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Australia's National
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Update on recent satellite tag deployments in GAB on juvenile SBT

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Contents

1 Executive summary

CSIRO has been conducting satellite tagging of juvenile SBT in the Great Australian Bight (GAB) to understand if the habitat and distribution of these fish has changed relative to observations collected from previous electronic tagging programs. The work is also examining oceanographic trends in the GAB which may drive changes in distribution of SBT. This paper provides an overview of tagging results from 14 short term popup tag data sets obtained during 2024. The tagged SBT remained in the GAB region, with deployments ranging from ~3 – 96 days. Several of the tags appear to have been ingested, most likely by other SBT. The aim for future deployments is to deploy tags from recreational or charter vessels immediately prior to or during the Australian surface fishery activities. Deployment of tags further east, for instance in Bass Strait, would be desirable in order to monitor movement and habitat preferences of 3-4 year-old SBT appearing in regions outside the traditional GAB grounds. The project requests 0.5t RMA to cover any incidental tagging mortality in the upcoming summer of 2024/25.

2 Results

The project team deployed 19 miniPATs (Popup Archival Tag) on southern bluefin tuna (SBT; length range 86-104 cm) in March 2024. Of those deployed, 14 have now reported back (Table 1), with a high proportion of short-term attachments and 5 tags remain deployed on SBT. We believe the early detachment to be a result of the fish being small relative to the size of the satellite tag. The smaller tag model (the microPAT), which was tested in 2023, is now available from the manufacturer and will be used for the majority of future deployments in this project.

Investigation of oceanographic products has begun, with the project now in a position to use data from the BOM's ACCESS-S model as well as data from CSIRO's ROAM model. The latter is a fine-scale relocatable model which will be used to look at oceanographic data over short time periods (i.e. 3-6 months). The ROAM data are likely to be more useful for investigating fine scale features that may influence SBT behaviour but comes with extra overheads of handling large model output.

This project has made progress against the overall objectives of characterising SBT habitat preferences using satellite tags and conducting comparative analysis of physical ocean conditions in the area utilised by the Australian surface fishery.

As detailed below, 19 miniPSATs were deployed on SBT (length range 86-104 cm) at the end of the 2024 summer; however, obtaining long term attachment durations has been challenging, with 14 out of the 19 tags deployed surfacing well before the programmed date. Currently 5 tags remain deployed on SBT. It is likely that the size of the miniPSATs used this year was slightly large for the size of fish tagged. The project will now pursue tagging with microPAT devices, which are smaller, in the hope of longer-term attachments. However, accessing larger fish (greater than 100 cm) remains a priority. Wildlife computers miniPSAT tags were programmed to be either 4- or 8-month deployments and carried on board while gene tagging operations were being conducted.

The project has been using oceanographic models to examine long term changes in the GAB and investigating the use of finer scale models operated and constructed by CSIRO. The project will continue to collect satellite tagging data and investigate whether deployment of tags on the appropriate size SBT is feasible towards the end of 2024.

Table 1. Release and popup locations for 14 tags which have reported to date.

Tag	Release date	Length (cm)	Release Latitude	Release Longitude	Pop-up date	Popup Longitude	Popup Latitude	Days deployed
22P1166	2024-03-06	87	-34.818	134.702	2024-04-15 01:37:26	132.823	-35.019	40.109 days
23P1078	2024-03-06	89	-34.767	134.665	2024-03-09 22:27:46	133.404	-34.193	3.936 days
21P0695	2024-03-06	89	-34.815	134.699	2024-03-21 21:32:50	131.197	-32.585	15.898 days
23P1077	2024-03-06	92	-34.765	134.664	2024-03-10 08:29:49	133.789	-35.347	4.354 days
21P11175	2024-03-06	88	-34.766	134.664	2024-03-22 17:04:51	133.672	-35.383	16.712 days
21P0671	2024-03-06	87	-34.782	134.675	2024-03-15 18:29:44	133.038	-34.860	9.771 days
21P0739	2024-03-06	86	-34.787	134.679	2024-03-29 07:44:54	132.462	-32.311	23.323 days
22P1159	2024-03-06	90	-34.809	134.695	2024-03-15 07:21:38	133.051	-34.653	9.307 days
21P0714	2024-03-06	86	-34.811	134.696	2024-03-26 11:13:43	130.676	-33.982	20.468 days
22P1150	2024-03-09	88	-32.666	133.274	2024-03-21 14:38:16	132.329	-32.133	12.610 days
21P0650	2024-03-09	90	-32.650	133.305	2024-03-16 10:31:26	131.762	-33.206	7.438 days
23P1021	2024-03-10	104	-32.203	131.917	2024-03-15 19:43:50	130.781	-31.892	5.822 days
21P1176	2024-03-11	87	-32.181	131.928	2024-03-19 03:59:41	130.999	-32.508	8.166 days
21P1181	2024-03-11	86	-32.171	131.931	2024-06-13 10:38:29	137.425	-36.831	94.485 days

Achieving targeted deployment duration was challenging and 14 of the 19 tags have now reported back. The average deployment duration was 19.5 days (range 4-94 days – see Figure 2 below). While 5 tags remain (we assume) attached to SBT, this is obviously problematic for obtaining long term data and the project will need to alter the tag programming to maximise data return.

At the time of compiling this report, a member of the public found what we suspect to be one of the deployed tags and will freight this to CSIRO. If it can be recovered, the complete detailed time-at-depth record can be downloaded and would be interesting for examining fine scale behaviour. The device has been returned to the manufacturers for interrogation and data recovery. Most of the deployments displayed westerly movements from the release to popup location (Figure 1). A longer deployment moved from the northern part of the central GAB to the east and surfaced south of Kangaroo Island (Figure 1).

