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SHORT NOTE

A STUDY OF PATAGONIAN TOOTHFISH (*DISSOSTICHUS ELEGINOIDES*) POST-TAGGING SURVIVORSHIP IN SUBAREA 48.3

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Abstract

During the 2005 fishing season, experiments on the survivorship of toothfish following tagging were carried out on eight different vessels fishing in Subarea 48.3. Toothfish were kept in tanks with seawater replacement for at least 12 hours after tagging. On one vessel, fish with a variety of injuries were selected to see if this affected recovery. In the final analysis, 396 animals were included, with an overall survivorship of 90%. Smaller animals and animals in better initial condition had a higher survivorship than large animals and those in poor condition. The results suggest that experienced observers using animals in good condition would normally achieve a toothfish post-tagging survivorship of 95% or more. An assumption of 90% post-tagging survivorship is a conservative value which might be appropriate to use in population estimators until further survivorship studies have confirmed the 95% rate.

Résumé

Pendant la saison de pêche 2005, des expériences de survie des légines au marquage ont été menées sur huit navires de pêche différents dans la sous-zone 48.3. Les légines étaient placées dans des réservoirs d'eau de mer circulante pendant un minimum de 12 heures après le marquage. Sur un navire, on a sélectionné des poissons aux blessures diverses pour déterminer si la récupération en était affectée. L'analyse finale concernait 396 individus, pour un taux de survie général de 90%. Les spécimens de plus petite taille et ceux en meilleure condition au départ avaient plus de chances de survivre que les autres. Les résultats indiquent que des observateurs expérimentés retenant légines en bonne condition peuvent normalement atteindre un taux de survie au marquage de 95% ou plus. La valeur de 90% est une hypothèse prudente qu'il pourrait convenir d'utiliser dans les estimateurs de population tant que des études de la survie n'auront pas confirmé le taux de 95%.

Резюме

В промысловом сезоне 2005 г. на 8 различных судах, осуществлявших промысел в Подрайоне 48.3, были проведены эксперименты по выживаемости клыкача после мечения. Клыкача держали в баках со сменяемой морской водой в течение по крайней мере 12 часов после мечения. На одном судне были отобраны особи с различными повреждениями, чтобы посмотреть, повлияет ли это на процесс восстановления. В окончательный анализ были включены 396 особей, итоговая выживаемость которых составила 90%. Более мелкие особи и особи в лучшем исходном состоянии имели более высокую выживаемость, чем крупные особи и особи в плохом состоянии. Эти результаты говорят о том, что опытные наблюдатели, отбирающие особей в хорошем состоянии, могут обычно добиться 95%-ной или более высокой выживаемости клыкача после мечения. Предположение о 90%-ной выживаемости после мечения является осторожной оценкой, которую было бы целесообразно использовать в оценках популяции до тех пор, пока дальнейшие исследования выживаемости не подтвердят показатель 95%.

Resumen

Durante la temporada de pesca de 2005, se llevó a cabo un estudio empírico de la supervivencia de la austromerluza tras el marcado, a bordo de ocho barcos que operaban en la Subárea 48.3. Los ejemplares de austromerluza fueron mantenidos en depósitos con agua salada fresca por un mínimo de 12 horas después del marcado. En un barco, se seleccionó una muestra de peces con varios tipos de heridas para evaluar su efecto potencial en la recuperación. El análisis final incluyó 396 peces, y la supervivencia total fue de 90%. Los peces más pequeños y los peces en mejores condiciones tuvieron una tasa de supervivencia mayor que los peces de mayor tamaño y aquellos en malas condiciones. Los resultados indican que los observadores con experiencia que marcan peces en buen estado normalmente consiguen una tasa de supervivencia de 95% o mayor después del marcado. Se considera prudente utilizar un valor de 90% para la tasa de supervivencia después del marcado en las evaluaciones de los stocks, hasta que otros estudios de la supervivencia confirmen la tasa de 95%.

Keywords: *Dissostichus eleginoides*, toothfish, tagging, mark–recapture, survivorship, discard, CCAMLR

Introduction

Mark–recapture methods are showing increasing promise for estimating population sizes for toothfish. Assessments of toothfish in both the Ross Sea and South Georgia are now based in part on the analysis of mark–recapture data (SC-CAMLR, 2005; Dunn et al., 2005; Hillary et al., 2006), although slightly different assessment approaches may be adopted in the different areas. Knowledge of post-tagging survival is extremely important for the accurate application of these methods, and is usually assumed to be high. Although toothfish mark–recapture studies have been under way for several years around Heard Island, South Georgia, and in the Ross Sea[1], and toothfish are reported to be robust and lively on release, it is understood that no directed tagging survivorship studies have yet been carried out.

