SHORT NOTE

MOVEMENT AND GROWTH OF TAGGED *DISSOSTICHUS ELEGINOIDES* AROUND SOUTH GEORGIA AND SHAG ROCKS (SUBAREA 48.3)

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Abstract

In 2000 the UK started a Patagonian toothfish (*Dissostichus eleginoides*) tagging program to investigate the spatial and temporal movement of fish and to validate otolith-based growth estimates. Approximately 2 260 toothfish have been tagged and released during groundfish surveys and CCAMLR observer trips. This includes about 900 that have been injected with either strontium chloride or oxytetracycline that places a permanent chemical marker on the otolith indicating the date of injection and release. To date, 51 fish have been recaptured, mostly around Shag Rocks where there is greatest fishing activity. Most of the fish recaptured to date were tagged and released during experimental pot fishing in 2000 and 2001, and have been at liberty from one to two years. Four fish were tagged and recaptured from the same longline vessel in 2002 after up to two months at liberty. The fish tagged during the groundfish surveys may not yet be large enough to be available to the longline fishery and there have been no reported recaptures of these fish tagged at South Georgia or elsewhere in the South Atlantic. Similarly, *D. eleginoides* tagged and released on the Patagonian Shelf have not been recaptured at South Georgia. Fourteen tags have been recovered from a high seas area on the Patagonian Shelf at 42°S after about one year at liberty from some opportunistic tagging carried out on a toothfish pot vessel in international waters at that latitude in 2001.

Résumé

En 2000, le Royaume-Uni a mis en place un programme de marquage de légine australe (*Dissostichus eleginoides*) pour étudier le déplacement spatio-temporel de ce poisson et valider les estimations de croissances fondées sur les otolithes. Quelque 2 260 légines ont été marquées et relâchées pendant les campagnes d'évaluation des poissons de fond et les campagnes des observateurs de la CCAMLR. Parmi elles, environ 900 ont subi une injection de chlorure de strontium ou d'oxytétracycline laissant une marque chimique permanente sur l'otolithe et indiquant la date de l'injection et de la relâche. A ce jour, 51 poissons ont été recapturés, pour la plupart autour des îlots Shag, site de l'activité de pêche la plus intense. La plupart des poissons recapturés à ce jour avaient été marqués et relâchés lors de la pêche expérimentale au casier de 2000 et 2001 et étaient donc en liberté depuis un ou deux ans. Quatre poissons ont été marqués et recapturés par le même palangrier en 2002 après deux mois de liberté. Les poissons marqués durant les campagnes d'évaluation du poisson de fond n'ont peut-être pas encore atteint une taille suffisante pour être la cible de la pêche à la palangre; aucune recapture de ces poissons marqués n'a été déclarée en Géorgie du Sud ou dans d'autres secteurs du sud de l'Atlantique. De même, *D. eleginoides* marqué et relâché sur le plateau de Patagonie n'a pas fait l'objet de recapture en Géorgie

du Sud. Quatorze marques ont été récupérées dans une zone de haute mer du plateau de Patagonie, à 42°S, un an environ après le marquage effectué au cours de la campagne de pêche à la légine d'un caseyeur en eaux internationales à cette latitude en 2001.

Резюме

В 2000 г. Соединенное Королевство приступило к выполнению программы по мечению патагонского клыкача (*Dissostichus eleginoides*) с целью изучения пространственного и временного перемещения рыбы и проверки оценок роста по отолитам. Примерно 2 260 особей клыкача было помечено и выпущено во время съемок придонной рыбы и рейсов наблюдателей АНТКОМа. Сюда включаются около 900 особей, которым была сделана инъекция либо хлористого стронция, либо окситетрациклина, оставляющих на отолитах постоянную химическую метку, по которой можно определить, когда была сделана инъекция и когда рыба была отпущена на волю. На сегодняшний день 51 особь была выловлена повторно, главным образом в районе скал Шаг, где ведется самая большая промысловая деятельность. Бóльшая часть повторно отловленной к настоящему времени рыбы была помечена и выпущена во время экспериментального ловушечного промысла в 2000 и 2001 гг. и находилась на воле от одного до двух лет. Четыре особи были помечены и вновь пойманы через два месяца одним и тем же ярусоловом в 2002 г. Особи, помеченные во время съемок придонной рыбы, вероятно, еще недостаточно велики для ярусного промысла, и пока не было зарегистрировано ни одного случая повторного вылова этой рыбы, помеченной в районе Южной Георгии или где-либо еще в Южной Атлантике. Аналогично этому, особи *D. eleginoides*, помеченные и выпущенные на шельфе Патагонии, не были повторно выловлены в районе Южной Георгии. Четырнадцать меток было получено на шельфе Патагонии в открытом море на 42°ю.ш. спустя почти год после того, как ловушечное судно, ведшее промысел клыкача, в 2001 г. провело мечение в международных водах на этой широте.