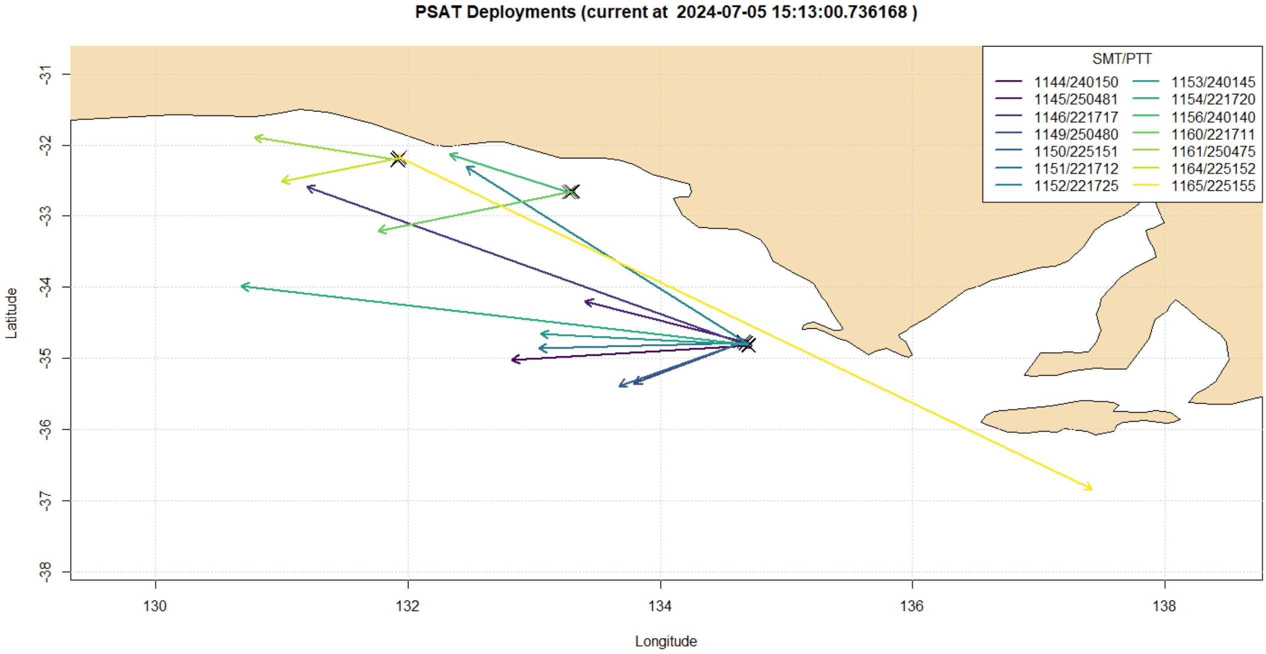


Figure 1. Movements from release to popup locations for deployments shown in Table 1.

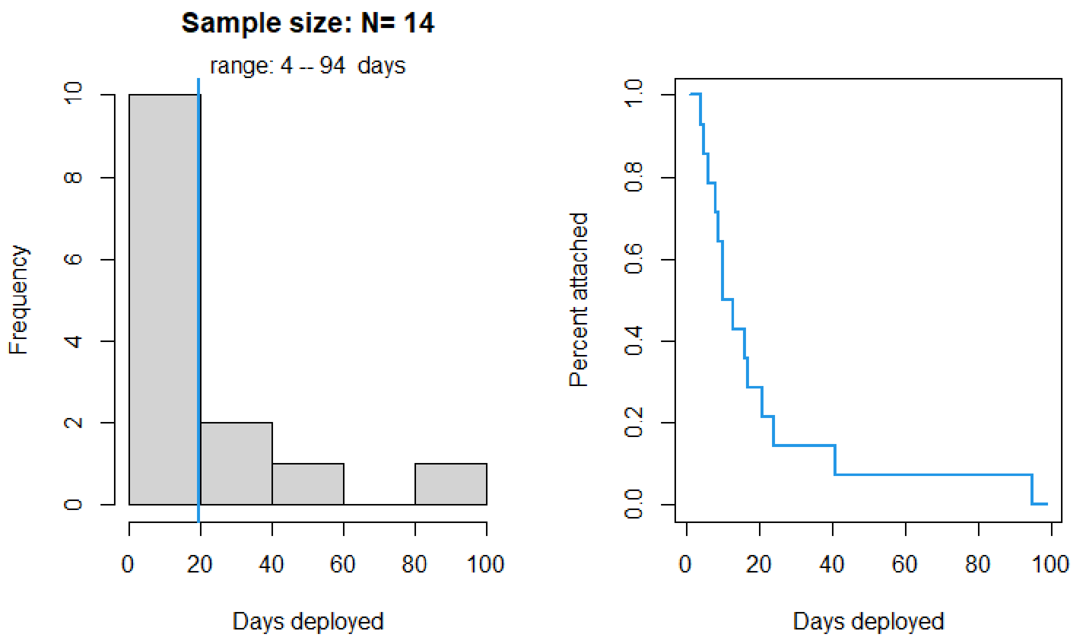


Figure 2. (left) Histogram of tag attachment duration (vertical bar shows the average attachment duration). (Right) Loss rate of tags as a function of days since deployment.

1.1 Movement paths

The geolocation models used to estimate positions indicated that tagged SBT spent a considerable proportion of time along the shelf break; however, many of these paths are derived from short data sets (Table 1).

