SHORT NOTE

VALIDATION OF SINK RATES OF LONGLINES MEASURED USING TWO DIFFERENT METHODS

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Abstract

Sink rates of integrated weight longlines (lines with 50 g.m^{-1} lead integrated into two strands of the ground line – IW-50 lines) were measured during commercial fishing operations using two methods: electronic time depth recorders (TDRs) and pieces of string of known length wrapped around empty plastic bottles (bottle method). Sink rates measured to 2 m with bottles averaged 0.23 ± 0.07 m.s^{-1} compared to 0.17 ± 0.03 m.s^{-1} recorded by TDRs. This difference was not statistically significant (t_{12} = –0.181, P = 0.859). When the target depth was 15 m, sink rates measured using the bottle method (0.20 ± 0.02 m.s^{-1}) were significantly slower than those measured by TDRs (0.24 ± 0.03 m.s^{-1}, t_{10} = –3.851, P = 0.003). Measuring sink rates to 15 m proved difficult with bottles because they were too far behind the vessel, i.e. out of the observer's sight, when they reached the target depth. Bottles had a high failure rate (60%) due to string becoming entangled during line setting, or bottles vanishing from sight behind waves or in congregations of seabirds before the target depth was reached. No TDRs were lost during the trial. Bottle tests were most useful, depending on sea state and weather conditions, for measuring sink rates to shallow depths when instant readings were required. TDRs can be used to measure sink rates to depths of more than 2 m down to the seabed. A major advantage of the TDRs is the archival nature of the data collected.

Résumé

La vitesse d'immersion des palangres à lest intégré (lignes à lest de plomb intégré de 50 g.m^{-1} dans deux fils de la ligne de fond – ou, en anglais, IW-50) a été mesurée au cours d'opérations de pêche commerciale par deux méthodes différentes : des enregistreurs électroniques temps/profondeur (TDR) et des morceaux de ficelle de longueur connue enroulés autour de bouteilles en plastique vides (méthode de la bouteille). Avec les bouteilles, la vitesse d'immersion à 2 m était en moyenne de 0,23 ± 0,07 m.s^{-1}, alors que les TDR la situaient à 0,17 ± 0,03 m.s^{-1}. Cette différence n'était pas importante sur le plan statistique (t_{12} = –0,181, P = 0,859). Quand la cible était à une profondeur de 15 m, la vitesse d'immersion mesurée par la méthode de la bouteille (0,20 ± 0,02 m.s^{-1}) était nettement moins importante que celle mesurée par les TDR (0,24 ± 0,03 m.s^{-1}, t_{10} = –3,851, P = 0,003). Il s'est avéré difficile de mesurer les vitesses d'immersion à 15 m avec les bouteilles car, celles-ci se trouvaient trop loin derrière le navire pour pouvoir être vues par l'observateur lorsqu'elles atteignaient la profondeur voulue. Les tests réalisés avec les bouteilles affichaient un fort taux d'échec (60%) dû soit à l'enchevêtrement des ficelles pendant la pose de la ligne, soit à la disparition des bouteilles derrière les vagues ou au milieu de nuées d'oiseaux, avant que la profondeur voulue ne soit atteinte. Aucun TDR n'a été perdu pendant l'expérience. C'est pour mesurer les vitesses d'immersion à de faibles profondeurs, lorsque les résultats étaient requis immédiatement que le test de la bouteille s'est révélé le plus utile, en fonction toutefois de l'état de la mer et des conditions atmosphériques. Les TDR peuvent servir à mesurer les vitesses d'immersion à des profondeurs de plus de 2 m et jusqu'au fond. L'un des principaux avantages des TDR est la nature des données collectées qui permet de les archiver.