Resumen

En el año 2000 el Reino Unido comenzó un programa de marcado de la austromerluza negra (*Dissostichus eleginoides*) para estudiar el desplazamiento de peces en una escala espacial y temporal, y para convalidar las estimaciones del crecimiento basadas en la lectura de otolitos. Durante las prospecciones de peces demersales y los viajes de los observadores de la CCRVMA se marcaron y liberaron unos 2 260 ejemplares de austromerluza, incluidos unos 900 peces inyectados con cloruro de estroncio u oxitetraciclina. Estos compuestos dejan una marca indeleble en los otolitos, indicativa de la fecha de inyección y liberación. A la fecha se han capturado 51 peces marcados, en su mayoría alrededor de las Rocas Cormorán, zona donde se concentran las actividades de pesca. La mayoría de los peces capturados hasta ahora fueron marcados y liberados durante la pesca experimental con nasas realizada en 2000 y 2001, y por lo tanto estuvieron en libertad por uno o dos años. En 2002 cuatro peces fueron marcados y capturados por el mismo palangrero después de dos meses en libertad. Es posible que los peces marcados durante las prospecciones de peces demersales no sean lo suficientemente grandes como para ser capturados por la pesquería de palangre, y no se ha registrado la captura de estos peces marcados en Georgia del Sur o en otra parte del Atlántico sur. Del mismo modo, ningún ejemplar de *D. eleginoides* marcado y liberado en la plataforma patagónica ha sido capturado en Georgia del Sur. Se recuperaron 14 marcas de una zona de alta mar en la plataforma patagónica a la altura de los 42°S. Estas marcas fueron colocadas un año antes durante las operaciones de pesca de austromerluza con nasas efectuadas en 2001 en aguas internacionales, en dicha latitud.

Keywords: *Dissostichus eleginoides*, South Georgia, tagging, movement, growth, CCAMLR

INTRODUCTION

The tagging program is coordinated by the Marine Resources Assessment Group (MRAG) Ltd in London. To increase the likelihood of recaptured tags being reported and to minimise the potential for non-reporting of recaptured tags, posters, in English and Spanish, advertising the scheme and the reward for tag returns have been displayed in ports in South America, the Falkland/Malvinas Islands, and on vessels operating in the South Georgia toothfish longline fishery. Crew members who find and report tags to observers are rewarded with £5 or its equivalent per tag and also entered into a prize draw for £1 000.

The objectives of the tagging program are to:

- investigate the spatial and temporal movement of Patagonian toothfish (*Dissostichus eleginoides*) at South Georgia; and
- validate growth rate estimates.

The groundfish surveys have aimed to tag juvenile *D. eleginoides* in shallow water in order to determine the fishing area to which they recruit and the time-scale of this process. Tagging in the experimental and commercial fisheries around South Georgia aims to provide information on growth and the movement of fish between fishing grounds.

MATERIALS AND METHODS

Tagging around South Georgia in Subarea 48.3 began during the 2000 South Georgia groundfish survey where live *D. eleginoides* were sampled from bottom trawling (Pilling et al., 2000). Tagging has subsequently been carried out by CCAMLR observers on three experimental pot fishing vessels, three longlining vessels, and again by scientists on the 2002 South Georgia groundfish survey.

Groundfish Surveys

The 2000 survey targeted juvenile toothfish for tagging by carrying out three trawls in shallow waters approximately 135 m deep near Shag Rocks. During the 2002 survey, however, trawl depths ranged from 120 to 472 m and fish were tagged opportunistically as they became available, and 17 trawls provided fish suitable for tagging principally around Shag Rocks.

Both surveys used holding tanks into which live fish were carried from the codend and observed prior to tagging and release. *D. eleginoides* were individually removed from the holding tank for measuring total length and weight (using marine scales), tagging and marking. Fish were tagged with uniquely numbered Hallprint 'T-bar' tags indicating a reward for the return of the tag on recapture as well as address, fax and email details. Tags were inserted into the muscle between the second and third second dorsal fin-rays that provided a secure anchoring position. Fish were then immediately returned to the holding tank prior to release close to the location of capture using pipes that allowed fish to enter the water submerged.