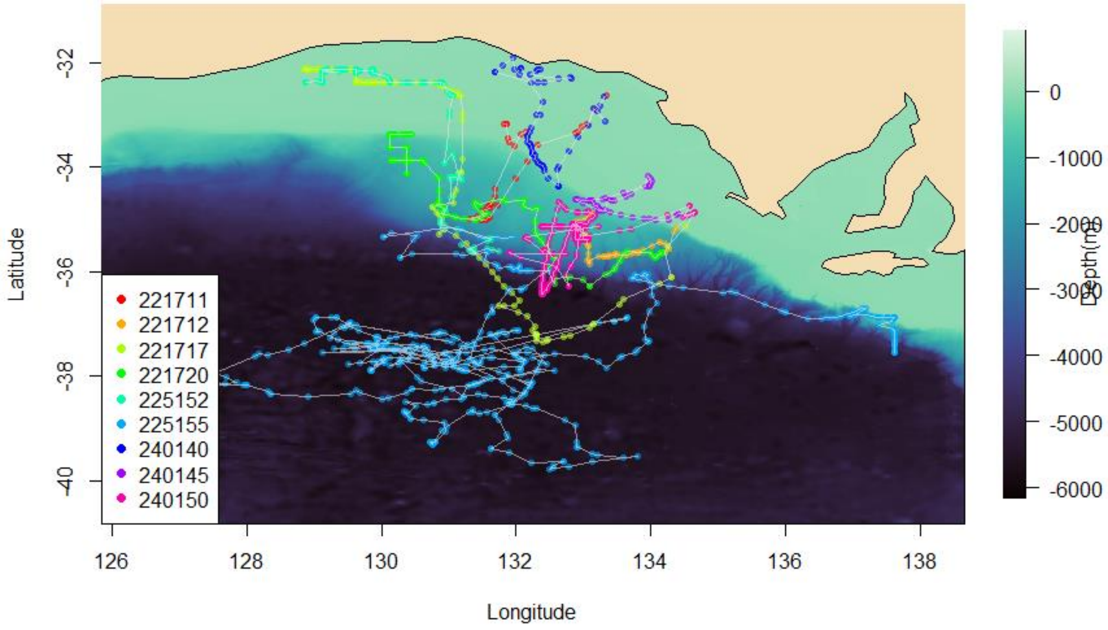


Figure 3. Estimated movement paths of tagged tuna using the Wildlife Computers GPE3 geolocation method.

Examination of the separate latitude and longitude components through time shows that most animals spent up until April within the GAB (Figure 4), largely between longitudes of 130°E and 135°E.

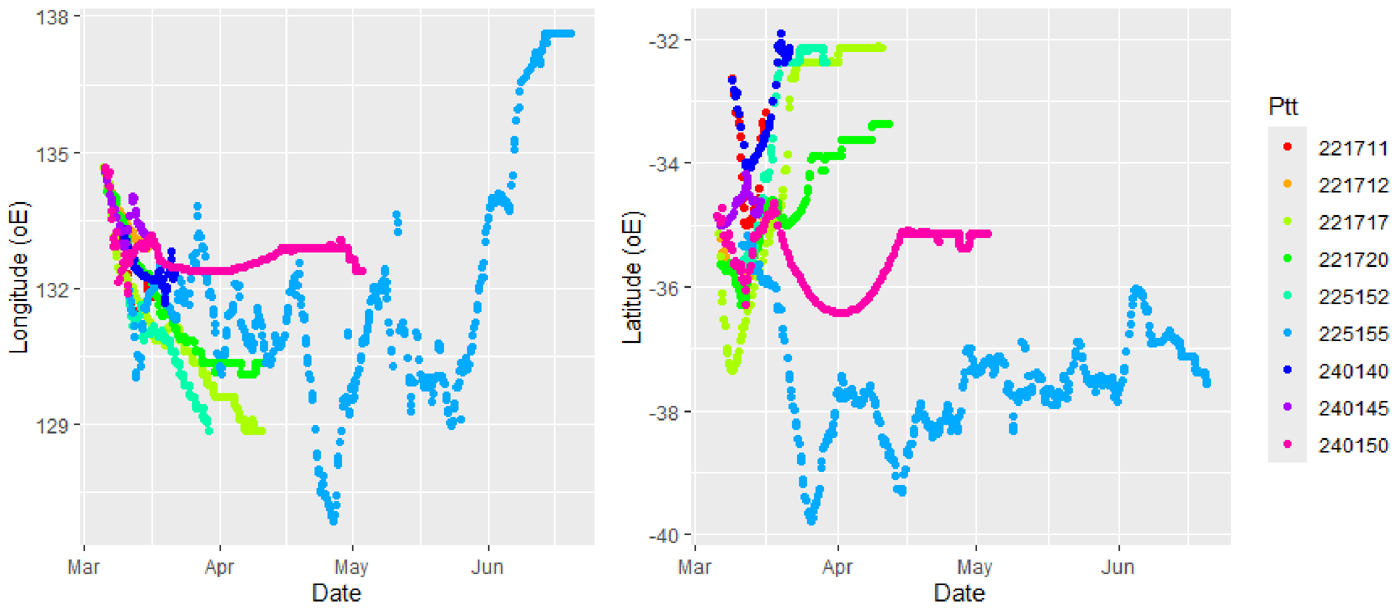


Figure 4 (Left) Longitudinal components of estimated movements through time. (Right) Latitudinal components of estimated movements through time.

1.2 Time-at-temperature and depth data

The aggregated time-at-depth data (Figure 5, left) showed considerable variability between individual SBT. However, there was a general trend (as expected) to most time being spent in waters shallower than 75 metres. Points in Figure 5 (left) for which a significant amount of time was spent below 500 m generally derives from tags where the fish died or where the tag was ingested (see below). The aggregated time-at-temperature data (Figure 5, right) showed a general preference for waters between 18 and 21°C. However, there was a higher proportion of time spent in waters between 14 and 18°C than expected. Some of this apparent preference for cooler temperatures will come from tags which sank to the bottom after mortalities, however, ongoing detailed analysis will also examine the possibility that SBT spend time in cooler water masses.

