SCIENTIFIC COMMITTEE
SECOND REGULAR SESSION

7-18 August 2006
Manila, Philippines

MEASURING EFFECTIVE LONGLINE EFFORT IN THE AUSTRALIAN EASTERN TUNA AND BILLFISH FISHERY

WCPFC-SC2-2006/FT WP-2

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July 2006

1. Introduction

Understanding the relationship between catch rates and resource availability is of critical importance to both stock assessments and the sustainable management of fisheries. However, catch rates are influenced by a multitude of factors apart from resource availability and so interpreting changes in catch rates remains problematic. For example, catch rates are highly dependent on the operational and gear setting practices associated with the targeting of different species, whilst the performance of longline gears is also influenced by changes in prevailing oceanographic conditions (Mohri and Yasuaki 1997, Yano et al 1998, Mizuno et al 1999). However, without a detailed knowledge on how all these factors influence the effective effort directed at particular species, it is not possible to account for the influence of these factors on catch rates. In turn, this makes it difficult to interpret changes in catch rates as changes in resource availability and as such severely limits our ability to assess the impact of the fishery on the underlying resource.

In order to overcome this problem, CSIRO is presently undertaking a project which aims to collect and analyse the data on a number of factors which influence the operational effectiveness of longline fishing gears to help improve the interpretation of catch rates as indices of resource availability and help address a number of other related issues pertinent of the successful management of the Australian Eastern Tuna and Billfish Fishery (ETBF). In particular, the following four issues highlight the need to better understand the relationship between catch rates and resource availability within the ETBF.

1. The need to develop indicators of resource availability off eastern Australia
Current stock assessments for the principal tuna species in the WCPO still remain uncertain, and uncertainties in the spatial distribution of both the resource and recruitment patterns makes it difficult to infer from these assessments the status of the resource in a limited region such as off eastern Australia. In order to provide an understanding of the impact of the ETBF on the fish resources which occur off eastern Australia, the Resource Assessment Group for the ETBF has identified as a high priority the need to develop a number of performance indicators for monitoring the status of these resources. These indicators are to be based on the monitoring of temporal and spatial changes in catch rates (and the sizes of fish caught) which, in turn, will require gaining a better understanding of the factors, apart from resource availability, which influence catch rates.

2. The need to improve the data and methods used to standardise catch rates.
To improve our understanding of those factors which influence catch rates, information needs to be collected on a range of operational factors which influence the effectiveness of longline fishery gears. These factors include targeting and gear setting practices, resulting hook depths, depth preferences of the target species, time-of-capture, and prevailing

oceanographic conditions. Furthermore, an understanding of these relationships is crucial if one is to make use of the new habitat-based models which have been developed to standardise longline catch rates.

3. The need to avoid the incidental capture of important bycatch species.
Information on the fishing characteristics of longline gears in the ETBF are also needed to help address the real or perceived threat that longlining has to threatened and endangered species. An improved understanding of the factors influencing the configuration of longline fishing gears and resulting catch rates will help identify fishing practices which may be used to avoid the incidental capture of important bycatch species, such as turtles and other threatened and endangered species (Polavina et al 2003). This will be similar to the observer-based research carried out in the mid-1990s in the Coral Sea to help identify methods to avoid the capture of black marlin (Campbell et al 1997).

4. The need to improve indicators of stock status in the WCPO.
Improvements in regional stock assessments are needed to assist managers of the ETBF gain a better understanding of the status of the stocks on which the ETBF depends. While several factors contribute to the uncertainties in the WCPO assessments, improvements in the construction of indices of stock biomass based on the analysis of longline catch-per-unit-effort were identified by the Standing Committee on Tuna and Billfish as a critical factor and a high priority for further research (SCTB 2003). The availability of accurate indices of stock biomass will also a critical input for the development of assessment models for those pelagic resources (such as swordfish and striped marlin) which have a more regional SW Pacific stock structure.

While methods to standardise fishing effort to account for those factors which influence catch rates have been developed and are routinely used as part of stock assessments world-wide, in most instances the success of this exercise is limited by the absence of data on many of these factors. This is particularly the case in a multi-species fishery such as the ETBF, where one needs to know not only whether there have been changes in the effectiveness of fishing gears, but whether there have been changes in the effective targeting of particular species. However, a number of recent developments have greatly improved the ability to collect and analyse the data required to characterise the effectiveness of longline effort in the ETBF:

- i) First, an observer program commenced in July 2003 within the ETBF and provides an ongoing ability to collect verified catch and effort data and other at-sea data (such as information on fishing practices) which until now has not available.
- ii) Second, there have recently been promising advances in the statistical integration of fisher behaviour (their targeting practices and effective depths of longline sets) with data from archival and pop-up tags on fish habitat preferences to standardize longline effort (Hinton and Nakano 1996, Bigelow, et al 2002, 2003). Put simply, these methods examine the effective fishing depths of longline hooks relative to the water mass, depth, temperature, oxygen etc preferences of the fish they are targeting to standardize the effort unit. However, the approach requires detailed information on the depth distributions of both the hooks fished by longlines and the different species which are caught, and application of this approach is presenting constrained by the lack of such data.
- iii) Finally, recent advances and use of archival tags (such as the ongoing work on bigeye in the Coral Sea), together with the integration of remotely sensed data and ocean-

circulation models, are greatly assisting in our ability to map the spatial habitat of target species.

Given the above needs and recent developments, the present project was developed to help achieve the following specific objectives:

1. Determine the depths attained by longline fishing gears deployed in the ETBF and investigation of the relationships between targeting and gear setting practices and hook depths and longline shape characteristics.
2. Investigate the relationships between hook depth and the capture depths and associated water temperatures for the principal species caught by longline gears in the ETBF.
3. Investigation of the time-of-capture of the principal catch species caught by longline gears in the ETBF.
4. Investigate, and where necessary refine, of the technical assumptions used in the habitat based models being used to standardise longline catch per unit effort in the WCPO.
5. Develop a habitat based method for standardizing longline catch rates and application to the ETBF.
6. Investigate the relationships between longline fishing practices, gear configurations and the incidental capture of bycatch and byproduct species in the ETBF.
7. Determinate the adequacy of information currently recorded in vessel logbooks for standardisation of longline CPUE and, where necessary, recommended changes.

The project commenced in mid 2005 and is scheduled to run for two years. During its first year the project has concentrated on the deployments of monitors for ascertaining the depths attained by longline gears deployed in the ETBF and the time that dish are caught on the hooks. This working paper outlines the work completed to date and provides a brief summary of the data collected. The full results of the project will be reported to the Scientific Committee in 2007.

2. Monitoring Completed To-Date

Twenty-six Star-Oddi DST Cent-ex Temperature-Depth data loggers (TDRs) and 250 Lindgren-Pitman HT-600 Hook Timers (HTs) were purchased in mid-2004 and deployment of these gear monitors by ETBF observers commenced in late August 2004 and has continued since. The gear monitors have been divided into two batches so that two observers can be deploying them at ant one time. An instruction manual on how to best deploy the gears, including additional observer forms for recording information associated with the deployment of the TDRs and HTs, has been produced..

A listing of observer trips during which the gear monitors have been deployed is provided in Table 1. To date 43 trips have been undertaken. Of the 266 sets deployed on these trips, TDRs have been deployed during 196 sets and HTs deployed during 166 sets (note: HTs are not deployed in rough seas as they get tangled in the mainline). Up to 12 TDRs have been deployed during any single set and, to date, data from 1575 TDR-deployments has been collected.

