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Incidental catch amounts and potential post-release survival of winter skate (*Leucoraja ocellata*) captured in the scallop dredge fishery in the southern Gulf of St. Lawrence (2006-2008)

Quantité de prises accidentelles et survie éventuelle après le rejet à la mer des raies tachetées (*Leucoraja ocellata*) capturées lors de la pêche de pétoncles à la drague dans le sud du golfe du Saint-Laurent (2006-2008)

Hugues P. Benoît, Douglas P. Swain, Monique Niles, Stéphan LeBlanc and Leslie-Anne Davidson

Gulf Fisheries Centre
Fisheries and Oceans Canada
343 avenue Université
P.O. Box 5030, Moncton, New Brunswick
E1C 9B6

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ABSTRACT

Winter skate (*Leucoraja ocellata*) in the southern Gulf of St. Lawrence were designated as endangered by the Committee on the Status of Endangered Wildlife in Canada in May 2005. A recovery potential assessment undertaken that year concluded that high adult mortality was responsible for the declines in abundance. There has been no directed fishery for winter skate in the area, and estimated bycatch in groundfish and shrimp fisheries was very low. However, the impact of discarding in the southern Gulf of St. Lawrence scallop (*Placopecten magellanicus*) fishery on winter skate mortality could not be quantified at the time due to a lack of information on incidental catches. Because there is considerable spatial-temporal overlap between the scallop fishery and the distribution of winter skate, there is potential for elevated fishing-induced mortality. In this report we present results from at-sea sampling of fish bycatch in the southern Gulf scallop fishery undertaken in 2006-2008, including the number, size, location of capture and post-discard survival potential of incidentally caught winter skate. Most winter skate captured in the scallop fishery were released alive and in very good condition, suggesting that post-release survival is high. Based on observed catches and estimates of discard survival, the estimated mean annual exploitation rate (percentage of the population killed) over the study period is 0.14% for juvenile winter skate and 0.06% for adults. This fishing-induced mortality is very small compared to mortality from other sources.

RÉSUMÉ

En mai 2005, la raie tachetée (*Leucoraja ocellata*) du sud du golfe du Saint-Laurent a été désignée espèce en voie de disparition par le Comité sur la situation des espèces en péril au Canada (COSEPAC). Une évaluation du potentiel de rétablissement réalisée en 2005 a permis de conclure que la diminution de l'abondance était attribuable au taux élevé de mortalité chez l'adulte. Aucune pêche ciblant la raie tachetée n'a été faite dans la région, et les estimations de prises accessoires de cette espèce lors de la pêche au poisson de fond et à la crevette étaient très faibles. Toutefois, l'incidence des rejets à la mer dans le sud du golfe du Saint-Laurent par la pêche au pétoncle géant (*Placopecten magellanicus*) sur le taux de mortalité de la raie tachetée n'a pu être quantifiée à cette époque en raison du manque d'information sur les prises accidentelles. Puisqu'il existe un chevauchement spatio-temporel considérable entre la pêche au pétoncle et la répartition de la raie tachetée, le risque de mortalité attribuable à la pêche est élevé. Dans le présent rapport, on présente les résultats d'un échantillonnage, effectué en mer de 2006 à 2008, des prises accessoires par l'industrie de la pêche au pétoncle dans le sud du golfe, notamment le nombre de captures, la taille, l'emplacement et le potentiel de survie après le rejet en mer des raies tachetées capturées. La plupart des raies tachetées capturées lors de la pêche au pétoncle ont été relâchées vivantes et en très bon état, ce qui suggère que le taux de survie après le rejet est élevé. À la lumière des prises observées et des estimations du nombre de raies ayant survécu après le rejet en mer, on estime que le taux annuel moyen

d'exploitation (le pourcentage de la population tuée) pour la période d'étude était de 0,14% pour les raies tachetées juvéniles, et de 0,06% pour les raies adultes. Le taux de mortalité attribuable à la pêche est donc très bas comparativement à la mortalité provoquée par d'autres sources.