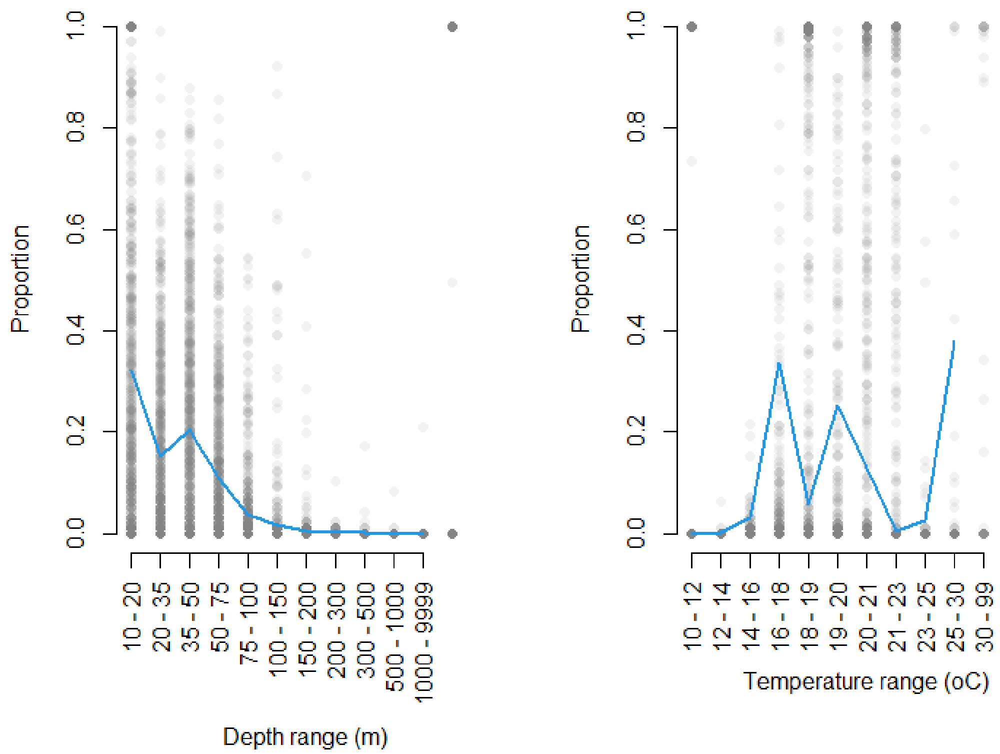


Figure 5. Aggregated time-at-depth (left) and time-at-temperature (right) data for all 14 tags which have reported to date. The grey dots show individual observations of proportion time within a depth/temperature interval. The blue lines show the average within each interval. The data at the extremes low/high ranges are from when the tags are surfacing or have dropped to the bottom. These were not used to calculate the depicted average time at depth/temperature.

The transmitted tags' depth-temperature profile (PDT) data allows for characterization of thermal conditions at depth through the water column. These data also allowed for examination of whether the tags were likely ingested by an animal. This is because, as in the situation where the tag was eaten by an animal that maintains its visceral temperature significantly above expected ambient conditions, the observed temperatures at depth become anomalously warm. However, there is no signal in the data that allows us to determine whether the tagged fish experienced predation or it was simply the tag itself that was ingested.

Several ingestions were recorded among the deployed tags. The IDs for these tags were 22P1966, 21P0695, 21P0671, 21P0739, 22P1159 and 22P1150 (see example plots in Appendix A). For each of these data sets, when the depth of the tag was in the range of hundreds of metres, the temperature remained greater than 20°C. The range of temperatures would suggest that the tags were ingested either by other tuna or by lamnid sharks, as mammalian gut temperatures would be in the mid to high 30°C range.

The PDT data also showed some obvious mortality events. These were indicated by the depth record showing fast descents to great depths, often relatively soon after the release and deployment of the tag. The pop-up tags have software mechanisms that trigger release procedures when the tag remains at depth too long (the attachment pin burns through allowing a tag to float to the surface), but in the case of tag 22P1166 there appears to have been something preventing the tag from surfacing. The PDT data shows that the tag remained at depths of between 1000 and 1200 metres for nearly a month after the tagged SBT presumably died. We can only speculate on what prevented the tag from surfacing after the death of the fish; however, it is possible that another fish or shark inhabiting deep water ingested the tag and the tag remained in its gut for an extended period.

The longest deployment among the 2024 releases was tag 21P1181, which remained attached to the SBT between tagging in March through to mid-June. The data transmitted by the popup tag shows the transition from warm coastal water up until early April, through to cooler water apparently off the shelf to the south of the GAB and then to deeper water of several 100 metres in June, at which point the tag surfaced just South of Kangaroo Island.

Previous CSIRO studies (Basson et al 2012) have detailed extended residence by three-year-old SBT in GAB. However, it would be more expected that an SBT of the size tagged in this round of satellite tag deployments would have begun a migration out of the GAB, most likely towards the Indian Ocean (based on previous movements – see Basson et al 2012). We await data from the remaining 5 tags to obtain a better picture of movement paths away from the GAB / tagging area.

1.3 Initial investigation of oceanographic trends in the GAB

The project is examining whether changes in the physical ocean state (primarily temperature at depth) is a potential driver in reductions in the apparent availability of SBT to the Australian surface fishery.

To that end, we have been investigating two data sources:

(1) Output of the BOM's ACCESS-S global coupled ocean/atmosphere model. This model, being global, has a coarse spatial scale (1 degree longitude/latitude), but provides long time series of model output. Additionally, the ACCESS-S output is provided as a monthly average. This means that while the model may be informative on decadal trends, it is unlikely to resolve temperature at a scale which is meaningful to SBT.

(2) The CSIRO fine scale forecast model, known as ROAM (Relocatable Ocean Atmosphere Model), is used for short term operational forecasts (e.g. for the Royal Australian Navy) and therefore more useful for short term (e.g. over the tag deployment period) but relatively detailed investigation of ocean conditions.

We do not present ROAM output as the project team are in the process of establishing data pipelines that will be suitable for the project needs. A preliminary model run has been initiated but this generates substantial data (e.g. ~250 GB for a 3-month model run), which requires investigation of data storage options.

1.4 Potential changes in thermal habitat

SBT has been shown to use warm surface layers to bask. This surfacing behavior makes them visible to spotter planes and surface fishery operations. The ecophysiology of SBT surfacing is not entirely clear; however, it is thought that, despite their endothermic capacity, SBT gain further energetic advantages by increased digestion rates in warm surface waters. This presumably facilitates higher rates of somatic growth as juveniles. There is potential that a deepening mixed layer would provide suitable thermal conditions for SBT to maximize digestion and growth at depths which preclude them being spotted or accessed by the Australian surface fishery.

Therefore, as an initial look at potential for long term trends in ocean conditions in the GAB, we extracted time series of temperature-at-depth from ACCESS-S for 6 locations spread across the GAB and across to the Bonny Upwelling region (Figure 6). The intent is to see whether the apparent eastward shift in SBT distributions over the season could be related to warming at depth.