Резюме

Скорость погружения ярусов со встроенными грузилами (линей IW-50, в которых свинцовое грузило (50 г.м$^{-1}$) включено в состав двух жил хребтины) измерялась во время коммерческого промысла с помощью двух методов: электронного регистратора времени и глубины (TDR) и бутылочного метода, где кусок веревки определенной длины наматывался вокруг пустой пластиковой бутылки. Скорость погружения на глубину до 2 м, измеренная с помощью бутылок, в среднем составляла 0.23 ± 0.07 м.с$^{-1}$, а зарегистрированная TDR – 0.17 ± 0.03 м.с$^{-1}$. Разница между этими показателями не была статистически значимой (t_{12} = –0.181, P = 0.859). Когда глубина погружения составляла 15 м, скорость погружения, измеренная с помощью бутылочного метода (0.20 ± 0.02 м.с$^{-1}$) была намного ниже, чем скорость, измеренная TDR (0.24 ± 0.03 м.с$^{-1}$, t_{10} = –3.851, P = 0.003). Измерять скорость погружения на глубину 15 м с помощью бутылок было сложно, поскольку бутылки были слишком далеко от судна, т. е. при достижении намеченной глубины они находились вне пределов видимости наблюдателя. Частота неудач в случае использования бутылок была высокой (60%) в связи с запутыванием веревки во время постановки яруса или из-за того, что до достижения намеченной глубины бутылки исчезали за волнами или в скоплениях птиц. Во время эксперимента потерь TDR не было. В зависимости от морской обстановки и погодных условий бутылочные испытания были наиболее полезны в случае измерения скорости погружения на небольшую глубину, когда требовалось моментальное снятие показаний. TDR могут использоваться для измерения скорости погружения на глубины от более чем 2 м и до дна. Основным преимуществом TDR является архивирование собранных данных.

Resumen

Se utilizaron dos métodos para medir las velocidad de hundimiento de los palangres con pesos integrados (líneas con plomos de 50 g.m^{-1} incorporados en dos ramales de la línea rastrera – líneas IW-50) durante las operaciones de pesca comercial, a saber: registradores electrónicos de tiempo y profundidad (TDR) y trozos de cordel de longitud conocida atados a botellas plásticas vacías (método de la botella). El promedio de las velocidades de hundimiento medidas hasta una profundidad de 2 m con la prueba de la botella fue de 0,23 ± 0,07 m.s^{-1}, en comparación con el promedio de 0,17 ± 0,03 m.s^{-1} obtenido con los TDR. La diferencia no fue estadísticamente significativa (t_{12} = –0,181, P = 0,859). Cuando la profundidad objetivo fue de 15 m, las velocidades de hundimiento medidas con el método de la botella (0,20 ± 0,02 m.s^{-1}) fueron significativamente menores que las medidas con los TDR (0,24 ± 0,03 m.s^{-1}, t_{10} = –3,851, P = 0,003). La medición de la velocidad de hundimiento hasta una profundidad de 15 m mediante botellas fue difícil dada la distancia excesiva entre ellas y la popa del barco, es decir, se encontraban fuera del campo visual de los observadores al alcanzar su profundidad objetivo. El método de la botella tuvo un alto porcentaje de pruebas fallidas (60%) debido al enredo del cordel durante el calado del palangre, o bien las botellas desaparecían de vista detrás de las olas o de las aves agrupadas antes de alcanzar su profundidad objetivo. No se perdieron registradores TDR durante las pruebas. En condiciones meteorológicas y del mar favorables, las pruebas con botellas fueron de mayor utilidad para medir la velocidad de hundimiento en escasa profundidad, cuando se requirieron lecturas rápidas. Los TDR pueden utilizarse para medir velocidades de hundimiento a partir de 2 m de profundidad hasta el fondo del mar. La mayor ventaja de los TDR es que los datos recopilados pueden ser archivados.

Keywords: toothfish fishery, bottom longline, seabird by-catch, line sink rate, evaluation of methods, CCAMLR

Introduction

In the search for mitigation measures that reduce or even eliminate seabird mortality in demersal longline fishing operations, the sink rate of the longlines was identified as a critical variable that could be controlled and measured. Faster sinking lines reduce the time and therefore the opportunity for seabirds to attack the baited hooks (Robertson et al., 2003). To minimise seabird mortality, vessels fishing in Antarctic waters during the summer were recently required by CCAMLR to achieve longline sink rates of 0.3 m.s^{-1} to a depth of 15 m (Conservation Measure 24-02, see CCAMLR, 2002). In principle, there are two methods of measuring sink rates: time depth recorders (TDRs) and plastic bottles to which a piece of string of known length is attached. Fenaughty and Smith (2001) described the method of deploying bottles and list a number of advantages that bottles have over TDRs, such as reduced costs and the immediate determination of sink rates.

However, both methodologies can entail errors and operational difficulties that may influence the measuring of sink rates. The aims of this study were to: (i) compare the sink rates of longlines as measured by TDRs versus bottles; (ii) highlight the potential problems with either method; and (iii) emphasise the importance of recording the water-entry time of TDRs. Based on TDR data, the differences in sink rates to various target depths and the variation in sink rates of longlines over four depth increments with increasing distance from the propeller-wash zone were also examined.