INTRODUCTION

In May 2005, winter skate (*Leucoraja ocellata*) in the southern Gulf of St. Lawrence (sGSL, NAFO Div. 4T) and on the eastern Scotian Shelf (Div. 4VW) were designated as endangered and threatened, respectively, by the Committee on the Status of Endangered Wildlife in Canada. Subsequently a recovery potential assessment (RPA) was undertaken to provide information on current status and trends, and to evaluate the impact of human activities and other threats to the species, as well as the potential for recovery (DFO 2005; Swain et al. 2006 a,b). The only anthropogenic threat that could be evaluated in detail in the RPA was capture of winter skate in demersal fish and shrimp fisheries (Benoît 2006; DFO 2005; Swain et al. 2006a,b). For southern Gulf winter skate, population modeling revealed that estimated exploitation rate (proportion of individuals removed) in those fisheries was very low for juveniles (≤0.01) and had declined from around 0.16 in 1971 to <0.05 in the 2000s for adults (Swain et al. 2006a, 2009). The trend in adult exploitation rate since 1971 is opposite to the increasing trend in total mortality (Z), and recent removals represent a negligible portion of Z. The sources of the remaining mortality of adults may include predation and human-induced mortality not incorporated in the models.

Bycatch in sea scallop (*Placopecten magellanicus*) fisheries was identified in the RPA as a potential unaccounted human-induced source of winter skate mortality (DFO 2005). In New England, scallop dredging has accounted for roughly 50% of fishery discards of skates (Sosebee and Terceiro 2000). In the southern Gulf of St. Lawrence there is considerable overlap in the spatial distribution of winter skate (Fig. 1; Clay 1991; Benoît et al. 2003; Darbyson and Benoît 2003; Swain et al. 2006b) and the scallop fishery during the fishing season (Fig. 2). Both are concentrated along the northeast New Brunswick coast from western Prince Edward Island (P.E.I.) to Miscou and along the southern shore of Baie des Chaleurs, at the eastern end of the Northumberland Strait southeast of P.E.I., and around the Magdalen Islands. The overlap suggests there is considerable scope for fishing mortality of winter skate, though prior to the RPA, there was no information available on the bycatch of fishes in the commercial scallop fishery of the southern Gulf. Following the RPA, a three year at-sea observer project was implemented to assess the quantity, species composition and condition (i.e., degree of injuries and potential for post-release survival) of incidentally captured fish and invertebrate species in that fishery. In this report we present results from that sampling for winter skate, including the number, size, condition and location of capture of incidentally caught individuals. Using these data we estimate the total number of winter skate caught in the southern Gulf of St. Lawrence scallop fishery in 2006, 2007 and 2008. We then evaluate the discard mortality of winter skate in the southern Gulf scallop fishery in light of other components of mortality affecting the productivity of the population.

METHODS

Directed observation is likely the only reliable manner of collecting information on the amount and species composition of fishery discards in most instances. Self-reported data such as those contained in harvester logbooks are typically not a suitable replacement for data collected directly by government or third-party at-sea observers (e.g., Walsh et al. 2002; H. Benoît, unpublished analyses; but see Stanley et al. 2009). Prior to 2006 there had been no at-sea observer program that quantified incidental catches in the scallop fishery in scallop fishing areas (SFA) 21 to 24 (Fig. 2). In 2006, 2007 and 2008 at-sea observers were deployed on a small number of scallop fishing trips to obtain quantitative samples of the biota captured by scallop dredges during commercial fishing activities. A total of 24 trips were sampled, distributed among the SFAs (21 to 24) roughly in proportion to fishing activity (Fig. 2; Table 1). The locations where scallop fishing is concentrated have changed little over the years since at least the 1980s (L.-A. Davidson, unpublished results).

Vessels for observation were selected randomly from the list of fish harvesters in each SFA that were both active in the fishery and which had interacted with the Department of Fisheries and Oceans Canada (DFO) Science Branch in the years leading up to the sampling. Willingness to carry an observer was completely voluntary, though there were no outright refusals on the part of contacted fish harvesters. Over the course of the study, 20 out of 326 active vessels were sampled. At-sea observers were DFO Gulf Region Science staff and technicians on contract with the Maritimes Fishermen's Union.

For each fishing set during the selected fishing trips, observers noted the geographic position and time of day at the beginning and end of the set, the depth fished, the vessel's fishing speed and the total number of winter skate captured (see Appendix I for the protocol used). In all but one set over the 3-year study, observers also undertook detailed sampling of individual captured winter skate, measuring their length (cm), visually assessing their vitality on a four level ordinal scale (Table 3) and visually assessing degree of injury on a three level ordinal scale (Table 4). Semi-quantitative assessment of vitality (and injury) has been used in a number of discard survival studies, and when it has been combined with survival estimates based on either tagging of discarded fish (e.g., Hueter and Manire 1994; Richards et al. 1995; Kaimmer and Trumble 1998) or aquarium holding of fish (Benoît and Hurlbut, 2010), ordinal scores have been found to correspond well with eventual relative survival.