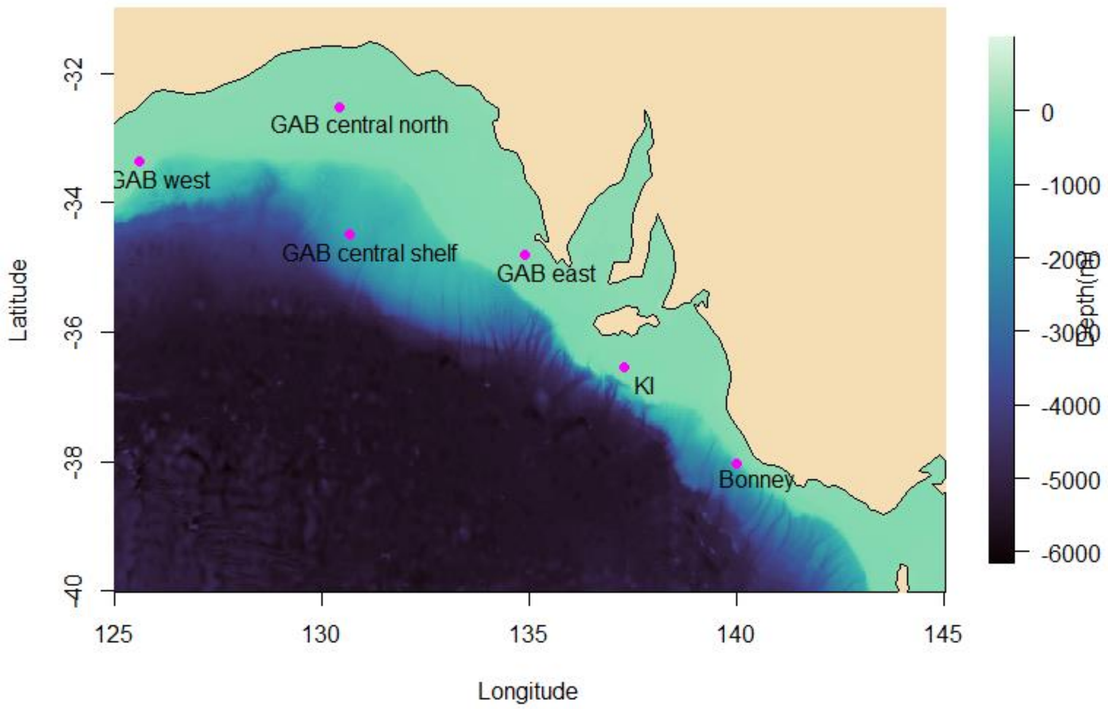


Figure 6. Map of locations where ACCESS-S temperature-at-depth data was extracted. These points were chosen based on coverage of the GAB and known areas of both fishing activity and SBT aggregations/residence.

As an initial look at potential for changes in temperatures at depth over time during the SBT season, we examined the time series of average monthly temperatures at depth from 1980 to present for each of the locations shown in Figure 6 (Figure 7). Figure 8 shows the time series data for January averaged over depth layers of 0-20m, 20-40m, 40-60m, 60-100m and 100-250m. Temperatures in the top 2-3 depth layers became warmer starting in about 2005 in all of the locations, before declining again in about 2018. While this pattern is most pronounced for January, it is present in all months of the SBT fishing season (December to March).

The horizontal dashed lines at 18.5 and 21.5°C in Figure 8 indicate the preferred temperature range of 3–4-year-old SBT based on historical archival tagging data (FRDC Project No 2018-194, Eveson et al. 2021). The warmer temperatures in the top depth layers in the period ~2005-2020 suggest that some locations which did not previously contain preferred habitat became warm enough in the top depth layers to be considered preferable (i.e., GAB central shelf above 40m, and KI above 20m), while other locations contained preferred habitat deeper than previously (e.g., GAB central north and GAB west).

In summary, this initial examination of the ACCESS-S output found average temperatures in the surface layers were greater during ~2005-2020 at the selected locations over the SBT season (December to March). Such changes over time could potentially influence preferred locations and depths at which SBT would be found. Clearly, data extracted from 6 points over a large area is a limited analysis, and further examination of both the ROAM and ACCESS-S model output will be considered as the project progresses.

The next steps are to use both historical (legacy archival tag data held by CSIRO) and current (PSAT data) to characterise depth and temperature distributions. These will be used to refine the spatial and vertical extent of habitat.