In 2002 fish were injected with a solution of strontium chloride ($SrCl_2$ buffered to pH 8) at a concentration of approximately 0.2 g/ml of Sr^{2+} using 5 ml syringes fitted with 40 mm needles. Subcutaneous injections were made at a dosage of 0.5 ml/kg of body weight equating to a concentration of 100 mg Sr/kg fish. The needle was inserted beneath the scales 1–2 cm below the dorsal midline on the opposite flank to which the tag was inserted. The solution provides a clear mark, indicative of the injection date, in the otoliths. This addition to the tagging program will improve growth rate estimates derived from otolith ageing techniques based on annual growth increments.

Pot Fishing

Experimental pot fishing was undertaken in 2000 and 2001 by one Uruguayan and two UK vessels. While catch rates were not high enough for fishing companies to pursue this method commercially, fish caught by pots are generally recovered in good condition with minimal damage from fising gear and are suitable for tagging and release. A large T-bar and a large dart tag were inserted either side of the anterior part of the dorsal fin. The fish were also large enough to accommodate two tags and this was done so that recapture rates are less affected by the bias that would occur following tag loss. Fish were also measured for total length. Fish mass was generally not recorded as it only increases the handling, time out of the water and stress for the fish in return for an approximate spring balance measurement that does not provide useful data for growth comparisons on recapture. It was also impractical to set up marine scales on deck where tagging took place.

Fish were released through a PVC pipe which was fitted to the side of the vessel. The bottom end of the pipe was submerged under the surface keeping tagged fish out of reach of the larger seabirds such as giant petrels and wandering albatrosses in the vicinity of the vessel.

Longliners

D. eleginoides caught by longline are generally not in as good a condition to tag and release as those caught either by pots or survey trawls, and fish are often seen with distended stomachs from water intake during hauling. Most vessels also have hook separators that rip the hooks from the fish when they are hauled aboard, often causing damage to the lips and eyes. Fish for tagging therefore have to be cut off the snoods before getting to the hook separator, although hook damage can still occur depending on the hauling distance out of the water and weight of fish. In 2001, a few *D. eleginoides* were sampled where haul conditions were favourable (e.g. shallower depth, expected sizes were smaller and hook damage was avoided) and also from deep water. In 2002, however, an observer noted that there appeared to be no relationship between the depth fished and the condition and liveliness upon hauling (Passfield, pers. comm.).

Some of the *D. eleginoides* tagged on longliners in 2002 were also injected with oxytetracycline (OTC) at a standard dosage level of 25 mg/kg of body weight (Gelsleichter et al., 1998). As with the use of strontium chloride on the groundfish survey, OTC provides a clear enduring chemical mark, indicative of the injection date, in most otoliths (Beamish and McFarlane, 2000).

Recaptured *D. eleginoides* are sampled for length, weight, sex and maturity. Otoliths are also taken where possible and the data including the date and position may be reported to MRAG Ltd via CCAMLR observers who are present on the vessels or, if the vessel is outside Subarea 48.3, by other observers or the vessel owners.

Comparisons of the size and date at release with that at recapture, and age estimates from otoliths, allow estimates of growth to be validated. In this analysis, three growth curves are used to predict an age at first capture from length at first capture, and age at recapture is calculated using the time at liberty for each fish. Von Bertalanffy growth parameters used are based on: (i) toothfish caught by longliners around South Georgia (Ashford et al., 2002); (ii) longlining and pots in Subarea 48.3 (SC-CAMLR, 2001); and (iii) toothfish caught in waters from the southern New Zealand Exclusive Economic Zone (EEZ) south to Subarea 88.1 (Horn, 2002).

RESULTS

Tagging Numbers and Distribution

A total of 360 toothfish were tagged and released from the three targeted tows near Shag Rocks during the 2000 survey. During the 2002 survey, 682 toothfish were tagged opportunistically from the randomised trawl survey and one deepwater haul (500 m) that caught larger toothfish (60–80 cm) for tagging. During the first experimental pot fishing cruise from March to May 2000, a total of 135 *D. eleginoides* were tagged and released by observers around the northwest, north and east of Shag Rocks as well as west, north and east of South Georgia (Table 1). On board the same vessel, a further 44 toothfish were tagged in January 2001 east of Shag Rocks where most fish were deemed too small for processing and would normally have been discarded by the factory crew, and 216, ranging in size from 51 to 130 cm, were caught and tagged in October 2001 northeast and southwest of Shag Rocks. An additional 80 fish were also tagged and released around South Georgia on pot fishing vessels by other observers in this year (Figure 1). One vessel that left the South Georgia maritime zone continued pot fishing in international waters between 41°–42°S and 57°–58°W (Figure 2) and an additional 274 *D. eleginoides* were tagged in this area. In the 2002 fishing season, a total of 401 *D. eleginoides* was tagged and released from longliners mainly west and southwest of South Georgia around the 1 000 m depth contour and ranging from 48 to 117 cm in length. The advantages and disadvantages of each tagging platform are provided in Table 1.