Methods

TDRs and bottles

Tests were conducted on the FV *Janas*, a 46.5 m freezer autoliner (New Zealand Longline Ltd) using 9 mm demersal integrated weight longlines (lines with 50 $g.m^{-1}$ lead integrated into two strands of the ground line – IW-50 lines). Each longline deployed by the vessel consisted of six magazines, each 1.8 km long.

Mk9 TDRs (Wildlife Computers, USA) and empty one-litre plastic bottles with a 'pop top' rather than a screw lid were used. Bottles and TDRs were deployed on the third and fourth magazine to avoid measuring effects on the sink rates caused by the anchors at either end of the lines. When lines were set during the day, bottles and TDRs were deployed on the same lines but on separate magazines, because an entangled bottle could have influenced the sink rate of the longline and, hence the measurement by the TDR. TDRs were deployed under any weather conditions and during the day and night, while bottles were deployed only during daylight hours.

TDRs

Attachment device for TDRs

To make the attachment device for TDRs, we used 50 cm lengths of 9 mm polyester rope of which both ends were eye-spliced (Figure 1). A 12 cm stainless steel spring-loaded clip (shark clip) was fixed into the smaller eye. The other eye-splice was made large enough to embed the TDR, which was held in place with three small plastic cable ties threaded through the weave of the rope. Care was taken to avoid putting cable ties across the sensors, especially the pressure transducer. Also, TDRs were fastened into the eye-splice with the sensors pointing to the far side of the eye-splice (Figure 1). This ensured that the sensors were fully submersed when placed into a bucket of water prior to deployment.

TDR deployment routine

TDRs were set to sample depth and light levels continuously every second. The depth resolution was 0.5 m. Each time a TDR was deployed, its internal clock was synchronised with a digital wrist watch to correct for drift over time which tends to occur with these devices even over 24 hours.

For optimal performance, the TDR must be thermally stable, i.e. at the ambient sea temperature prior to the deployment. For that purpose all TDRs were put into a bucket filled with seawater at ambient seawater temperature where they soaked for at least 30 minutes before being deployed.

Since the TDRs may hang on the longline for several seconds before they leave the vessel and enter the water, the instruments were placed into small zip-lock bags which were closed with a small plastic cable tie well above the TDRs once the bags were filled with seawater at ambient seawater temperature. This helped to acclimatise the internal temperature sensors of the TDRs and kept them at the same temperature as the seawater through the entire deployment process. TDRs were deployed by clipping the shark clip onto the longline proper in the centre of a magazine.

Recording the exact time a TDR entered the water was essential because it can usually not be determined from the records. To achieve this, a crew member signalled the deployment of an instrument about 30 s before it passed through the setting chute. The observer positioned on the aft deck directly above the chute recorded the water-entry time with the same digital watch used to synchronise the TDR clocks.

Recovery and calculation of sink rates

The communication ports were thoroughly rinsed with fresh water and dried with compressed air prior to downloading. Data from about 45 s prior to the timed water entry of the TDRs were put into MS Excel for analysis. To determine the time taken for the longline to sink to the target depth, the number of seconds from the time it entered the water until it reached the chosen depth was counted. Because of the 0.5 m depth resolution, depth data tended to 'bounce' between