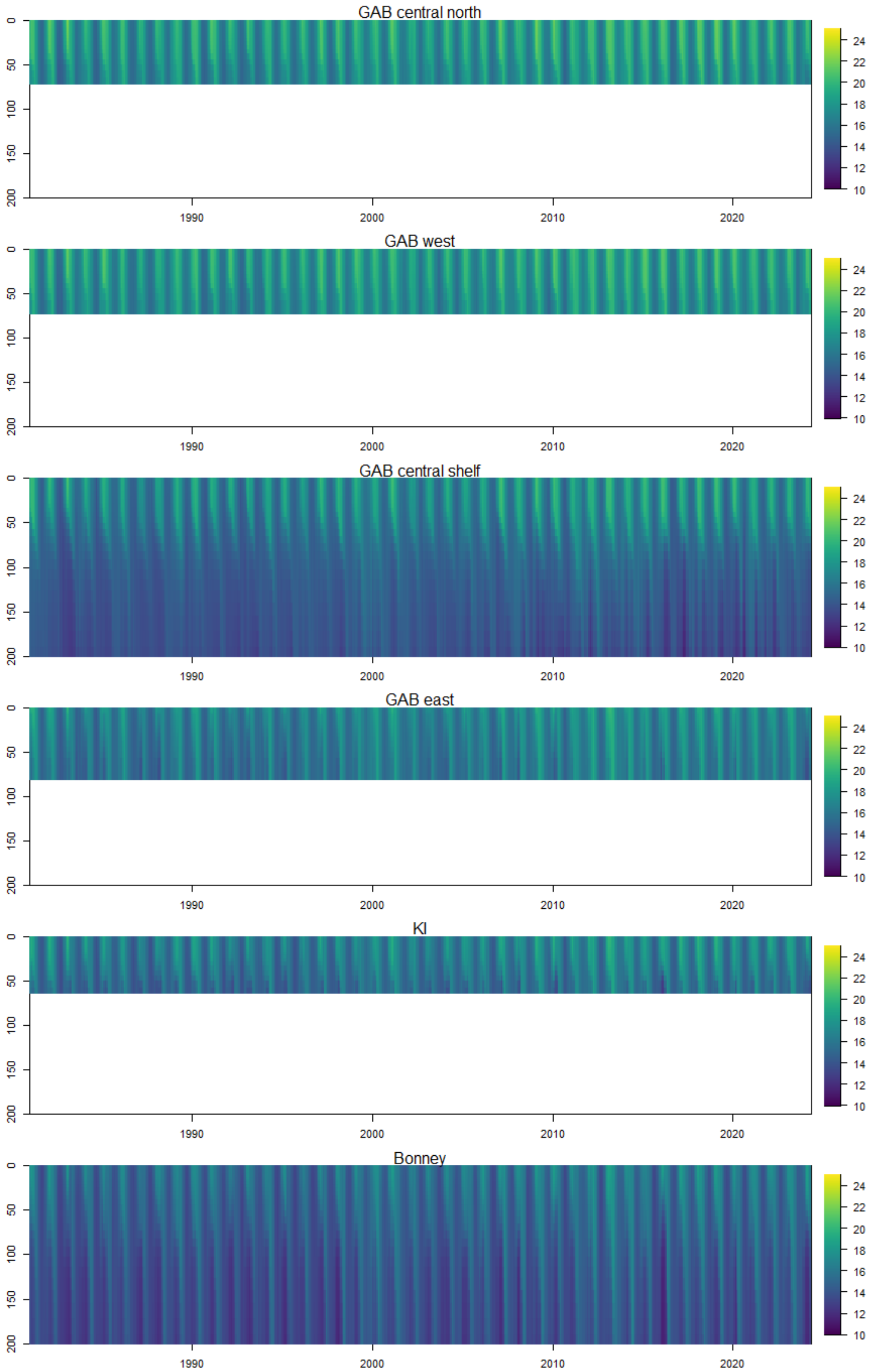


Figure 7. Temperature-at-depth time series for the locations shown in Figure 6. The bathymetry is deeper at some stations than others, but the y-axis has been set uniformly across series for cross-comparison.

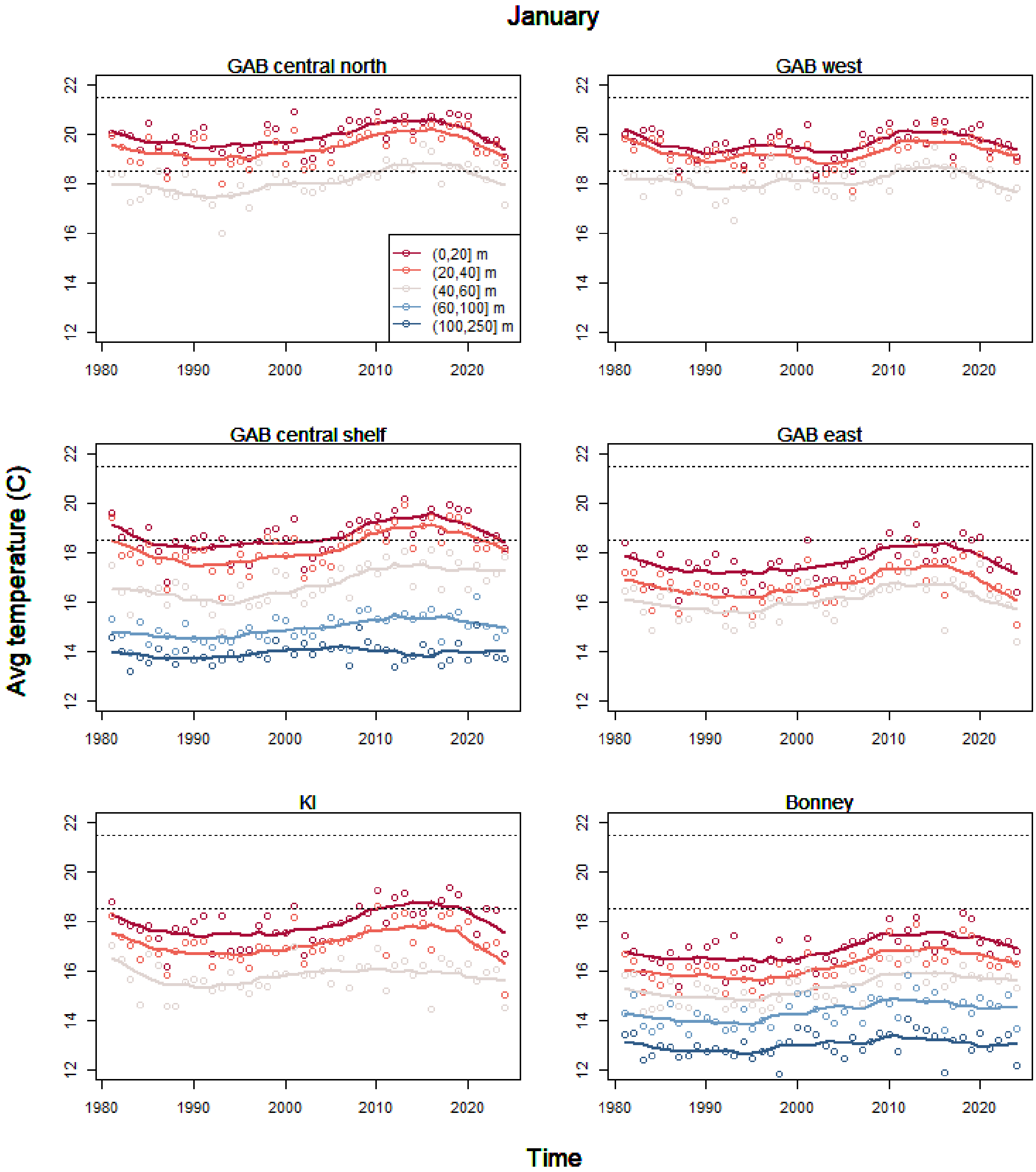


Figure 8. Average temperature at depth time series for January for the locations shown in Figure 6. The dashed horizontal lines at 18.5 and 21.5 °C indicate the preferred temperature range of 3–4-year-old SBT based on historical archival tagging data.

1.5 Research Mortality Allowance request

The project requests 0.5t RMA to cover planned deployment of ~30 Pop up tags in the 2024-25 summer season.