Recaptured Tags

To date 51 tagged *D. eleginoides* have been reported as being recaptured, 30 from Shag Rocks, 7 from around South Georgia and 14 from around 42°S. Figure 2 shows the distribution of recaptured tags and indicates the distances from release to recapture locations. To date there have been no recaptured tags where the fish was chemically marked as these were generally of sizes that are, as yet, unlikely to be available to the longline fishery (46 cm average).

Subarea 48.3

The majority of recaptured *D. eleginoides* have been caught around Shag Rocks at similar depths to the release locations, which is consistent with the number of fish tagged and released in this area and the greater concentration of fishing activity compared with other areas around South Georgia. It is also consistent with the findings of Williams et al. (2002) that fish have not been recaptured far from their release locations. Of 37 fish recaptured around South Georgia, 28 (76%) were within 25 km of their release location. Two fish, however, had

Table 1: Summary of *Dissostichus eleginoides* tagging activities in Subarea 48.3 by fishing method and area.

	Groundfish Surveys		Pots		Longliners	
	South Georgia	Shag Rocks	South Georgia	Shag Rocks	South Georgia	Shag Rocks
Number Tagged						
2000	..	360	77	58	..	..
2001	..	..	146	194	..	7
2002	73	609	..	..	230	171
Total	73	971	223	252	230	178
Depth range (m)	183–472	120–375	276–1317	200–1560	375–1580	325–1390
Average length (cm)	63	36	72	66	76	77
Modal length (cm)	59	33	72	59	81	77
Length range	43–81	16–73	51–130	42–114	51–105	40–117
Number and percentage recaptured	..	..	3 (1.3%)	30 (11.9%)	4 (1.7%)	..
Advantages	Able to tag large numbers. Juveniles tagged.		Very good condition fish. Large and small fish tagged from a wide depth range.		Accessible fishery for tagging, targeted fish and high catch rates. Even shallow-caught fish have recruited to fishery.	
Disadvantages	Long delay from tagging to recruitment of fish into fishery increases potential for tag loss. Relatively shallow-water tagging only. Possible damage from fishing gear.		Not a commercially attractive fishing method. Low catch rates.		Many fish suffer hook damage.	

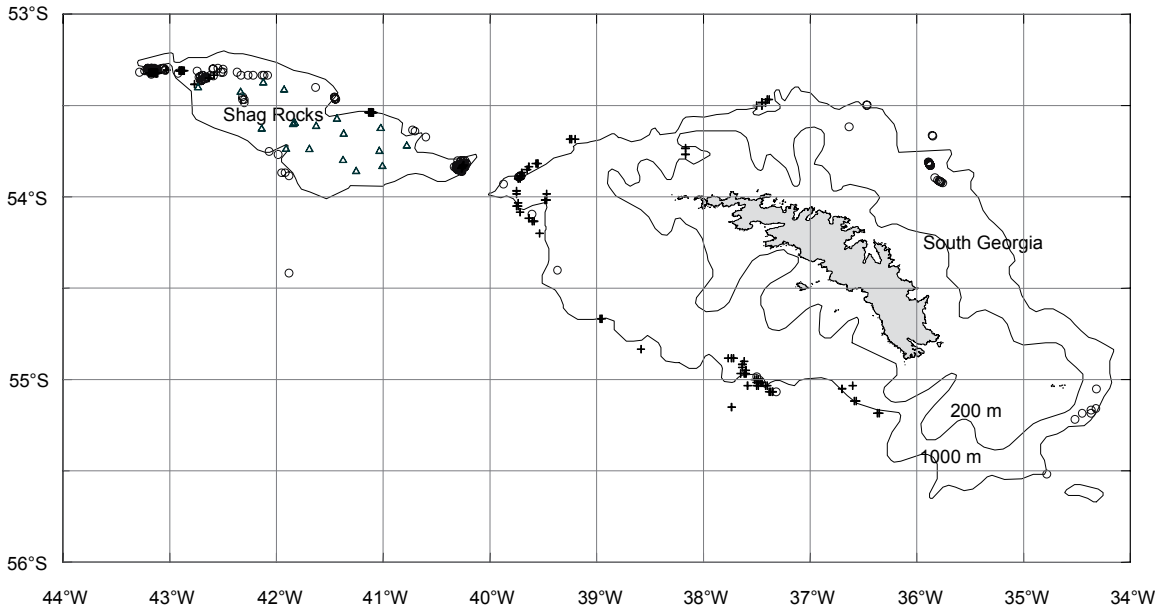

Figure 1: Tagging locations by survey trawls (Δ), experimental pot fishing (o) and longliners (+) in Subarea 48.3 from 2000 to 2002.