Despite the amount of data collected, a number of problems have been encountered during the deployment of the gear monitors, particularly the TDRs. While several of the TDRs have been lost many TDRs have subsequently failed and have had to be returned to the manufacturer for testing and replacement resulting in considerable delays. An additional 10 TDRs were purchased in mid-2005, however, most of these were found to be faulty and had to be returned to the manufacturer for replacement. However, with replacement TDRs and the purchase of additional units it is hoped that the coverage rate can be increased over the next 12 months.

Of the thousands of HTs which have been deployed, to date 595 have been triggered, with 319 of these being associated with the catch of a fish (note, HTs often are retrieved in a triggered state believed due to either the fish escaping from the hook or the fish taking the bait but not being hooked). Around one-third of the HTs have been lost or failed and a further 100 were purchased in mid-2005 to replace these and to provide back-up as required.

To date, all observed trips deploying the gear monitors have commenced from the port of Mooloolaba. This is despite one set of gear monitors being re-deployed in early 2006 to an observer undertaking trips off southern NSW. However, due to a combination of bad weather, a general lack of fishing due to the low availability of fish, and the fact that few vessels now remain fishing in this region no observer trips were undertaken. Given the small number of vessels which now remain fishing in both the southern and northern sector of the fishery (eg operating out of Cairns) it is considered prudent to continue to deploy the gear monitors on vessels operating out of the ports in the central (eg Mooloolaba) region for the remainder of the project.

All data collected by the project to-date has been stored in the ORACLE database maintained by CSIRO in Hobart. The number of individual temperature-depth records stored in the database is presently 671,571. In order to relate the data collected by the TDRs and HTs to the extensive data relating to fishing operation and catch for each set recorded by AFMA observers, a complete copy of data collected by all observers deployed on ETBF longline vessels has been obtained from AFMA. As there is a time-lag between the receipt of TDR data (which is sent directly to CSIRO after each trip) and AFMA observer data, at present these two data sets have been linked for only 123 of the 196 TDR sets.

3. Initial summary of TDR-data

The spatial distribution of monitored sets (for those sets which presently have been linked to the observer logbook data) is shown in Figure 1. The coverage is seen to be reasonably good across this main fishing area.

A FORTRAN program have been written to analyses the TDR data to identify the following periods during the total time each TDR is underwater:

a) period the TDR takes to sink to its initial fishing depth,
b) period the TDR takes to be hauled.
c) period the TDR is fishing (i.e. not sinking or being hauled)

The average depth and temperature for each TDR were then calculated for the period the TDR was fishing and together with additional information relating to each TDR deployment has been stored in the ORACLE database.

Depth and Temperature profiles based on the TDR data from all sets are shown in Figures 2a and 2b. The four profiles shown are based on the total observations recorded during different six monthly sampling periods. The pre-2006 depth profiles display a similar pattern with nearly all hooks fishing above 120m, whilst the 2006 profile indicates some hooks are spending a significant proportion of their time fishing at depths down to 300m or more (with the deepest recorded depth being 397m). This change is related to the increased targeting of albacore tuna by vessels in the fishery and the concomitant setting of deeper longlines. On the other hand, the four seasonal temperature profiles display quite dis-similar patterns, with the hooks fishing in relatively higher temperatures during the first half of 2005.

Observers record the primary target species for each set. Again, by linking the TDR data to the data recorded by the observer for each set, it is possible to compare the depth profile of hooks across each target species. These profiles are shown in Figure 3. The profile for yellowfin tuna shows a strong unimodal distribution with hooks spending, on average, 90% of their time between 20 and 70 meters. Hooks targeting bigeye tuna and broadbill swordfish display similar unimodal distributions, with hooks spending 90% of their time between 20-80m and 30-100m respectively. Alternatively, hooks targeting albacore tuna display a significantly different and much flatter distribution, with hooks spending 90% of their time between 50 and 270m.

Historically, Japanese longliners changed the number of hook-between-floats in order to change the depth profile of the hooks whilst fishing. Generally, deeper depths were reached by setting more hooks-between-floats and this fact underlines attempts to standardize longline CPUE data. The practice of deploying different number of hooks-between-floats has also been used by the ETBF longline fleet, but given the variation in other factors influencing the deployment of the gears a good understanding between depths fished and the hooks-between-float configuration of the longline has been missing for this fleet. Using the data collected during this project, the depth profile of hooks stratified by the number of hooks-between-floats is shown in Figure 4. The profiles for those configurations using 6 to 11 hooks-between-floats are seen to be quite similar indicating that the depths fished by these hooks must be dependent upon other factors apart from the number of hooks-between-floats. On the other hand, the depth profiles of hooks when 25 and 30 hooks-between-floats are deployed do show the expected increase in depth profile, with the latter reaching depths in excess of 300m.

The data recorded by observers during the deployment of the longline for each set is being used to ascertain a list of factors which may influence the depths attained by the fishing gear after being deployed. These factors include:

1) Float-line length
2) Snood-line length
3) Number of hooks-between-floats
4) Distance between branchlines
5) Vessel setting speed
6) Whether a line-shooter is used
7) Tension in mainline
8) Primary and secondary species targeted

Histograms of the range of settings for each of these factors used for the 123 sets for which observer data is currently available are shown in Figures 5. A statistical analysis to ascertain the relationship between each of these factors and the depths attained by the gear (as recorded by the TDRs) will be carried out over the next year. The list of factors to be included in this analysis will be expanded to include environmental conditions during the set.

For each shot during Trip 38 the mean depth recorded by each TDR whilst each hook was fishing versus the position of the hook (hook number past the float) that the TDR was attached to is shown in Figure 6a. For all shots during this trip 8 hooks were deployed between the floats. For any given shot, the range of mean depths varies between 20m for shot 2 to 52m for shot 3, whilst the range of mean depths for any given hook position varies between 2m for the two TDRs at hook-position 5 during shot 4 to 30m for the three TDRs at hook-position 7 during shot 5. Across all sets and hook-positions the mean hook depths range between 25 and 100 meters. Whilst it is difficult to discern a pattern in the mean depths versus hook-position for any individual set, there is a general catenary pattern (as suggested theoretically) when the data is aggregated across all sets (Figure 6b). The observer logbook data for this trip is not yet available and so a complete analysis of the factors influencing hook depths is still to be undertaken.

The mean depths recorded by the TDRs deployed during Trip 27 are shown in Figure7. Unlike the previous result described above, for all shots during this trip albacore tuna was the primary target species and 30 hooks were deployed between the floats. The depths attained are significantly greater than previously, with the mean hook depths ranging between 54 and 332 meters across all sets and hook-positions. Again, there is a considerable range of depths observed for any particular hook-position within a shot, with the nine TDRs at hook-position 15 displaying a 141m range during shot 1. Across all sets, again there does appear to be an increase in mean depth as the hook-position shifts towards the centre of the basket, though the 300m mean depth recorded by a single TDR at hook-position 5 is close to the deepest depths attained by hooks in the middle at hook-position 15. The observer records for this trip indicate that for all sets the tension in the mainline upon deployment was slack, with the vessel speed during deployment being between 6.0-6.4 knots and the line-shooter speed around 4.6 m/s. Weather conditions varied between 1 and 3 on the Beaufort Scale with the sea-swell between 0.2 and 0.8 meters.

Unlike the previous two results, which both indicate an increase in mean depths fished as the hook position shifts towards the centre of the basket, the results for Trip 37 display no overall relationship between mean depths and hook-position (cf. Figure 8). For all shots during this trip yellowfin tuna and broadbill swordfish were the primary and secondary target species and only 6 hooks were deployed between the floats. Whilst the range of mean depths (27-103m) is similar to that observed during Trip 38, it is possible that the lack of variation in mean depth with hook position is due to the prevailing environmental conditions. The observer records indicate conditions being windy (up to 4 on the Beaufort scale) with the sea-swell around 1.0 meter for all shots. The greater swell, combined with the relatively shallow setting of the hooks, may result in the line being keep taught subsequently keeping all hooks at a similar depth range.