1.6 Conclusions

The paper provided details on recent tag deployments on SBT. At this stage, the data collection has been limited by the availability of appropriately sized SBT. Ingestion of tags, presumably by other SBT in the school, appears to be likely for several premature detachments. The next phase of deployments, based on these results obtained in 2024 will aim to program tags with the expectation of short term attachment duration and provide higher resolution of returned data during the fishing season.

1.7 References

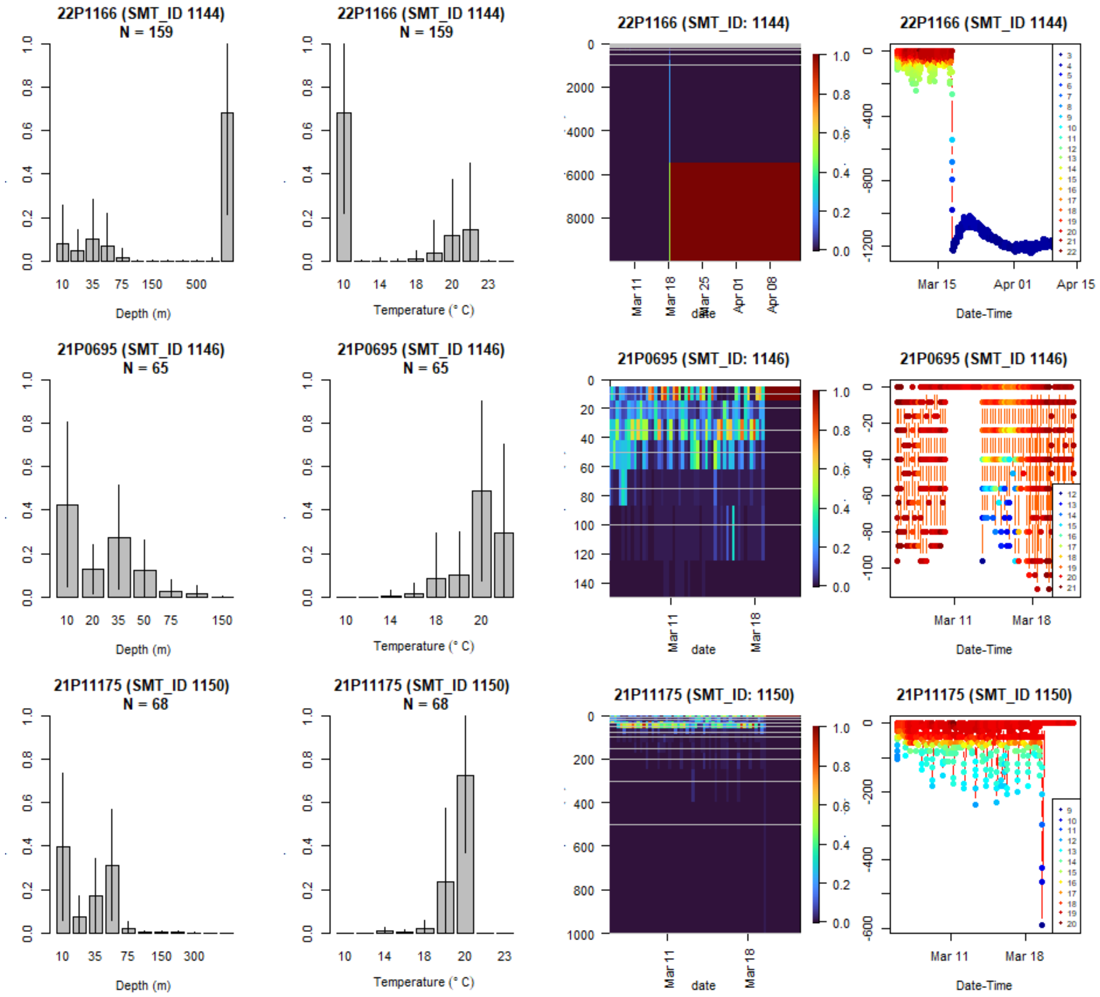
Basson M, Hobday AJ, Eveson JP, Patterson TA (2012) Spatial interactions among juvenile southern bluefin tuna at the global scale: a large-scale archival tag experiment. Final Report, FRDC Project No. 2003/002.