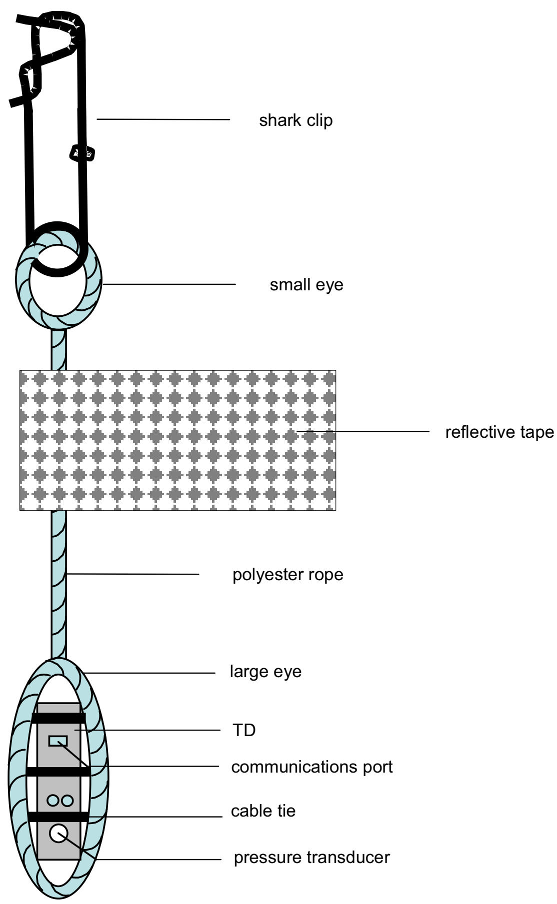

Figure 1: Attachment set-up of TDRs for deployment on longlines on the FV *Janas*.

two depth readings immediately below and above 0.5 m depth. When readings of the target depth occurred more than once in the record, sink rates were conservatively estimated based on the second measurement of the target depth.

For the comparison of data obtained from bottles and TDRs, sink rates from TDR data were estimated to depths of 2 and 15 m. To investigate variations in estimates of sink rate to different target depths, average sink rates of the TDRs were obtained for four target depths: 2, 5, 10 and 20 m. It was then determined how sink rates varied incrementally from 0–2 m, 2–5 m, 5–10 m and 10–20 m. This gave a measure of how a sinking longline behaved in the propeller-wash zone near the surface and at greater depths with increasing distance to the propeller-wash zone.

Bottle tests

Bottle deployment routine

The method used in this study was based on Fenaughty and Smith (2001). In brief, to increase visibility, a strip of reflective tape about 7 cm wide was wrapped around the centre of the bottle body. Then 15 m and 2 m long strings of 2 mm nylon cord were attached to the bottle's neck and firmly wrapped around the body of the bottle. A shark clip, as used for the TDRs, was fastened to the end of the cord. The end of the string was loosely attached to the bottle with a piece of sticky tape that prevented the cord from unravelling prior to deployment. The crew member who deployed the bottles could quickly remove the tape just before a bottle went down the setting chute. When the bottles exited the setting chute, note was taken as to whether the string unravelled freely or became fouled with the longline. To determine sink rates, the time difference between the moment the bottle reached the water and the time when the bottle flipped from a horizontal to a vertical position was recorded.

A crew member attached a bottle with a 15 m string about one-third into a magazine and a bottle with a 2 m string approximately two-thirds into a magazine on the swivels of the line to allow free movement of the clips when entering the water.

The time at which the bottle reached the water surface and the moment it turned from a horizontal to a vertical position to sit upright in the water was recorded with the same watch as used for the TDRs.

Analyses

The sink rates of TDRs and bottles were compared with Student's *t*-test. Mean sink rates to different depths measured by TDRs were tested with a One-Way Analysis of Variance after tests for normality and homogeneity were passed. For comparisons of more than one group Tukey's All Pairwise Multiple Comparisons were carried out. Significance levels were set at 0.05 unless stated otherwise.

Results

Deployment success

In total, TDRs and bottles were deployed 16 and 24 times respectively. With the bottles, six of the 12 tests to a depth of 2 m and four of the 13 tests to 15 m provided useable results. Overall, of the 25 bottle tests, 15 (60%) were successful, while all TDRs were retrieved and delivered sink rate information.

Sink rates measured by bottles and TDRs

Average sink rates of IW-50 lines to 2 m were 0.23 ± 0.07 m.s^{-1} (n = 6) and 0.17 ± 0.03 m.s^{-1} (n = 8) for bottles and TDRs respectively. This difference was statistically not significant (t_{12} = 0.181, P = 0.859). To a target depth of 15 m, the bottles yielded sink rates of 0.20 ± 0.02 m.s^{-1} (n = 4) compared to 0.24 ± 0.03 m.s^{-1} (n = 8) measured with TDRs. This difference was significant (t_{10} = –3.851, P = 0.003).

Sink rates to different target depths – TDR data

Sink rates to depths of 2, 5, 10 and 20 m were extracted from the TDR files. The mean sink rates to the four depths were significantly different ($F_{3, 28}$ = 12.270, P < 0.001, power of performed test with α = 0.05 was 0.999). The mean sink rates to 2 m equalled 0.168 ± 0.032 m.s^{-1} as compared to 0.239 ± 0.016 m.s^{-1} to 20 m and were thus 30% slower than those measured to 20 m (Table 1). This difference was statistically significant (Tukey's test P < 0.001, see Table 1).