4. Initial summary of Hook-Timer Data

For the 43 trips listed in Table 1, hook-timers (HTs) have been deployed on 166 sets. Upon retrieval of the fishing gears, 595 HTs have been recorded as having been triggered of which a fish has been recorded on the attached hook for 319. A listing of all species caught and the associated life-status profile upon retrieval for each species is given in Table 2.

The profile of the number of fish caught versus elapsed time (number of hours between HT being triggered and retrieval) for those fish caught on a line with a hook-timed is shown in Figure 9a. Subtracting the elapsed time from the time-of-day that the HT is retrieved gives the time-of-day that the HT was triggered (which is assumed to have occurred when the fish took the bait and was hooked). Based on this calculation, the profile of the number of fish caught versus time-of the day for those fish caught on a line with a hook-timer is shown in Figure 9b. This indicates that most of the fish have been caught during the evening hours.

The profile of the time-of-day that fish are observed caught will be influenced by the profile of the hours of the day that the longline gears are deployed. For example, if there is a preference to soak the gears during the night then it is not surprising that there is a greater tendency for more fish to be caught during this period of the day. Using the times that the first and last hooks are set and the times that the first and last hooks are hauled, as recorded by the observer onboard, it is possible to calculate the profile of the hours during the day that the gear is deployed for each set. For those sets for which the observer data was available, the overall profile of the hours of the day that the gears were in the water was calculated and is shown in Figure 10a. The result indicates a large preference for soaking the fishing gears during night hours such that there is a significant decrease in the proportion of the 24-hour period that the gears are deployed during the day. Adjusting the profile of the bite-times of fish caught to account for these differences in the proportion of each hour-of-the day that the gears are deployed, should provide an more accurate profile of the time-of-the –day that fish are likely to be caught. This adjusted profile (together with the observed profile) is shown in Figure 10b. Unlike the previous result, this adjusted profile indicates that most fish are caught during the afternoon period.

Similar results to that described in the previous section can be obtained using the hook-timer data for individual species. The results for eight species are shown in Figure 11 and indicate a number of different behaviours for different species. For example, both yellowfin tuna and dolphin fish have a high propensity to the caught during the afternoon, while both swordfish and bigeye are most likely caught during the night. However, these results still need to take into account differences in the depth profiles of the species and the fishing gears. The former will be obtained from archival data whilst the latter are being obtained from the TDR data as described in the previous section.

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Table 1. Summary of observer trips deploying TDR and HT gear monitors in the ETBF.

Trip Number	OBS Voyage_ID	Vessel	Depart	Return	Total Sets	TDR Sets	TDRs Loaded	HookTimer Sets	HTs Triggered
1	595	Rahi Aroha	23-Aug-04	03-Sep-04	5	0	0	4	14
2	598	Samurai	04-Sep-04	08-Sep-04	4	0	0	4	18
3	600	Moon Shadow	16-Sep-04	05-Oct-04	12	0	0	7	14
4	599	Demi Maddison	15-Sep-04	20-Sep-04	4	4	51	4	29
5	601	Ocean Wanderer	19-Sep-04	07-Oct-04	10	10	109	10	47
6	602	Demi Maddison	22-Sep-04	26-Sep-04	3	3	39	3	8
7	633	Esbjorn	15-Oct-04	05-Nov-04	12	9	102	0	0
8	621	Sarah J	23-Oct-04	09-Nov-04	8	8	88	7	31
9	620	Ocean Dawn	18-Nov-04	24-Nov-04	2	1	11	2	9
10	650	Malibu	25-Nov-04	07-Dec-04	9	4	44	7	21
11	618	Ocean Dawn	25-Nov-04	07-Dec-04	6	6	60	4	12
12	613	Seeker	15-Dec-04	21-Dec-04	5	0	0	0	0
13	603	Fortuna II	27-Dec-04	06-Jan-05	7	7	62	0	0
14	605	Demi Maddison	16-Jan-05	17-Jan-05	1	1	0	1	7
15	607	Demi Maddison	20-Jan-05	23-Jan-05	4	0	0	4	17
16	608	Demi Maddison	29-Jan-05	06-Feb-05	4	0	0	4	13
17	664	Megan M	10-Mar-05	17-Mar-05	3	0	0	0	0
18	672	Fortuna II	26-Mar-05	03-Apr-05	8	8	50	8	22
19	710	Samurai	12-Apr-05	19-Apr-05	6	4	21	0	0
20	701	Ocean Wanderer	16-Apr-05	25-Apr-05	6	6	43	6	11
21	703	Blue Mistress	22-Apr-05	30-Apr-05	6	6	0	0	0
22	702	Ocean Wanderer	26-Apr-05	03-May-05	4	4	17	3	6
23	818	Malibu	12-Jun-05	22-Jun-05	6	0	0	4	15
24	815	Blue Moves	10-Aug-05	21-Aug-05	6	0	0	6	18
25	877	Ocean Wanderer	08-Aug-05	25-Aug-05	11	11	74	9	42
26	0	Ocean Odyssey	08-Sep-05	28-Sep-05	11	11	99	10	16
27	829	Mutiara II	23-Sep-05	27-Sep-05	5	5	45	0	0
28	836	Ocean Wanderer	10-Oct-05	25-Oct-05	12	12	108	10	19
29	839	Ocean Wanderer	09-Nov-05	14-Nov-05	3	2	24	2	3
30	840	Seeker	14-Nov-05	17-Nov-05	1	1	12	1	2
31	841	Seeker	19-Nov-05	27-Nov-05	5	5	60	5	22
32	851	Mutiara II	13-Nov-05	26-Nov-05	6	1	5	0	0
33	838	Ocean Dawn	30-Nov-05	13-Dec-05	7	6	70	5	14
34	842	Ocean Dawn	14-Dec-05	22-Dec-05	3	2	22	2	5
35	0	Blue Moves	08-Dec-05	13-Dec-05	6	6	38	0	0
36	0	Blue Moves	16-Dec-05	20-Dec-05	6	6	30	0	0
37	859	Ocean Dawn	05-Jan-06	22-Jan-06	4	4	44	3	10
38	0	Samurai	10-Jan-06	15-Jan-06	6	6	36	0	0
39	0	Samurai	20-Jan-06	25-Jan-06	5	3	18	3	5
40	0	Papanui	31-Jan-06	22-Feb-06	14	14	84	10	22
41	0	Esbjorn	12-Apr-06	19-Apr-06	2	2	12	0	0
42	0	Esbjorn	22-Apr-06	10-May-06	12	12	68	12	96
43	0	Blue Moves	19-May-06	26-May-06	6	6	29	6	27
TOTAL					266	196	1575	166	595

Table 2. Listing of all species caught and the associated life-status profile upon retrieval for each species caught on lines with an attached hook-timer.