Tagging and releasing is a special case of discarding, and discard mortality has been investigated in some detail for many fish species, including for skates and rays at South Georgia (Endicott and Agnew, 2004). One of the most extensively investigated is pacific halibut, which is caught in trawls and on lines. Studies of discard survivorship have been made using a combination of on-board tank experiments and the difference in mark–recapture recovery rates for fish in different test categories (such as condition, type of hook etc.) (Hoag, 1975; Kaimmer and Trumble, 1998). Such studies have identified that animal size, condition and release method are important in determining discard survivorship.

At Heard Island, where most tagged toothfish are released on research cruises, fish are retained in tanks for several hours post-tagging to ensure that the releases are all in good condition (D. Williams, pers. comm.; see also Williams et al., 2002). At South Georgia and in the Ross Sea most tags are released by scientific observers operating on fishing vessels. Lively candidates with little damage are identified by observers who retrieve them from the product line, tag and immediately release the fish. Pre-release tanking of fish would be practically very difficult, and might subject the fish to greater stress through having to move them further and keep them in tanks on deck in what are often very exposed conditions.

Thus it is difficult to know whether fish tagged and released by observers will survive to the same extent as fish tagged on research cruises. The

[1] These tagging studies are coordinated and standardised by CCAMLR according to the CCAMLR Fish Tagging Protocol. See www.ccamlr.org/pu/e/sc/tag/intro.htm.

present study was initiated in an attempt to quantify the assumed high survivorship of toothfish tagged by observers.

Methodology

In the 2005 fishing season all vessels fishing at South Georgia installed one or two tanks with which to test post-tag survivorship. These tanks were either stored on deck or in the factory and most were supplied with running seawater. During this season, observers were given the objective of tagging 1.5 fish for every tonne caught, using a method adapted from the CCAMLR Fish Tagging Protocol. This involves alerting the gaffer when a suitable fish is spotted so it can be removed from the sea as gently as possible and, once it is on board, cutting off the snood and removing the hook. Once on board, fish are checked for damage and overall condition, with suitable fish being measured and, if possible, weighed before being double tagged with T-bar tags either side of the dorsal fin. If conditions allow, the fish are immediately released. However, when birds, seals and cetaceans are present, the fish are placed in a holding tank until the release area is clear of predators.

In the 2005 fishing season, observers were additionally requested to randomly and occasionally take fish that they had tagged as part of the normal tagging protocol and place them in the experimental tank, measuring fish length prior to tanking and recording whether they survived 12 hours in the tank. Previous work (Endicott and Agnew, 2004) suggested that this was a reasonable time to expect tank conditions to remain favourable to survivorship experiments. No limit was put on the number of fish to be subjected to this treatment, since the actual configuration of the tanks varied considerably between vessels. Instead, it was left up to the observer to judge the extent of the experiment that he could implement. An examination was conducted on all fish that did not survive the experiment, recording biometrics, sex and maturity.

Details of the tanks and number of fish examined is provided in Table 1. All vessels were longliners and fish were captured from between 500 and 1 760 m depth.

On most vessels the condition of the fish was assessed before they were placed in the holding tank. Methods of assessment included describing the damage to each individual fish, giving the animals a rating depending on their condition and liveliness (e.g. on the *Polarpesca I*; good – fish very lively, with only minor abrasions and no major visual damage; average – fish active, with some damage around the jaw, and sometimes to the eye; poor – fish lethargic, major damage to the jaw and often cuts or gashes to the body cavity), or simply judging them to be in a good, average or poor state. On vessels where no assessment was made it was assumed that the observer had only chosen fish that were judged to be in good or average condition and otherwise suitable for tagging.

Some complications were experienced with some of the tanks freezing in extremely cold weather (Figures 1 and 2), with the consequent death of the fish. These fish have been removed from the analysis (seven, in total, froze within the 12-hour period on the *Viking Bay* and the *Isla Santa Clara*). Observers were at liberty to extend the tanked period beyond 12 hours, but in many cases, it was found that because the tanks were small and exposed to weather conditions, fish survivorship deteriorated after this time. These instances have been noted in Table 1 but were not included in the analysis.

Results

Observations

Injuries were mainly incurred as mouth damage from the hook as the fish was being hauled, as body damage from the gaffe pole as the fish was being brought onto the vessel, and as mouth damage from the line separator as the hook was removed from the mouth. Some animals also showed evidence of having recovered from serious injuries in previous years including extensive scarring around the head, portions of lips missing and new dermal growth over missing eyes. These were either fish that had been tagged and released in earlier years, or were assumed to be fish that had fallen off the line before being landed in previous years.