In 2007, scallop dredging was undertaken in a number of plots at a site in the Northumberland Strait and another in Baie des Chaleurs (Fig. 2), as part of an experiment aimed at understanding the short and long term impacts of dredging on benthic biodiversity (S. LeBlanc, MS in prep.). The species incidentally captured during the experimental dredging were sampled in the same manner as those caught in the commercial fishery. The results for winter skate are presented here in support of the results from the commercial fishery sampling, though only the latter were used in estimating total discarded amounts of winter skate.

Discard Estimation

Design-based estimation was used to calculate total winter skate discards, rather than model-based estimation using a covariate such as target species catch or fishing effort (Rochet and Trenkel 2005; Cotter and Pilling 2007). Design-based estimation is preferable, amongst other reasons, because it doesn't require making assumptions about the relationship between bycatch amount and the covariate (Rochet and Trenkel 2005). The individual fishing trip was treated as the sampling unit in the estimation because that was the level at which the decision to sample or not was made (recall that winter skate catch was recorded for all sets during observed trips). The point estimate for total discards used the standard estimator for stratified random sampling (e.g., Krebs 1989, p. 213-216), with SFAs as strata. Because complete sampling of all SFAs was only achieved when the three sampling years were pooled, the estimator for the number of winter skate discarded in year *y*, $\hat{D}_y$, was defined as follows:

Eqn 1. $$\hat{D}_y = \sum_{s}^{S} \left(T_{sy} \cdot \frac{\sum_{y=2006}^{2008} \sum_{i=1}^{o_{sy}} w_{isy}}{\sum_{y=2006}^{2008} o_{sy}} \right)$$ where $$y \in (2006, 2007, 2008)$$ $$s \in (21A, 21B, 21C, 22, 23, 24)$$

T_{sy} is the total number of scallop fishing trips in SFA *s* and year *y* (Table 2) obtained from DFO's zonal interchange file format database (ZIFF; database which combines landings and logbook data), w_{isy} is the total number of winter skate observed during trip *i* in *s* and *y*, and o_{sy} is the total number of observed trips in *s* and *y*. Because there is no dockside monitoring of the scallop fishery in the southern Gulf, landings and fishing effort data are based on sales slips and reports provided by the harvesters, and T_{sy} may therefore not be entirely accurate. The extent to which the number of reported and actual trips differs is unknown and may result in an unknown bias in the estimates.

The estimator for the standard error from a stratified random sampling design (e.g., Krebs 1989, p. 215) could not be used because there was only a single sampled trip in three of the strata and only two sampled trips in a third stratum (Table 1). Instead, 95% confidence intervals around $\hat{D}_y$ were constructed using an unrestricted bootstrap of all sampled trips (Efron and Tibshirani 1993). In each iteration, 24 trips were selected with replacement from the sampled trips. A simple arithmetic mean winter skate catch rate calculated over all selected trips was then applied to the total number of trips across SFAs 21 to 24 to yield a bootstrapped value of total winter skate discard. Using such an unrestricted bootstrap, the variance component resulting from regional differences in winter skate catches that results from differences in abundance between SFAs, is incorporated in the estimated 95% confidence intervals for total catch. The confidence intervals will therefore be wider (i.e., more conservative) than they would otherwise be under proper stratified random estimation. Based on simulations of the stability of estimated confidence limits as a function of the number of bootstrap iterations, 5000 iterations were deemed amply sufficient to properly characterize the confidence intervals (Fig. 3).