			Life-Status					
Species Code	Species Name	Number	0	1	2	3	4	5
UNK	Unknown	276	272	0	0	1	0	3
SWO	Swordfish	51	3	5	19	8	8	8
ALB	Albacore Tuna	96	3	55	22	5	6	5
MLS	Striped Marlin	8	0	0	0	0	1	7
DOL	Dolphin Fish	24	0	0	0	0	2	22
YFT	Yellowfin Tuna	63	6	13	5	6	9	24
BET	Bigeye Tuna	14	3	2	2	0	2	5
LEC	Black Oilfish	21	2	0	2	3	7	7
BSH	Blue Shark	7	0	0	0	0	1	6
MOP	Sunfish	5	1	0	0	0	2	2
SKJ	Tiger Shark	7	0	7	0	0	0	0
ALX	Longnosed Lancetfish	4	1	0	1	1	1	0
KAW	Eastern Little Tuna	2	0	2	0	0	0	0
DUS	Dusky Shark	2	0	0	0	0	0	2
WAH	Wahoo	2	0	0	2	0	0	0
CEO	Rudderfish	2	1	0	0	0	0	1
PTH	Pelagic Thresher	2	1	0	0	0	0	1
BRO	Bronzed Whaler Shark	1	0	0	0	1	0	0
ALV	Thresher Shark	1	0	1	0	0	0	0
BLM	Black Marlin	1	0	1	0	0	0	0
BLZ	Blue Marlin	1	0	0	1	0	0	0
OCS	Oceanic Whiteip Shark	1	0	0	0	0	0	1
TIG	Tiger Shark	1	1	0	0	0	0	0
MOO	Moonfish	1	0	0	1	0	0	0
LAG	Opah	1	0	0	0	0	1	0
SMA	Shortfin Mako Shark	1	0	0	0	0	1	0
Total		595	294	86	55	25	41	94

Figure 1. Map showing the locations of longline sets on which TDRs have been deployed.

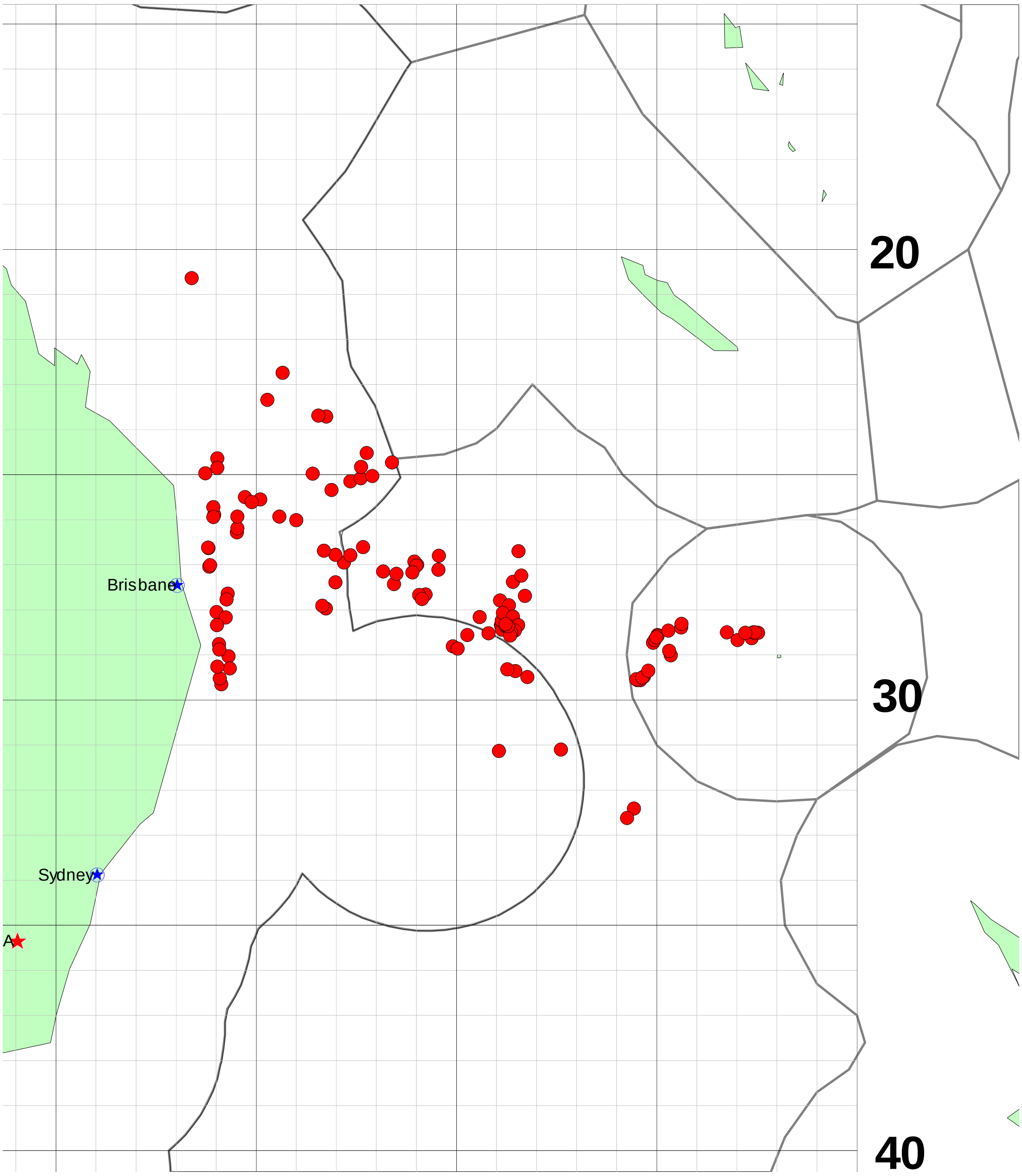


Figure 2a. Profile of fishing depths attained by hooks recorded by TDRs for all sets monitored during each six month period of the year shown (1=Jan-Jun, 2=July-Dec).

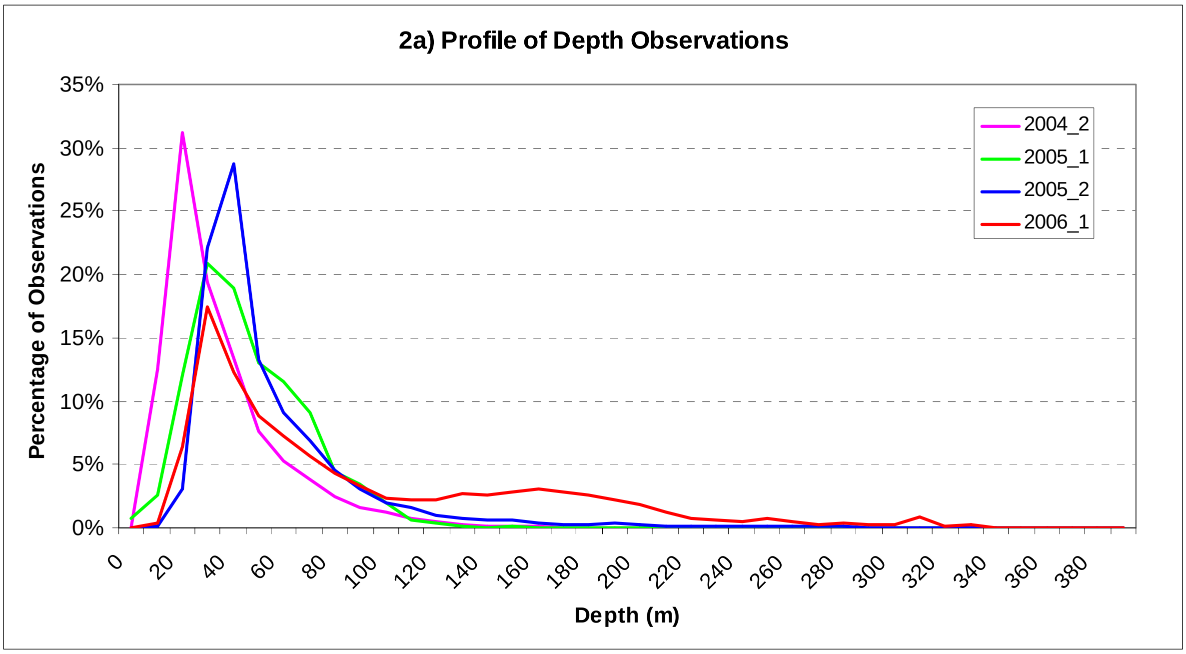


Figure 2b. Profile of the water temperatures fished by hooks recorded by TDRs for all sets monitored during each six month period of the year shown (1=Jan-Jun, 2=July-Dec).