Once in the tanks most fish were inactive except when being handled, although swimming was often difficult because of the tank size and could result in additional damage being done to the eyes. Typically the fish would remain stationary on the bottom of the tank close to the area where seawater was pumped into the tank. Sometimes the eyes of the fish started to grey over after 12 hours, a phenomenon that was attributed to exposure to the bright factory lights. However, after 12 hours in the holding tank, most fish were vigorous and evasive when approached which made release, especially of larger fish, quite difficult.

The water replacement/circulation system was a problem on many vessels, often resulting in less than perfect conditions for the experiment. This

Table 1: Details of equipment used and fish examined by vessel.

Vessel	Equipment	Experimental design	Sample size	Deaths within 12 hours	Comments
Isla Santa Clara	Two insulated experimental tanks of the same design as those used to determine the survivorship of Rajidae caught in the fishery (Endicott and Agnew, 2004). The tanks were located on deck.	In one tank, three fish were kept alive for as long as possible, one for over one month. The other tank was used for the main survivorship experiments.	16	0	
Viking Bay	One tank with water periodically replaced. The holding tank dimensions were: length 1.5 m, width 1.5 m and depth 0.88 m. Volumetric capacity of the tank was 1 000 litres when full, but due to the movement of the vessel the capacity average was 800 litres. The tank was constructed from polyurethane and had no cover. The tank was placed in an exposed area in the factory.	Standard random selection of fish.	12	1	Although only one fish died in the first 12 hours, one other died between 12 and 24 hours as a result of the exposed condition of the tank (this does not include fish which froze).
Polarpesca I	One tank with a flow-through of water.	Standard random selection of fish.	104	22	None out of 15 animals which were in good condition when they were tagged died; eight out of 48 animals in average condition died; 14 out of 41 animals in poor condition died.
Protegat	One tank with a flow-through of water.	Fish placed in the tank dependent on their size. Fish >80 cm placed three at a time in the tank for 24 hours, <80 cm five or six at a time for 36 hours.	109	6	No additional deaths occurred after 12 hours.

(continued)

Table 1 (continued)

Vessel	Equipment	Experimental design	Sample size	Deaths within 12 hours	Comments
Argos Helena	One tank with flow-through of water.	Standard random selection of fish.	37	6	Six fish died within 12 hours. Six others died between 12 and 24 hours. Since a number of these fish were in good condition at the start of the trial, it is suspected that the tank design and water flow was insufficient for long-term maintenance of captive fish.
Koryo Maru No. 11	One stainless steel tank 1.5 x 1 x 0.5 m deep. Constant flow of water and thermometer. The tank was placed in a sheltered area in the factory with a lid to cover it.	Seven fish selected as healthy specimens and handled with care as if they would have been tagged and released. Sixteen remaining fish randomly chosen and damage assessed.	23	0	Two fish were recorded as initially being lethargic and weak, but they improved after time in the tank.
Jacqueline	Glass fibre tank, 1.7 x 0.8 x 1.2 m deep giving it an internal volume of approximately 1 600 litres. A tap and outlet valve allowed the water to be changed regularly.	All fish tagged were placed in the tank first and assessed. Times in the tank ranged from a few minutes to 73 hours. For the purpose of the analysis only fish that were in the tank for longer than 12 hours were included. Damage to the eyes of fish kept in the tank for long periods of time was observed to be caused by rubbing on the fibreglass sides.	86	6	These six fish died in under an hour, suggesting they were in poor condition before being placed in the tank, although condition was not recorded. No additional fish died after 12 hours.
Argos Georgia	Stainless steel tank fitted. Problems with tank meant only a small number of fish were subsequently tested.	Standard random selection of fish.	9	0	

Figure 1: Experimental tanks used on the *Isla Santa Clara* and weather conditions experienced during the period.

Figure 2: Experimental tanks used on the *Viking Bay*. The exposed position, lack of lid and lack of flow-through water led to the water freezing on several occasions.

was due either to the fact that there was no water replacement system fitted or because the water in the replacement pipes would freeze. This would reduce the oxygen levels in the water and in some extreme cases cause the water in the tanks itself to freeze.

On the *Isla Santa Clara* some fish were held for many hours to investigate their long-term survivorship (24 hours or longer). These animals were offered a variety of different food items, including sardine and squid used as bait on the lines (identified as diet items by Arkhipkin et al. (2003) and Pilling et al. (2001)), which were placed within the tank and removed on a daily basis. Only one toothfish fed during the period taking sardine, initially on 7 June, 23 days after being placed in the tank and again eight days later on 15 June.

