	147.50	Scheduled
152567	No Hook	2015-08-09	Observer/researcher	0.00	Lost
148983	Deep	2015-06-26	Fisherman	150.50	Scheduled
148976	Deep	2015-06-25	Fisherman	150.75	Scheduled
148991	Light	2015-06-25	Fisherman	122.50	Float
148986	Light	2015-06-24	Fisherman	138.50	Scheduled
148996	Light	2015-06-24	Fisherman	20.75	Float
148988	Light	2015-06-25	Fisherman	79.50	Too Deep
148999	Light	2015-06-26	Fisherman	58.75	Float
148987	Light	2015-06-26	Fisherman	0.00	Lost
148985	Light	2015-06-25	Fisherman	147.25	Scheduled
148982	Light	2015-06-26	Fisherman	110.50	Float
148980	Light	2015-06-25	Fisherman	107.25	Too Deep
149014	No Hook	2015-08-22	Fisherman	150.00	Scheduled
149012	Light	2015-08-23	Fisherman	9.00	Lost
149010	Light	2015-08-30	Fisherman	27.00	Float
149008	No Hook	2015-08-20	Fisherman	150.00	Scheduled
149002	Light	2015-08-20	Fisherman	150.00	Scheduled
149015	Deep	2015-07-23	Fisherman	150.00	Scheduled
149011	No Hook	2015-08-30	Fisherman	150.00	Scheduled

Table S1: PTT tag IDs, hooking location, deployment date, deployment length and inferred fate for all turtles in the study