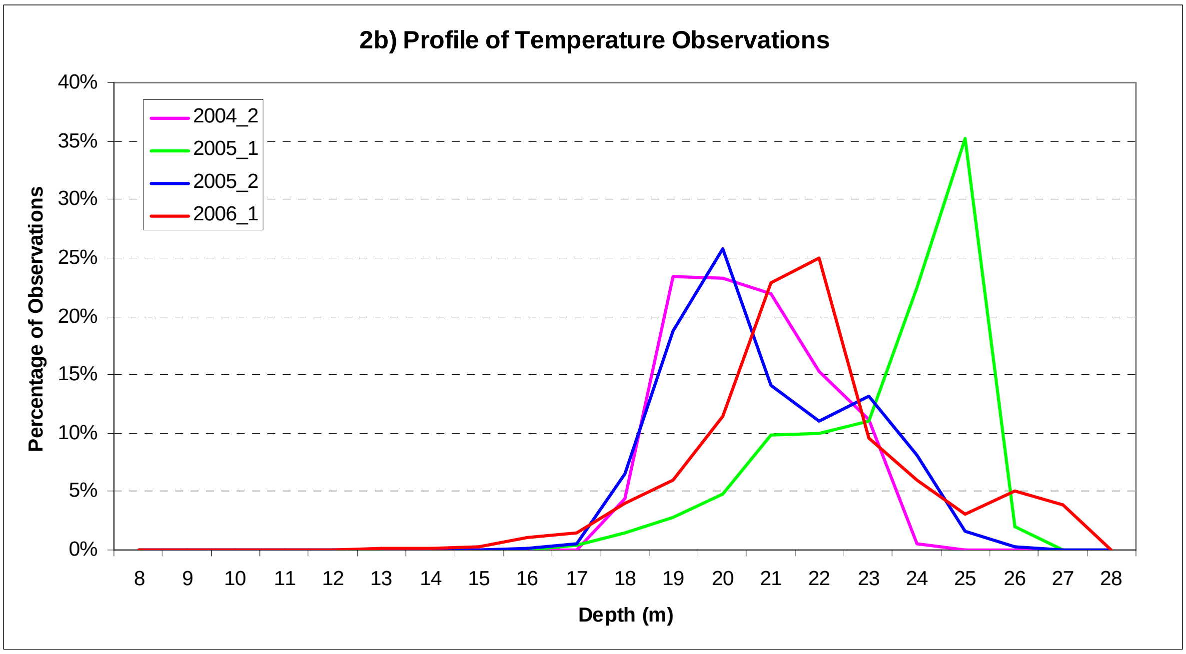


Figure 3. Profile of fishing depths attained by hooks recorded by TDRs stratified by the primary target species recorded by the observer.

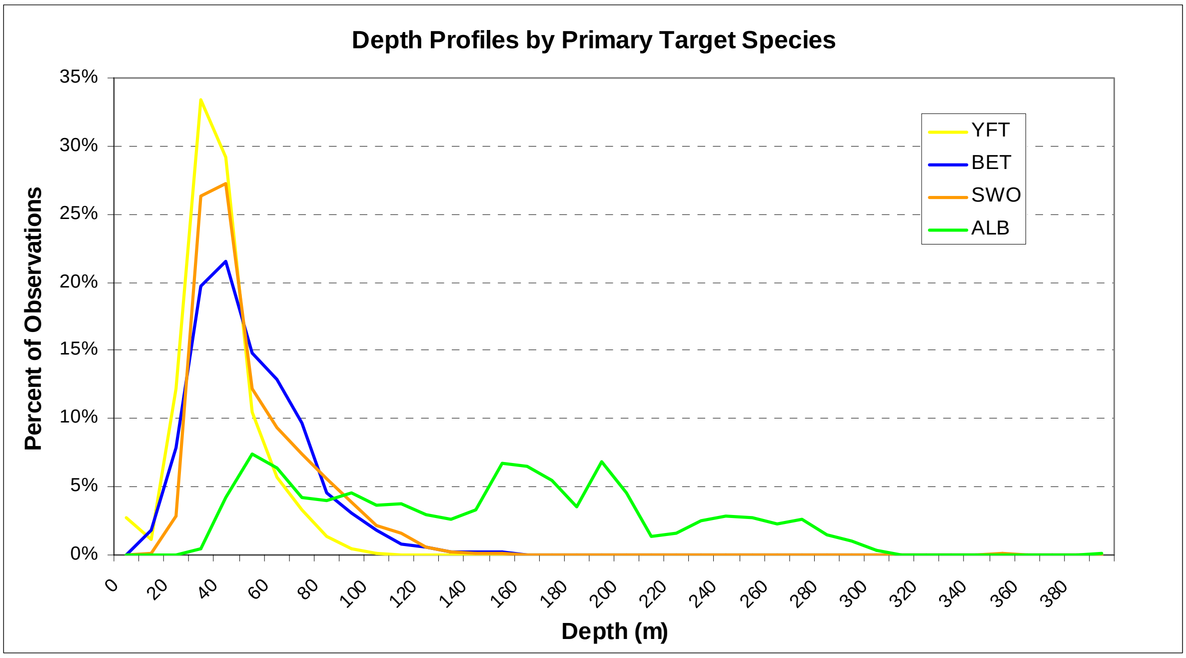


Figure 4. Profile of fishing depths attained by hooks recorded by TDRs stratified by the number of hooks-per-float as recorded by the observer.

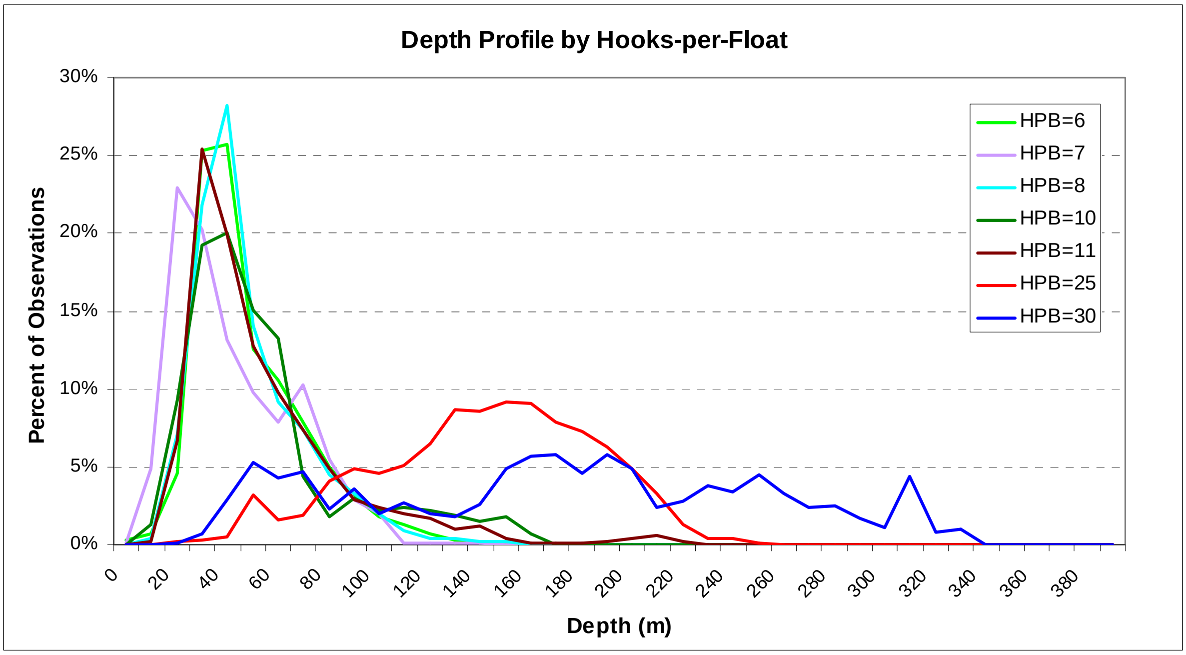


Figure 5. Range of gear settings for eight factors which are likely to influence the configuration of the deployed longline used during the monitored sets.