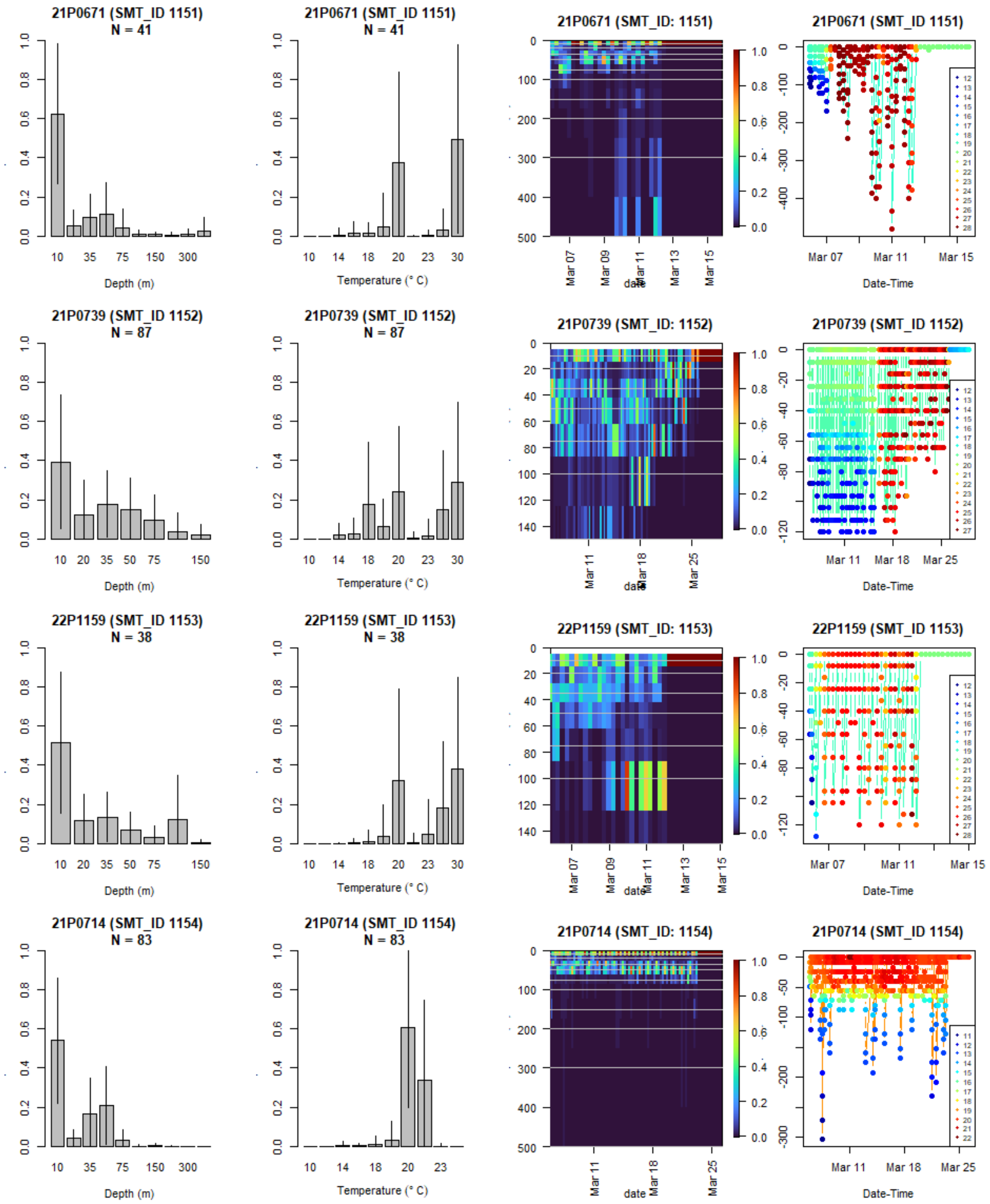
Eveson JP, Hartog JR, Spillman CM, Rough K (2021) Forecasting spatial distribution of southern bluefin tuna habitat in the Great Australian Bight – updating and improving habitat and forecast models. Final Report, FRDC Project No 2018-194.

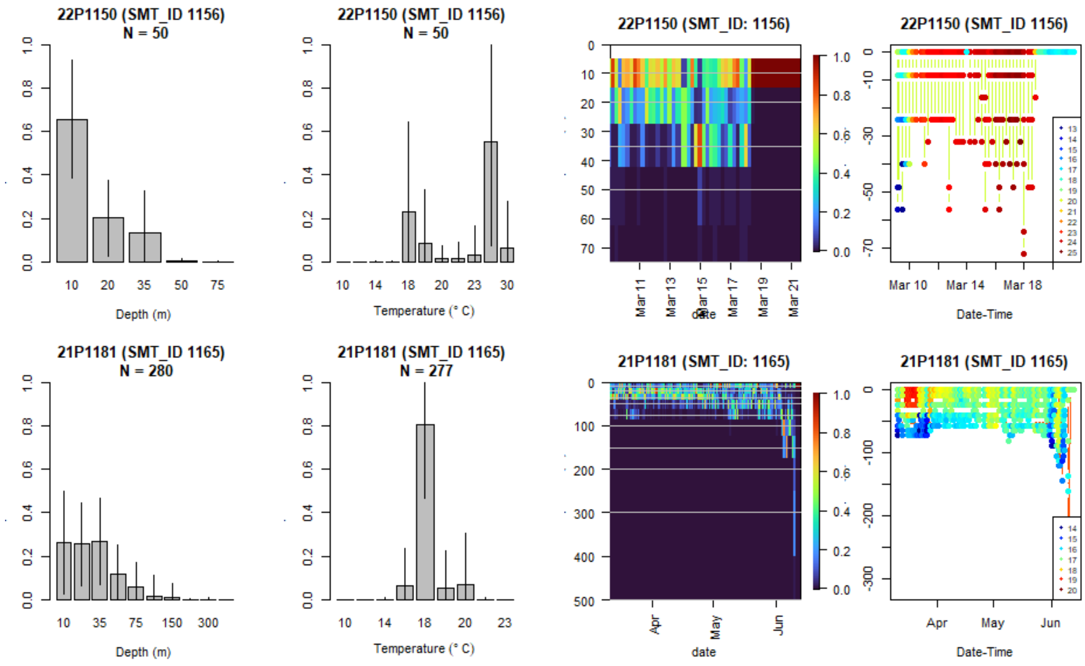
Appendix A Plots of habitat data for individual tags

The following shows individual data series for selected deployments (see Table 1 for release and recapture details). From left to right, the figures are:

- Average proportion of time at depth (bars) with standard errors (vertical bars).
- Average proportion of time at temperature (bars) with standard errors (vertical bars).
- Proportion of time spent at depth. Each vertical column of data is a histogram is a histogram of time spent at depth.
- Depth-temperature profiles through time. The tag dynamically selects a set of depth points spanning the range of the data collected over the histogram period (we used 6-hour time intervals). At each depth point, it calculates the minimum and maximum temperature recorded over the 6-hour interval and transmits this as an indicator of the thermal structure of the water column selected by the tuna.




21P0671 (SMT_ID 1151)
N = 41
Depth (m)
Temperature (° C)
21P0671 (SMT_ID: 1151)
date
Date-Time
21P0739 (SMT_ID 1152)
N = 87
21P0739 (SMT_ID: 1152)
22P1159 (SMT_ID 1153)
N = 38
22P1159 (SMT_ID: 1153)
21P0714 (SMT_ID 1154)
N = 83
21P0714 (SMT_ID: 1154)


22P1150 (SMT_ID 1156)
N = 50
Depth (m)
22P1150 (SMT_ID 1156)
N = 50
Temperature (° C)
22P1150 (SMT_ID: 1156)
date
22P1150 (SMT_ID 1156)
Date-Time
21P1181 (SMT_ID 1165)
N = 280
Depth (m)
21P1181 (SMT_ID 1165)
N = 277
Temperature (° C)
21P1181 (SMT_ID: 1165)
date
21P1181 (SMT_ID 1165)
Date-Time

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