It is important to note that estimating total fishery discards from observations made on a subset of trips implies that observed trips directly or conditionally (given some sort of adequate model) approximate a random sample of all trips (Cotter and Pilling 2007; Benoît and Allard 2009). For this assumption to be met, observers must be deployed to fishing activities in an unbiased manner. Furthermore, the presence of an observer must not influence the fishing procedures (e.g., set duration, fishing locations, etc). Failure to meet the assumption of random sampling can result in biased estimates of discards and improperly characterized uncertainty surrounding those estimates (Cotter and Pilling 2007; Benoît and Allard 2009). In the present study, the deployment of observers was not truly random (fish harvesters drawn from a list that itself represented a subset of active fish harvesters), though it may be that the activity of those fish harvesters was in practice random with respect to other fishing trips and harvesters in the SFA. The effect on our estimates is unquantifiable with the data at hand. Furthermore, given that the fish harvesters were aware of the study's objective to quantify winter skate catches and of the potential ramifications of listing winter skate under the Species-at-Risk Act (general prohibition on harming listed species leading to closures of fisheries that capture the species), some may have modified their operations to minimize skate catches, though this too is unquantifiable. These caveats should be borne in mind when interpreting the results presented here.

Post-capture Survival Experiments

Experiments were undertaken in 2005 and 2006 aboard the *CCGC Opilio* to relate 'pre-release' vitality codes (Table 3) of captured fishes to short term survival, in a number of fish taxa (Benoît and Hurlbut 2010). Fish were captured using a bottom trawl (286 Rock-hopper) rigged for commercial fishing and following common commercial fishing tow speed (2.75 knots) and set duration (1-2 hrs). When fish were brought aboard the vessel, they were handled as they would be on a commercial fishing vessel and sampled in the same manner as the observers would during the commercial fishery: measured for length and vitality assessed. Fish were then individually tagged and placed in onboard refrigerated holding tanks (each 310 gal) containing continuously exchanged sea water. Tank temperatures were set to the bottom temperatures where the fish were captured. Fish were held for at least 48 hrs to assess short term survival. Fish surviving the entire holding period were released alive. A total of 152 skates (4 winter skate; 22 smooth skate, *Malacoraja senta*; and 126 thorny skate, *Amblyraja radiata*) were included in the experiments. Data for these three species were pooled to calculate the percentage of skates in each vitality code category that survived at least 48 hrs after being captured. Though the results were obtained in experiments using a bottom-trawl and considerably longer set durations than those used in the scallop fishery, survival estimated as a function of vitality code from those experiments should be generally valid for the present study (i.e., the biggest difference in survival potential between the fisheries should be reflected in the frequency distributions of vitality code, not code-specific short-term survival).

Update of Estimated Winter Skate Catch Numbers and Mortality

The population dynamics of winter skate had previously been modeled for the period 1971-2004 (Swain et al. 2006a, 2009). For the present study, estimates for the 2006-2008 period of winter skate abundance, exploitation rate in fisheries other than the scallop fishery and natural mortality were required. These were obtained by refitting the Swain et al. (2009) model using additional recent data from the annual September bottom-trawl survey of the southern Gulf (details on the survey methodology in Hurlbut and Clay 1990) and estimates of winter skate bycatch in other fisheries (see Benoît 2006). Previously, Swain et al. (2006a, 2009) estimated the natural mortality (M) of juvenile and adult winter skate in decadal blocks (1970s, 1980s and 1990s to 2000s). For this study, M was estimated in four blocks: 1970s, 1980s, 1990 to 2004 and 2005 to 2009. The 2005 to 2009 block was included to provide an estimate of M for the period covered by the 2006 to 2008 scallop fishery bycatch study. Details on the model, the fitting process and model evaluation are available in Swain et al. (2009).

RESULTS

A total of 624 fishing sets (19 minute mean set duration) in 24 trips (1 trip/day) were observed in the commercial scallop fishery in SFAs 21 to 24 during 2006 to 2008. There were approximately 1,300 fishing trips undertaken in each of 2006 and 2007 and approximately 1,100 trips in 2008 in these SFAs (Table 2). Most fishing sets in both the commercial fishery and experimental dredging caught no winter skate, and those sets that did catch them typically caught one or two individuals (Fig. 4a). Summing over sets, over half of commercial fishing trips caught no winter skate (Fig. 4b). The remaining trips generally caught one to four winter skate (Fig. 4b), though 30 individuals were captured in one trip off western P.E.I. (Fig. 2; Table 1). The largest and most frequent daily catches of winter skate occurred in SFA 22 (Northumberland Strait) (Fig. 2, Table 1), the area in which winter skate have been particularly concentrated in recent years (Swain and Benoît 2007). The frequency distributions of winter skate catches were similar in the commercial fishery and experimental dredging.