Figure 6a. The mean depth recorded by each TDR during the fishing phase of deployment versus the hook-number the TDR was attached for each shot during observed trip No. 38.

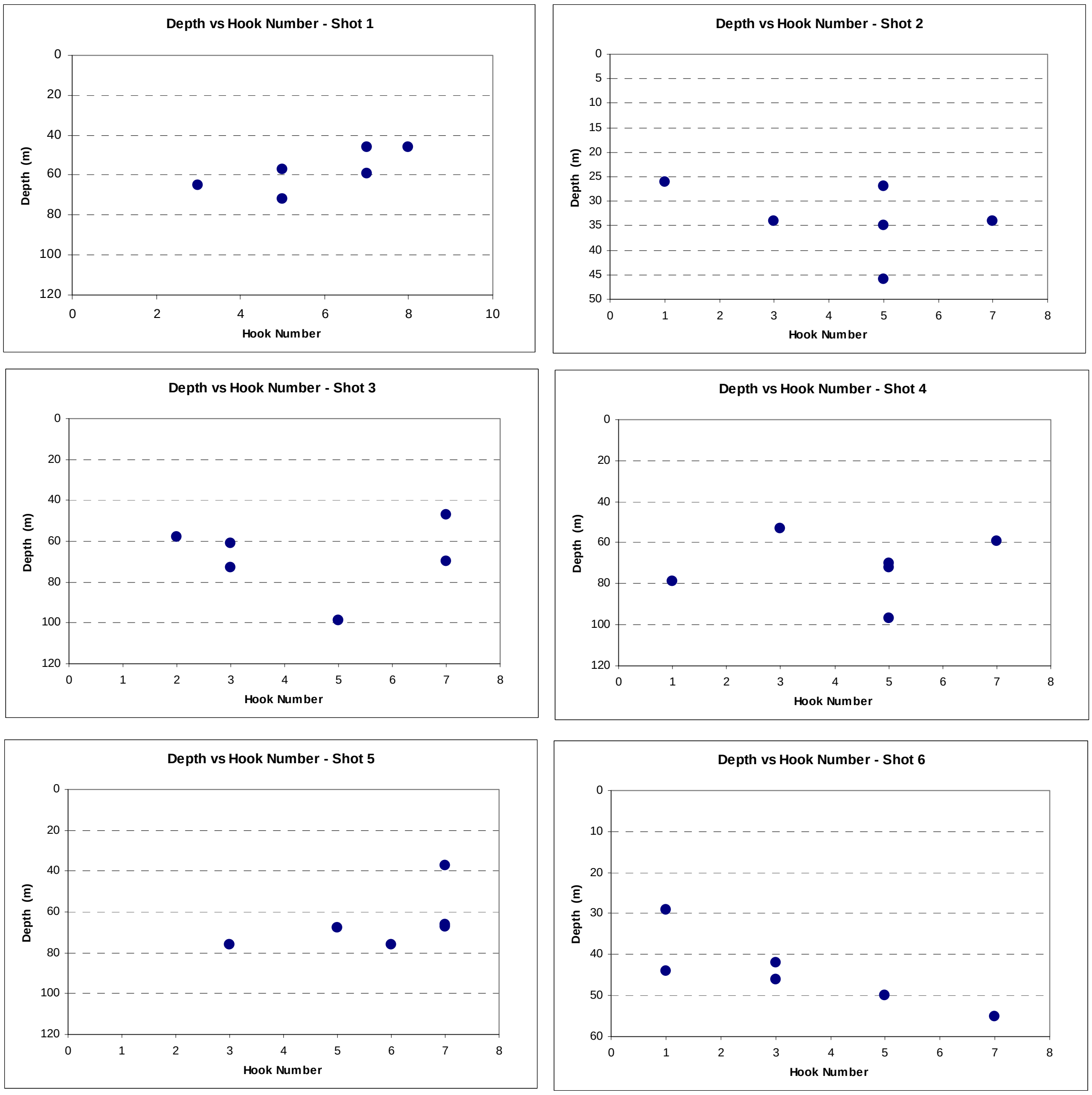


Figure 6b. Results aggregated across all shots for Trip 38.

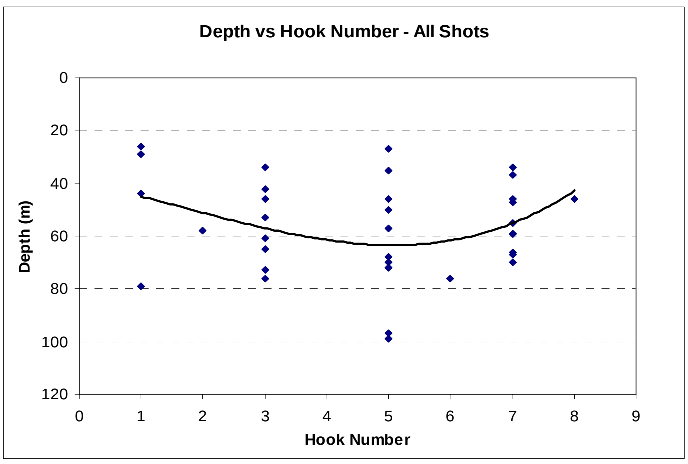


Figure 7 The mean depth recorded by each TDR during the fishing phase of deployment versus the hook-number the TDR was attached for each shot during observed trip No. 37.