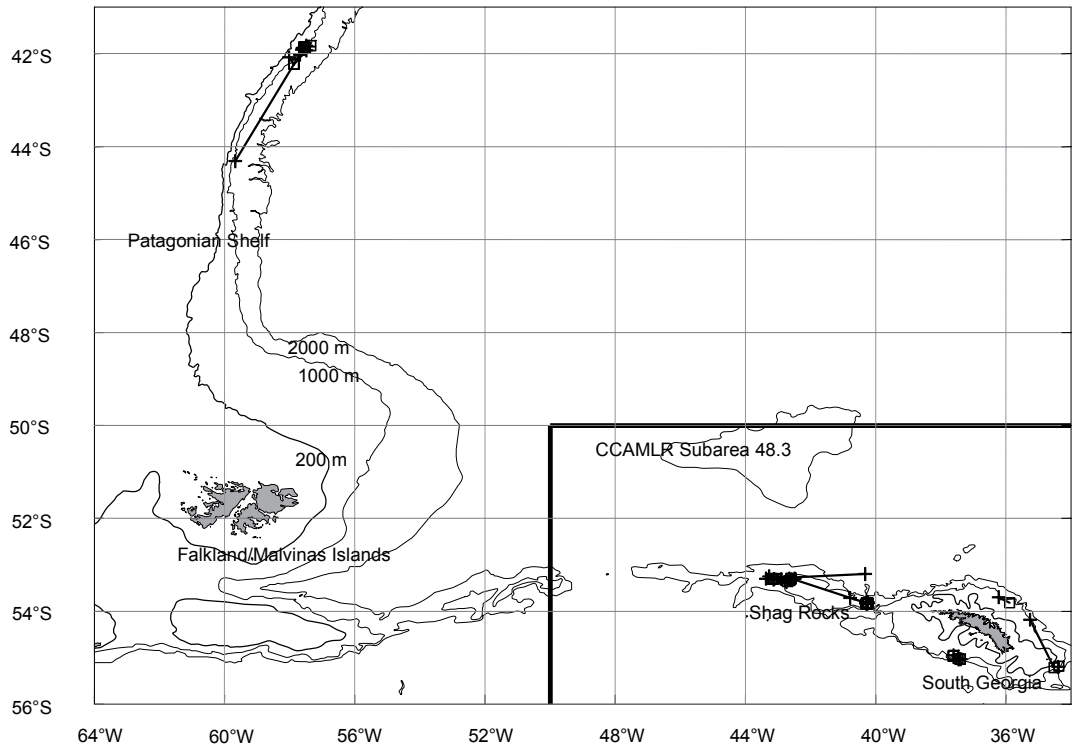

Figure 2: Vectors between release (□) and recapture (+) locations for tagged *Dissostichus eleginoides* in the Southwest Atlantic.

moved 192 and 163 km, moving southeasterly and easterly respectively towards South Georgia (Figure 2).

Two fish recaptured east and northeast of South Georgia had also moved further from the release locations in a northwesterly direction around the island consistent with the direction of prevailing currents around the islands. Figure 3 shows the distances moved against days at liberty for the recaptured tags in these areas.

In 2002 one vessel recaptured four line-caught fish tagged during the same observer trip. Three of these were recaught at depths over 1 100 m and all four fish appeared to be in good condition, with any hook damage observed in the 39 to 71 days after capture having healed completely. This adds to results from the Ross Sea for *D. mawsoni* (Smith and Bond, 2001) and *D. mawsoni* and *D. eleginoides* in Subareas 88.1 and 88.2 (Hanchet et al., 2002) that longline-caught fish survive after release.

Patagonian Shelf

Tagging on a pot fishing vessel in international waters at 42°S during June and July 2001 has, to date, resulted in 14 (5.1%) of the 274 fish released being recaptured. Most of the fish recaptured were relatively close (less than 20 km) to the release locations on the shelf break (approximately 58°S 42°W). One tag, however, was recaptured at a reported location 322 km from its point of release after 217 days at liberty, and another at a distance of 46 km after 409 days. Both tag movements were consistent with the direction of the Brazil Current although no observers were present to confirm the exact recapture locations.