Based on the observed catches, the estimated total number of winter skate captured in the sampled southern Gulf scallop fisheries in SFAs 21 to 24 was 3,779 (95% C.I., 701 to 5,793) in 2006, 3,830 (703 to 5,810) in 2007 and 3,392 (590 to 4,876) in 2008. These estimates correspond to an average bycatch rate of 3.0 winter skate per trip in the fishery. By comparison, the bycatch rate during experimental dredging was 1.9 winter skate per day of fishing (equal to approximately one trip).

Scallop fishing also takes place in the southern Gulf outside the SFAs studied here, mainly along the northern shore of Baie des Chaleurs and east of Gaspé, with some fishing around the Magdalen Islands. Fishing in these areas represented on average 21.8% of annual scallop fishing trips in 2006 to 2008 according to records in the ZIFF database (Table 2). Based on catches in the annual multi-species bottom trawl survey, winter skate are only occasionally found and in low concentrations along the north shore of Baie des Chaleurs and around the Magdalen Islands during the late summer (Benoît et al. 2003). Though the bycatch rate of winter skate in scallop fishing in these areas is unknown, we assumed the same rate as in SFA 21 to 24 as a reasonable value. Prorating the estimated winter skate catches in SFAs 21 to 24 to account for scallop fishing in other areas yields estimated total catches for the southern Gulf of 4,832 (95% C.I., 896 to 7,408) winter skate in 2006, 4,898 (899 to 7,430) in 2007 and 4,338 (754 to 6,235) in 2008.

The sizes of winter skate captured in both the commercial fishery and during the experimental dredging varied between approximately 15 to 60 cm, with a mode in the upper 30 cm (Fig. 5). These sizes are comparable to the sizes of skates captured in bottom-trawl fisheries in the southern Gulf (Swain et al. 2006b). Based on the sizes observed in the scallop fishery and a length-weight relationship from the annual survey of the southern Gulf ($\log_{10}$weight = -2.204 + 2.966$\log_{10}$length), the average weight of a winter skate caught in the scallop fishery in 2006 to 2008 was approximately 0.266 kg. The total biomass of winter skate captured in 2007, for example, in the southern Gulf scallop fishery was therefore approximately 1.3 t (95% C.I. 0.2 to 2.0 t). By comparison, the average estimated catch of winter skate in southern Gulf groundfish and shrimp fisheries in 2007 was 7.7 t (95% C.I. 4.0 to 13.0 t) (H. Benoît, unpublished results obtained following the methodology of Benoît, 2006). In the Bay of Fundy and southwest Nova Scotia (SFA 29), estimated catch of winter skate in the scallop fishery ranged from 0.04 to 1.5 t annually over the period 2001 to 2008 (Table 5 in Smith et al. 2009).

Winter skate captured in scallop dredges in the southern Gulf are generally in excellent or very good physical condition prior to being released (Table 5). Approximately 84% of individuals were observed to be in excellent condition (i.e. vitality score 1) and about 8% in good condition (score 2). In the commercial fishery the remainder of the fish had a vitality score of 3, whereas in the experimental dredging the remaining fish included one moribund individual. The frequency distribution of vitality codes for skates observed in the scallop fishery is very comparable to the one predicted for bottom-trawl fisheries when fish spend little time on the vessel deck prior to being discarded (H. Benoît, manuscript in prep.), as is the case in the scallop fishery. A majority (74%) of observed winter skate appeared injury-free and approximately 6% suffered major injuries mainly involving bruising, cuts or partially torn wings (Table 5).

Fish that were released while in good condition and with minor injuries only were observed to readily swim away from the vessel and towards the bottom (A. Nadeau pers. comm..; S.