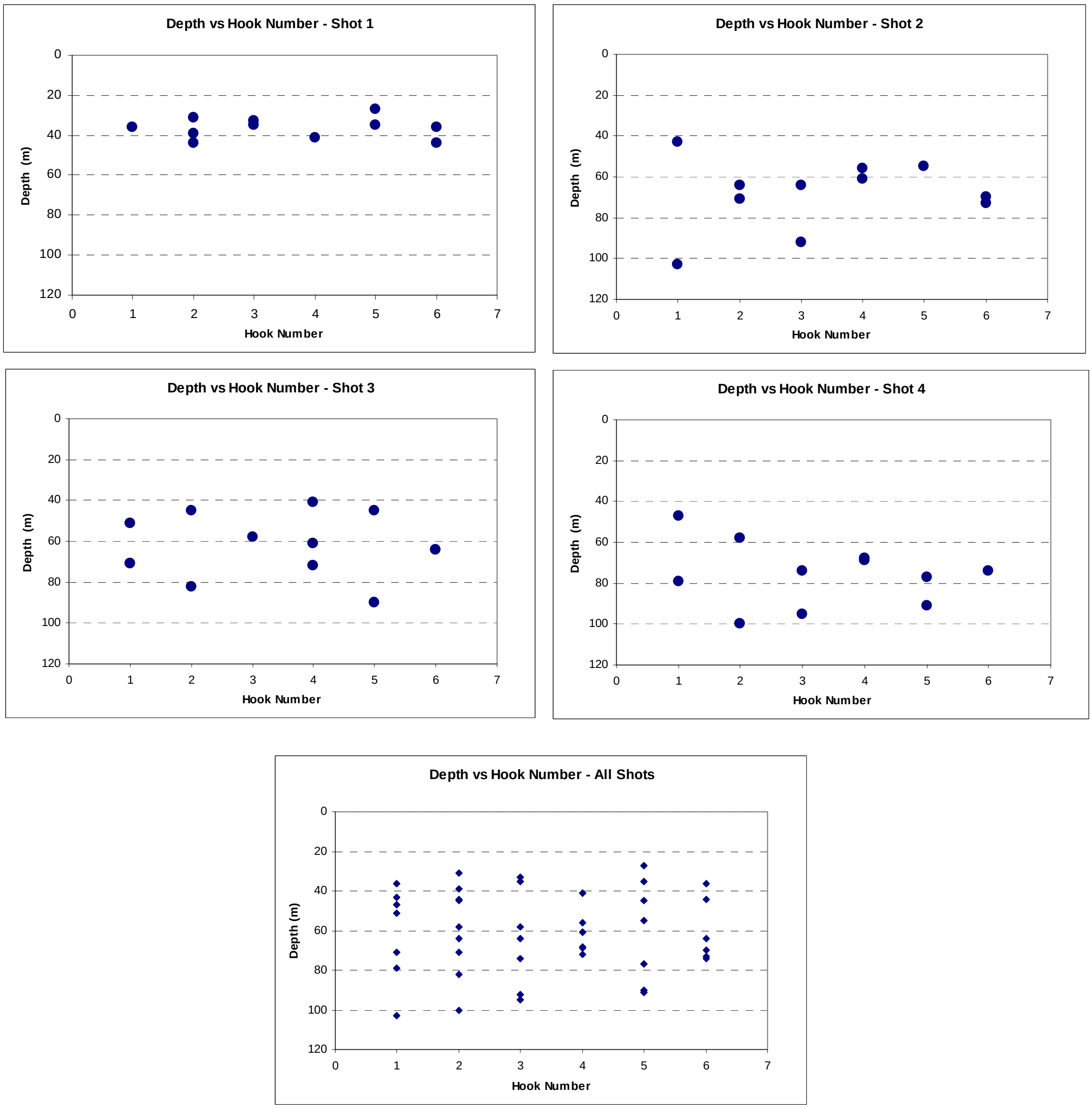


Figure 8. The mean depth recorded by each TDR during the fishing phase of deployment versus the hook-number the TDR was attached for each shot during observed trip No. 27.

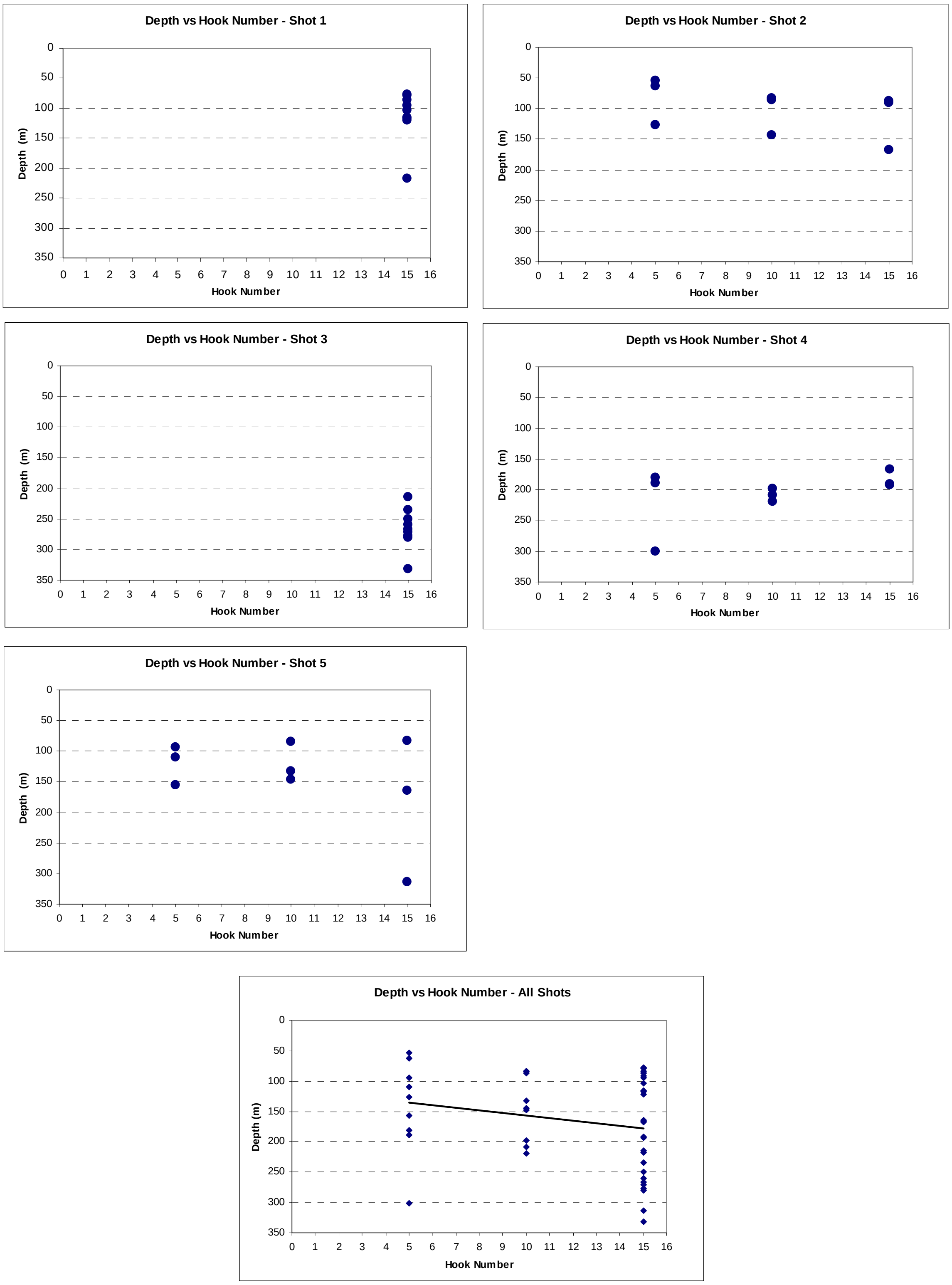


Figure 9. (a) Profile of the number of fish caught versus elapsed time (number of hours) for those fish caught on a line with a hook-timer, and (b) Profile of the number of fish caught versus time-of the day for those fish caught on a line with a hook-timer (all species).