Analysis

The 396 fish on eight vessels used in the experiment exhibited an overall survivorship of 90% (Table 2). The lowest survivorship was reported by the *Polarpesca I*. This was because the observer was purposefully selecting fish from a range of conditions and a relatively high percentage of animals in poor condition died. The *Argos Helena* also had a relatively low survival rate, partially due to the deliberate inclusion of fish in poor condition, but probably also due to an inadequate tank system. Although there were differences between the experimental configurations on the other six vessels – including the size of the tanks, their distance from the hauling/sorting point and their exposure to weather – there was no significant difference between the survivorship reported by them (χ^2 = 3.5, d.f. = 5) which, combined, was 95%.

An exploratory generalised additive model (GAM) was constructed to investigate the various influences on survivorship. A GAM is similar to a parametric model, such as a generalised linear model, except that the parametric terms are replaced by smoothing functions. Unfortunately, complete datasets including data on fish condition, depth and length were available from only four vessels, and only one (the *Polarpesca I*) conducted a systematic trial of survivorship of fish in different conditions using a large number of fish. The analysis was restricted to the data from this vessel, with the dependent variable being the probability of survivorship, and predictor variables being fish condition, depth of fishing, fish length and date. A binomial error model was assumed (Venables and Ripley, 1998). A smoothing spline was imposed on fish length, date and depth of fishing. A loess smoother gave practically identical results to the spline smoother.

The strongest and only significant influences on survivorship were condition and fish length (Table 3). The *Polarpesca I* reported 100% survivorship of fish in good condition (15 out of 15 fish), 83% (40 out of 48 fish) in average condition and 66% (27 out of 41 fish) in poor condition. Similarly high survivorship of fish in good condition was reported from the other vessels on which fish condition was recorded (*Argos Helena* – 89% (n = 28), *Koryo Maru No. 11* – 100% (n = 7) and *Isla Santa Clara* – 100% (n = 4)). The influence of length on survivorship was most significant for fish greater than 90 cm, with a suggestion that survivorship decreases quite markedly in animals larger than this size. This could be taken to confirm information from observers, who report that large fish are difficult to tag. However, it also might be an artefact of the experiment, arising from the added stress of confinement of large fish in small tanks, and it must be noted that there were relatively few fish in this size category.

Although fishing depth and date were not significant predictor variables, there was a suggestion that survivorship decreased as the season progressed, perhaps because of increasingly stressful conditions in the experimental tanks (Figure 3). Another possible explanation is that toothfish spawn in late July and August at South Georgia (Agnew et al., 1999), and their increasing maturity might have influenced their survivorship. It is possible that the depth effect was confused with the length effect, since the average length of fish did increase gradually with depth, from 75 cm below 1 000 m depth to 86 cm below 1 500 m depth. However, removing the length factor did not make depth significant in this GAM. Although there is a suggestion in Figure 3 that survivorship is better at shallower depths, perhaps because of less stress during the shorter hauling times from these depths, the sample size at these depths is small.

Discussion

To the best of the authors' knowledge, this is the first extensive experimental study of survivorship in toothfish, although toothfish survivorship post-tagging has always been assumed to be high. In the past it has been observed that toothfish have shown remarkable durability and tagged fish have been recovered that have often survived serious injuries, ranging from gaff puncture wounds in the head and jaw to missing eyes. Tagging studies around Heard Island have given a relatively high

Table 2: Results of the tag survival experiment, by vessel.

	n	Survivorship after 12 hours (%)
Argos Georgia	9	100
Argos Helena	37	84
Jacqueline	86	93
Koryo Maru No. 11	23	100
Polarpesca I	104	79
Protegat	109	94
Isla Santa Clara	16	100
Viking Bay	12	92

Table 3: ANOVA results from the exploratory generalised additive model (GAM) on the *Polarpesca I* data. The addition of fish condition and fish length (with smoothing spline signified by *s*) contributes significantly to improving the model fit (explaining significant amounts of the residual deviance), whereas date and depth do not add significantly to the model.