Growth

The size range of recaptured fish ranges from 54 to 90 cm, averaging 69 cm, which is consistent with the sizes targeted by longliners around South Georgia. Figure 4 shows the difference in total length between release and recapture against days at liberty for the 33 fish where measurements were possible on recapture. Some fish exhibited no change or reduced length in up to 270 days at liberty, owing to the measurement method (lengths were recorded to the nearest cm below) and/or the reduced growth rate due to the effects on biology of the tagging process relative to untagged fish (McFarlane and Beamish, 1990).

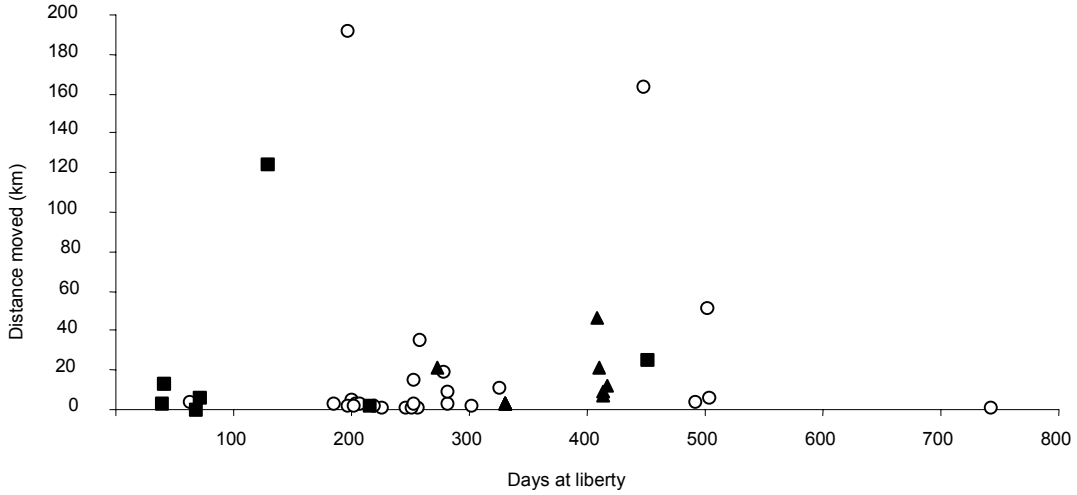

Figure 3: Distance moved from release to recapture location (km) by number of days at liberty for fish tagged around Shag Rocks (o), South Georgia (■) and Patagonian Shelf at 42ºS (▲).

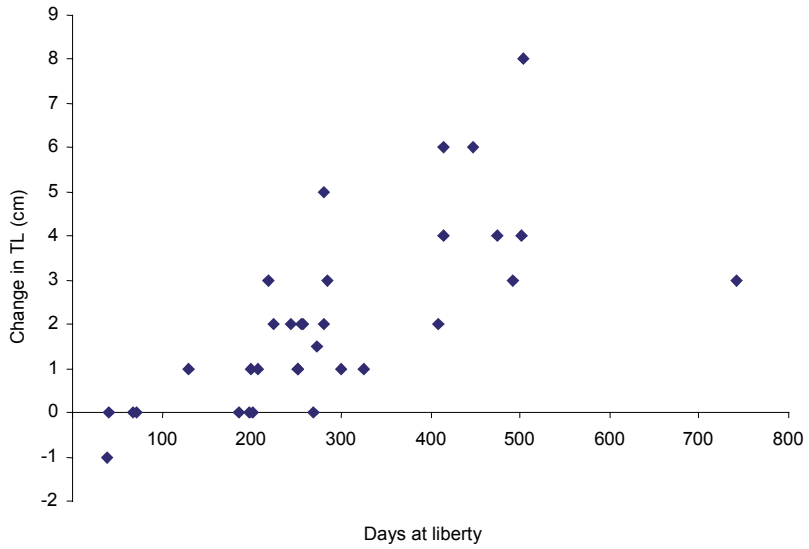

Figure 4: Change in total length of recaptured tagged fish in the South Georgia fishery.

Figure 5 superimposes the observed growth of these fish and the mean growth predicted by three growth curves mentioned above. It can be seen that all growth curves are overestimating the rate of growth of males, although the Ashford et al. (2002) growth curve (a) is the closest match to the data from tagging.