Sink rates in four increments to increasing distance from propeller-wash zone – TDR data

Sink rates from 0–2 m (A) averaged 0.168 ± 0.032 m.s^{-1}, increased from 2–5 m (B) to 0.241 ± 0.041 m.s^{-1}, remained steady from 5–10 m (C) at 0.239 ± 0.024 m.s^{-1}, and increased again from 10–20 m (D) to 0.267 ± 0.022 m.s^{-1} (Figure 2). Thus, from the first to the second increment sink rates increased by 30%, and by a further 10% over the last two increments. The mean values among the four groups differed significantly ($F_{3, 28}$ = 15.789, P < 0.001). A Tukey test showed that group A (0–2 m) differed significantly from the other three groups (P < 0.001 for all comparisons).

Discussion

Problems arising during bottle tests

Five major problems were encountered with the bottle tests. First, difficulties occurred when the string wrapped around the bottles did not completely unfurl. This appeared to be more of a problem when measuring sink rates to 15 m than when measuring them to 2 m and may have been caused by insufficient tension of the string when wrapped around the bottle. Second, the string unfurled but then entangled with the longline or got caught on the hooks. Both events shortened the string and therefore made it impossible to determine sink rates accurately. Another problem arose when the swell and wave height exceeded about 2 m as it became difficult to observe the bottles behind the vessel because waves and swell obscured visibility. This was particularly true for the deployment of bottles to 15 m which, by the time the string is entirely unfurled, are more than 100 m behind the vessel. However, unsuccessful deployments occurred commonly with bottles even under generally good weather conditions and calm seas. When seabirds were abundant and sat on the water in the wake of the vessel, bottles could become concealed by the birds particularly when they had gathered in dense aggregations.

While the first four problems could be described as 'operational' difficulties, another problem with the bottle method was inherent and became apparent in the great variability of sink rates among bottles. In part, the problem was due to the need for the observer to take two time measurements: the time the bottle hits the water and then the time when the bottle sits upright at target depth. While the water-entry time is easily determined (this takes place at the very stern of the vessel) it

Table 1: Sink rate estimates to four target depths as measured by TDRs ($n = 8$).

Depth (m)	A 2	B 5	C 10	D 20
Sink rate ± SD ($m.s^{-1}$)	0.168 ± 0.032	0.202 ± 0.027	0.218 ± 0.019	0.239 ± 0.016
All pairwise comparison Tukey's test		B vs A* $P = 0.040$	C vs A * $P = 0.002$	D vs A* $P < 0.001$
			C vs B $P = 0.586$	D vs B* $P = 0.024$
				D vs C $P = 0.304$

* Significant

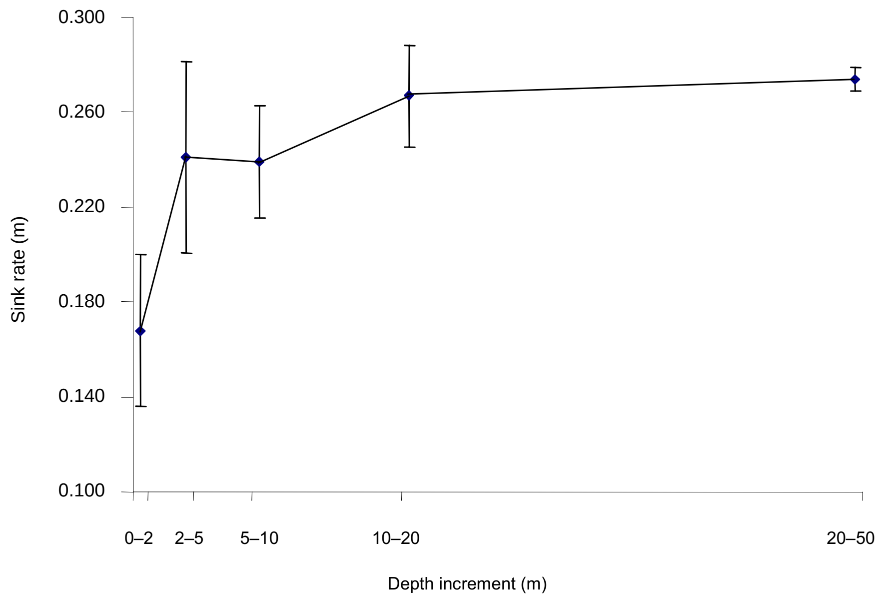

Figure 2: Incremental sink rates ($m.s^{-1}$) of IW-50 longlines from the water surface to 50 m depth.

is more difficult to determine the time when the bottle reaches an upright position in the water. It is common for the bottles to bob around on the surface, stand up, lie on their sides, and stand up again. It can be very difficult to determine the precise time a bottle reaches a certain position and it is the observer's subjective decision as to when this time has come.