Full model	Additional predictor variable	Residual deviance	Significance
	Null	107	
Survival = condition + ε	+ condition	96	$P < 0.001$
Survival = condition + *s*(length) + ε	+ *s*(length)	84	$P < 0.05$
Survival = condition + *s*(length) + *s*(date) + ε	+ *s*(date)	77	NS
Survival = condition + *s*(length) + *s*(date) + *s*(depth) + ε	+ *s*(depth)	74	NS

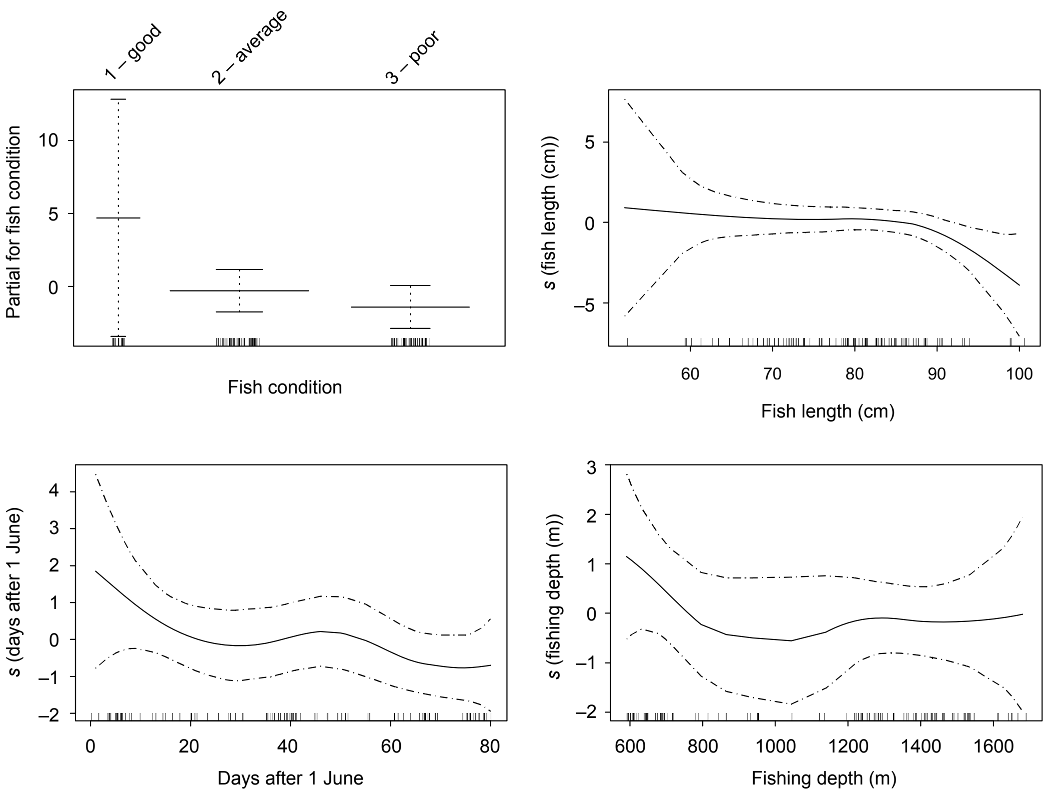

Figure 3: Plots showing the influence of different independent variables on survivorship within the generalised additive model of the *Polarpesca I* data. The separate plots show the normalised effect of each predictor variable on the survivorship estimated by the model, with 95% pointwise confidence intervals. The ticks along the x-axis show the position of individual data points.

recapture rate over several years, with some fish surviving several cycles of capture and recapture suggesting high ability to survive, but tagging is normally done under research rather than commercial conditions (D. Williams, pers. com.).

The results presented in this paper suggest that, like halibut (Kaimmer and Trumble, 1998), toothfish survivorship is significantly influenced by fish condition and size. Animals may be expected to experience greater stress, and lower survivorship, when confined to tanks on the deck of a vessel rather than being immediately released, especially when the tank is in an exposed position (Figures 1 and 2). Although average survivorship in this experiment was 90%, confirming the assumed value used in mark–recapture estimates of vulnerable toothfish biomass by Hillary et al. (2006), this is probably lower than one would expect in normal tagging operations, when only animals in good condition are used and the animals are not subjected to the additional stress of tanking. Excluding the *Polarpesca I* and *Argos Helena*, both of which included fish in poor condition in their sample, the six other vessels in the experiment reported an overall survivorship of 95%. The *Polarpesca I* experiment recorded 100% survivorship of animals in good condition. The survivorship recorded on the *Argos Helena* was lower than on the other vessels, and the high number of deaths of fish held between 12 and 24 hours on this vessel (Table 1) strongly suggests that poor tank conditions were a significant factor in this reduced survivorship.

Based on these results it is concluded that observers should be able to achieve survivorship rates of considerably higher than 90%, at least approaching 95%, if they use only animals in good condition and return them to the sea immediately after tagging. These survivorship rates are similar to the 96% assumed for longline-caught halibut in good condition (Kaimmer and Trumble, 1998). An assumption of 90% post-tagging survivorship is a conservative value which might be appropriate to use in population estimators until further survivorship studies have confirmed the 95% rate.

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