DISCUSSION

All recaptured *D. eleginoides* to date were originally tagged and released from pot fishing or longline vessels. None tagged on the 2000 and 2002 groundfish surveys have yet been recaptured. It is likely that these have not yet recruited to the longline fishery. The modal lengths of tagged fish of 32 cm and 33 cm from the 2000 and 2002 surveys respectively indicate that most of the fish are unlikely to be available to this fishery until at least the 2003 season when they should reach sizes targeted by longliners. Currently, therefore, there is no information on patterns of migration of recruiting fish, nor on their growth rates.

As yet there is no independent estimate of the mortality rate of released fish. Although trawled *D. eleginoides* were selected for liveliness and observed in holding tanks prior to release, they

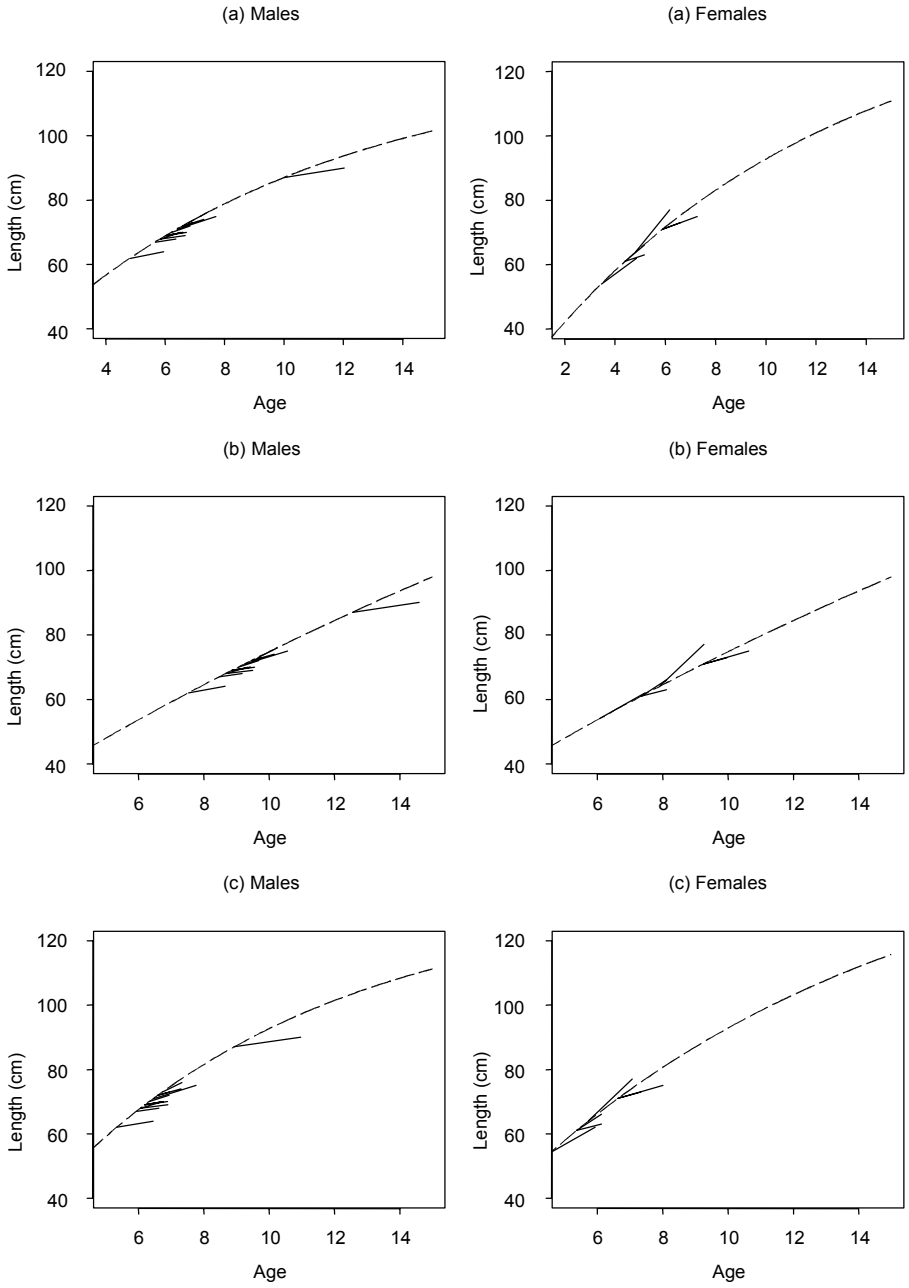

Figure 5: Age–length growth differentials in recaptured *Dissostichus eleginoides* by sex based on three von Bertalanffy growth parameters (a–c). The dashed line is the predicted length at age, the solid lines are the growth of individual tagged fish.