One way of reducing the effect of these problems is by deploying large numbers of bottles on the same line rather than relying on a single bottle to provide sink rate information. Only by increasing the sample size can a relatively acceptable average sink rate be obtained. Multiple bottle deployments, however, require the observer to spend more time on the aft deck.

Sources of error

Problems encountered with TDRs included: (i) the relatively coarse depth resolution (0.5 m); (ii) the inability of the TDRs to determine the sea surface; and (iii) the drift of the internal clock.

When measuring sink rates of longlines to shallow depths, the depth resolution of the TDRs is such that the actual sink rates of the longlines are probably underestimated because the instruments record depth in 0.5 m increments. In this experiment, the sink rates to target depths of 2 and 20 m differed significantly by 30% (Table 1). As the pressure on the sensor gradually increases, for example, from 1.5 to 2.0 m, the recorded depth changes at some point from 1.5 to 2.0 m but the real depth at which this occurs is not known. However, once the depth reading has changed it does not record a shallower depth as long as the instrument continues to sink (R. Hill, pers. comm.).

Line sink rates varied throughout the initial setting period. In the top 2 m of the water column, the lines sank more slowly due to the effects of the propeller wash and sea state. At greater depths these effects became minimal or negligible (Figure 2). Because of this initial lag, sink rates should not be extrapolated from shallow to greater depths. If it is deemed necessary to measure sink rates to greater depths, for example, because deep-diving seabirds are following a vessel, the sink rate should be measured from the surface to a target depth of more than 10 m. Once the lines are 20 m below the water surface, sink rates of IW-50 lines become relatively constant at 0.274 ± 0.005 m.s^{-1} (n = 8). However, it should be kept in mind that the slow sink rates to shallow depths confound the rates estimated to greater depths. At best an average sink rate can be estimated.

Determination of sink rates to 15 m and more is most reliably achieved by the deployment of TDRs. Even with fast-sinking IW-50 lines the longline reaches a depth of 10 m at a distance of about 100 m behind the vessel. In situations where large numbers of seabirds crowd the water surface or sea and weather conditions are unfavourable, it is difficult to get precise sink rates from bottle tests because of impaired visibility of the device.

The second problem pertains to the fact that TDRs do not reliably record exactly where the sea surface is. This problem could be significant with Mk7s and older recorders and could require a substantial correction of depth during the data analysis. The 'depth' at the recorded water-entry time, for example, could read 7.5 m although the instrument had only just reached the water surface. Thus, to determine the sink rate to say 10 m, 7.5 m has to be subtracted from the recorded depth readings until the corrected depth equals 10 m. The number of seconds to reach this depth is then counted and the sink rate is established.

With Mk9s, the problem is greatly reduced because the effect of these 'wrong' depth readings is minimal. Occasionally negative readings in the order of –0.5 or –1 m can be encountered but it is much more obvious when the line starts to sink.

The third problem arises only when the water-entry time of the TDR is not recorded externally. In principle, TDRs can be programmed to start recording only once they get wet. However, there is a lag from the time the instrument switches on to the time it starts recording. This is why, in this study, the instruments recorded continuously, i.e. from the time they were set up. Given the combination of the continuous data record and the crude depth resolution of the instruments, it is important to determine the exact water-entry time of the TDR if sink rates are to be determined accurately (see below).

Comparison of bottle tests and TDRs

Both methods of measuring sink rates have their strengths and weaknesses (Table 2). While the cost of TDRs is considerably higher (>1 000 times) than of plastic bottles, the instruments, if secured well when being deployed, can be reused many times. The major advantage of TDRs over bottles is that the observer obtains a record that can be scrutinised long after the data were collected. With the bottle test, an observer has only one chance to get the information. Because of the detailed records TDRs provide, events such as tangling of the rope that may slow down the sinking line can be discovered while bottle tests will not deliver any useable results under such circumstances. Moreover, estimates of sink rates to various target depths can be obtained from the same TDR record and may be useful in answering other research questions (e.g. how long did it take the longline to reach the bottom? Is there a relationship between fish catches and soak time?).