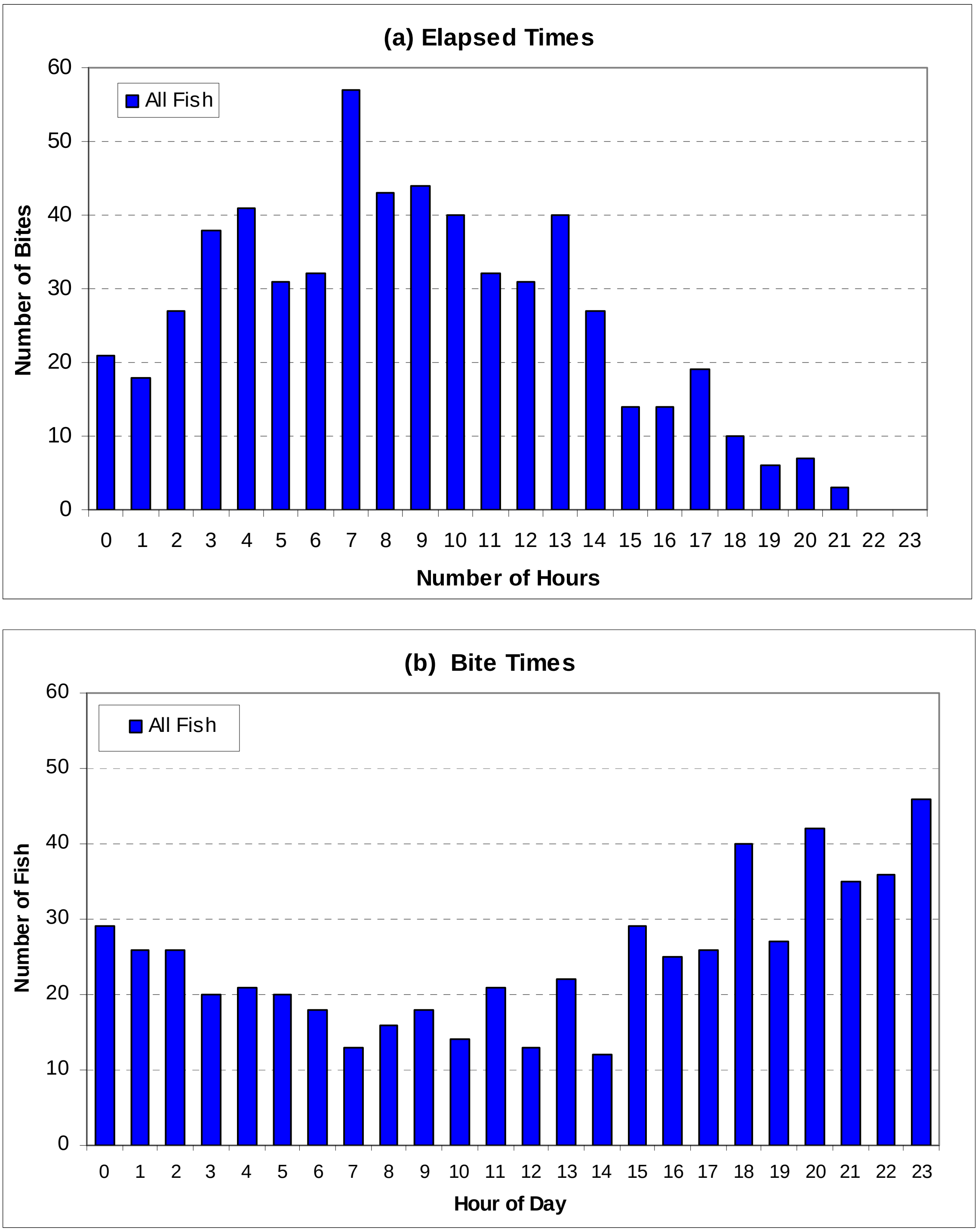
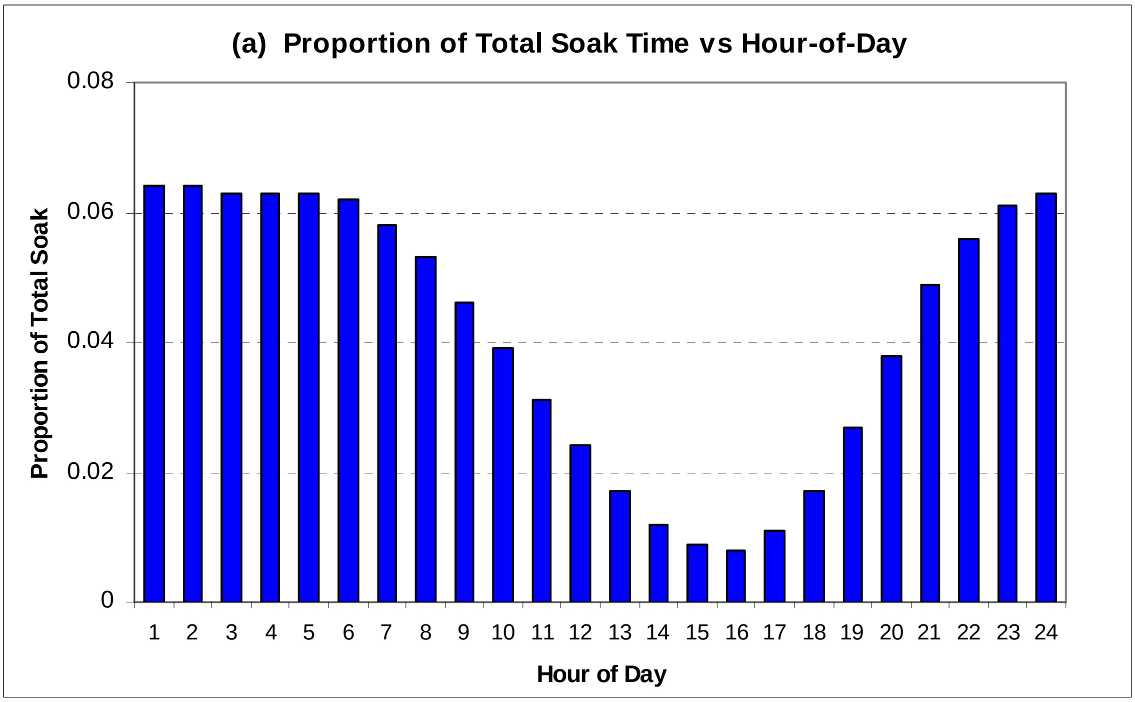


Figure 10. (a) Proportion of the total soak time of all sets deploying hook-timers within each hour-of-the day, and (b) Observed and adjusted profiles of the number of fish caught versus time of capture (for all species).



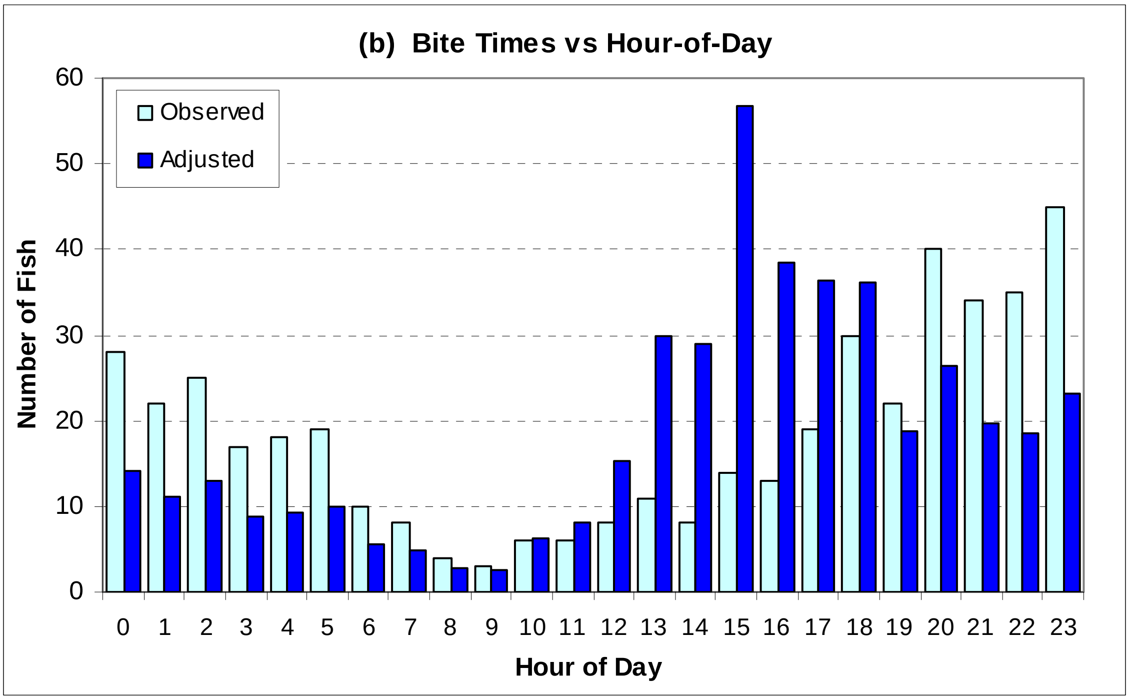


Figure 11. Observed and adjusted profiles of the number of fish caught versus time of capture for eight individual species.