may be subject to greater distress and internal bruising than those caught with pots. Longlined *D. eleginoides* are also prone to hook damage and the distress from hauling may similarly cause released fish to survive less well than those tagged and released from pots. However, Williams et al. (2002) reported good recovery results from the tagging of *D. eleginoides* in the Heard Island fishery (Division 58.5.2). Their results suggest that most fish survive capture and release from trawling at depths similar and greater to those from the South Georgia groundfish surveys. Recaptured fish had also been at liberty for up to three years, again indicating that the numbers tagged during the surveys may yet become available to the fishery from 2003 onwards. Similarly, Smith and Bond (2001) expect that longline-tagged fish will have reasonable survivorship, although they also regard smaller fish (<95–100 cm) as being more likely to survive. The results presented in this paper and

those of Williams et al. (2002) indicate that fish of 80–90 cm can be expected to survive and be recaptured.

Fifty percent of tagged *D. eleginoides* have had two tags inserted and some of these samples have been recaptured with both tags still attached. Tag loss is therefore estimated to be low and Hanchet et al. (2002) also report the excellent condition of a tag insertion point on a recaptured *D. mawsoni* after one year at liberty.

Owing to the potential reduction in fish growth from the effects of an external tag, McFarlane and Beamish (1990) urge caution in extrapolating from tagged to untagged populations. While growth data from recaptured tags suggest that unit growth rates may be too high for South Georgia, those derived by Ashford et al. (2002) appear to be more appropriate, particularly for females, which exhibited greater average growth over comparative times at liberty than males.

There is little evidence for large-scale fish migrations at South Georgia as most fish were recaptured a few kilometres from their release locations. This is similar to the findings of Williams et al. (2002) around Heard Island where fish dispersed short distances up to 15 n miles. There was no apparent relationship between fish size and distance moved or days at liberty.

The tagging program and reward system have been publicised in the Falkland/Malvinas Islands, Uruguay and Argentina. While the presence of CCAMLR observers assists with the reporting of recaptures, reported recaptures by three non-CCAMLR vessels at 42°S provide some confidence that, were tagged fish being caught in Falklands/Malvinas or Argentine waters or high seas areas, they would also be reported. Recaptures of fish tagged at 42°S in international waters confirm this, with few of these animals moving very far. Although this does not prove that the population in Subarea 48.3 does not interact with Patagonian Shelf populations, if such movement takes place it has not yet been detected by the tagging program.

CONCLUSION

Results to date indicate that the tagging from potting and longlining platforms has been successful. Survey-tagged *D. eleginoides* from 2000 and 2002 are expected to recruit to the longline fishery and further tagging will take place on subsequent trawl surveys around South Georgia. Following the success of tagging trials on longliners in 2002, a major expansion of the program will be carried out by 10 CCAMLR observers in the 2003 South Georgia fishery.

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Liste des tableaux

Liste des figures

Список таблиц

Список рисунков

Рис. 5: Разница в росте (возраст–длина) между полами для повторно выловленных особей *Dissostichus eleginoides* на основе трех параметров роста по Берталанфи (a–c). Пунктирной линией показана прогнозируемая длина по возрастам, сплошными линиями – рост отдельных помеченных особей.

Lista de las tablas

Tabla 1: Resumen de las actividades de marcado de *Dissostichus eleginoides* en la Subárea 48.3 de acuerdo con el método y área de pesca.

Lista de las figuras

Figura 1: Lugares de marcado durante las prospecciones de arrastre (Δ), durante la pesca experimental con nasas (o) y durante la pesca de palangre (+) en la Subárea 48.3 de 2000 a 2002.

Figura 2: Vectores entre los lugares de liberación (□) y captura posterior (+) de ejemplares de *Dissostichus eleginoides* marcados en el Atlántico suroeste.

Figura 3: Distancia recorrida entre la liberación y la captura posterior (km) por número de días en libertad para los peces marcados alrededor de las Rocas Cormorán (o), Georgia del Sur (■) y plataforma patagónica (▲) en el paralelo 42°S.

Figura 4: Variación de la longitud total de los peces marcados y capturados en la pesquería de Georgia del Sur.

Figura 5: Coeficiente diferencial entre la edad y el crecimiento de *Dissostichus eleginoides* marcado y vuelto a capturar, por sexo, sobre la base de tres parámetros de crecimiento de von Bertalanffy (a–c). La línea entrecortada representa la talla por edad esperada, las líneas continuas representan el crecimiento individual de los peces marcados.