Apart from providing faster sink rates, the data obtained using bottles were more variable compared to those from TDRs. Thus, a greater number of bottles is needed in each deployment to estimate sink rates reliably. More deployments mean more time for the observer on deck so the time component increases overall for the bottle tests.

In our experience, TDRs were more useful for measuring sink rates under all conditions. At night, a torch was needed to determine the water-entry time but only for a few seconds. With bottles it would have been necessary to continue shining a strong light until the bottle stood upright. The light may attract seabirds closer to the vessel and, more to the point, to the area where the longline is still high in the water column, and therefore accessible to birds.

Recording water-entry times

For both deployment methods, it is important to record the time either bottles or TDRs reach the water surface. For the interpretation of data collected by Mk9 recorders it is less crucial than for Mk7s or bottles. The widely fluctuating depth readings of the Mk7s do not occur in the newer Mk9s. However, since the minimal depth

Table 2: Comparison of bottle tests and TDRs.

Factors	Bottles	TDRs
Cost	Inexpensive (< US$2)	Expensive (US$1 300)
Data availability	Immediate	After retrieval of instrument.
Time commitment	Low to moderate depending on the number of bottles deployed.	Moderate to high as it takes time to set up the instruments and download data post deployment.
Ease of setting up	Minimal instructions necessary.	Requires use of computer and easy-to-use software.
Deployment success	About 60% (highly dependent on weather conditions and sea state).	100% (assuming proper attachment to longline).
Deployment conditions	Most effective in calm weather, not recommended in windy and choppy weather.	Can be deployed in all weather conditions and during day and night.
Data	One observation by eye only.	Archival
Data consistency	Data highly variable, multiple deployments per line.	High consistency among deployments requiring only a single deployment per line.
Precision of data	Depends on skills of observer.	Relatively imprecise at shallow depths but precise at >3 m.
Target depth	Good for shallow depths (<5 m) but highly dependent on sea state and visibility; measurements to greater depths become unreliable because the bottle is a long way aft.	Reliable to any depth, particularly >2 m; target depth can also be changed post deployment if necessary.
Data use	One record of sink rate only.	Can be used to answer other research questions.
Record	Dependent on observer; only one record in notebook. Single record.	Independent of observer with exception of water-entry time. Continuous record.

increment of both types of TDRs is only 0.5 m, some variability still occurs. Hence, a precise water-entry time is essential to determining where the start point is in the data for the calculation of sink rates. The drift of the internal clocks of the TDRs can be as much as 7 s in 24 hours. For fast-sinking lines a difference of 5 s can make a 7% difference to the sink rate (e.g. 75 s over 20 m = 0.27 $m.s^{-1}$, 70 s over 20 m = 0.29 $m.s^{-1}$, 65 s over 20 m = 0.31 $m.s^{-1}$).

When TDRs are deployed at night, light levels can provide some information on water-entry times. A strong torch was shone onto the longline as it exited the chute and both Mk7 and Mk9 recorded a flash of light. During daylight hours, the change in light levels is more gradual and less reliable as an indicator for water-entry time.

Conclusions

TDRs were originally built to be deployed on marine mammals and diving birds to record their activities at sea. The depth resolution did not need to exceed 0.5 m for this purpose. However, this coarse resolution limits the use of TDRs in shallow depths for measurements of sink rates of longlines. Ideally, manufacturers of TDRs would build instruments with a finer depth resolution and dedicated to measurement of sink rates of longlines, while at the same time being able to resist the pressure at, say, 2 000 m.

Until such time as such purpose-built TDRs are obtainable, the best choice of currently available methods for measuring sink rates will depend upon the line deployment method of a vessel, sea state and weather conditions, as well as the crucial depth to which a sink rate needs to be determined. When a vessel is surrounded by surface-seizing seabirds, bottle tests with 2 or 5 m strings may be adequate. However, because of the variability in bottle-test data, a sufficient number of bottles need to deployed to reduce the error.

In areas where deep-diving seabirds occur, TDRs are preferable simply because they provide more reliable and consistent data than bottles for depths to 15 m. Given the high number of unsuccessful deployments and the practical difficulties with bottles, it is recommended not to use them when sink rates to more than 5 m need to be estimated.

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