LeBlanc and M. Niles, pers. observations), indicative of low impairment of stimulus response. Behavioural response impairment in other fishes has been associated with elevated post-capture mortality (e.g., Davis and Ottmar 2006; Davis 2007; Humborstad et al. 2009). Based on the 2005 to 2006 post-release survival experiments, the 48-hr survival rate of skates in vitality categories 1 and 2 was 100% and for those in category 3 it was about 62% (Table 5). The short-term survival rate of skates in vitality category 4 was 42% (i.e., some apparently dead individuals nonetheless survived), though in the bottom-trawling experiments these were individuals with few injuries that had experienced prolonged deck times. By contrast, in the experimental dredging, the one observed moribund individual had been crushed by rocks and was very unlikely to survive when released. Based on the results of the vitality code sampling in the scallop fishery and the short-term survival experiments, the average short-term survival of discarded winter skate in the scallop fishery is estimated to be about 97%. While there may be some additional delayed mortality resulting from injuries sustained as a result of capture by the dredges (e.g., Davis 2002), generally this delayed mortality is considerably smaller than the mortality observed during the first 24 to 48 hrs following capture (H. Benoît, unpublished analyses). Based on available information, it would be reasonable and likely conservative to assume that overall discard survival of winter skate in the southern Gulf scallop fishery is 90%. In contrast, the survival rate of winter skate discarded in groundfish and shrimp fisheries was set at 30% in the RPA (Swain et al. 2006a), based on information available at the time (Benoît 2006).

The RPA assessed the status, trends and threats to juvenile and adult winter skate separately. Winter skate ≥42 cm were considered to represent the adult portion of the population, based on recent observations for females and males in the southern Gulf (J.M. Hanson, DFO Moncton, pers. comm.). Using this same cutoff, approximately 82% of winter skate captured in the scallop fishery would be considered juveniles. Based on the estimated total winter skate bycatch in the scallop fishery in SFAs 21 to 24, an additional 21.8% of fishing trips outside those SFAs and a 90% survival rate, the estimated number of winter skate killed in the 2007 southern Gulf scallop fishery (the year with the highest mean catches in our study) is 402 juveniles (95% C.I., 74 to 600) and 88 adults (16 to 132) (Table 6). The mean number of winter skate in the population in 2007, estimated using the Swain et al. (2009) model, was 274,700 juveniles (95% credibility interval, 60,800 to 793,400) and 205,151 adults (111,600 to 355,200) (Table 6). Using the upper confidence interval (i.e., a conservative estimate) for the number of juvenile and adult winter skate killed in the scallop fishery that year, we estimate an average 2007 exploitation rate (percentage lost) of 0.22% for juveniles and 0.06% for adults (Table 6). Estimated in this manner, the average annual exploitation rates for the 2006 to 2008 period were 0.14% for juveniles and 0.07% for adults. Even if a more conservative approach is used, estimating the average annual exploitation rates for the period 2006 to 2008 using the lower credibility interval for the estimated abundance of juveniles and adults and the upper confidence interval for mortality in the scallop fishery, the estimated losses as a percentage of the estimated populations are still very small at 0.69% for juveniles and 0.13% for adults.

The annual natural mortality of winter skate can be estimated by subtracting estimated losses of winter skate caught in the scallop, groundfish and shrimp fisheries, from the estimated total annual mortality. This natural mortality includes losses due to processes such as predation and disease, as well as unaccounted human-induced mortality. Based on the updated values of population size (as per the model of Swain et al. 2009), the estimated mean natural mortality of winter skate in 2007, expressed as a percentage of total abundance, was 75% for juveniles and 34% for adults. The bycatch mortality of both juvenile and adult winter skate in the southern Gulf scallop fishery therefore appears to be very small relative to natural mortality.

DISCUSSION

Based on our analyses of available data and using conservative assumptions, we conclude that the fishing mortality of winter skate captured incidentally in southern Gulf scallop fisheries is presently very small, particularly compared to mortality from other causes. Though we have attempted to incorporate different sources of uncertainty and to compensate or adjust for sources of bias affecting the estimates, some likely remain. For example, non-random sampling of fishing activities and a failure to account for all fishing activities (i.e., T_{sy} in eqn. 1) would certainly affect our estimates, though it is highly unlikely that their effect would be so strong as to increase our estimated number of captured winter skate by the two orders of magnitude required to make the fishing mortality an important component of total mortality.

The results of vitality sampling, post-capture survival experiments and observations of released winter skate all suggest that the potential survival of discarded individuals in the scallop fishery is high. This result is perhaps not surprising in the context of the literature on discard mortality. Discard mortality is known to increase with the amount of time a fish spends out of water, and the depth and duration of the fishing set, amongst other factors (Davis 2002; Suuronen 2005; Broadhurt et al. 2006). In the southern Gulf scallop fishery, conditions relative to these factors would be considered favourable for high discard survival. Education of fish harvesters on handling procedures favourable to good survival could further reduce fishing mortality in this fishery, and might constitute a simple measure amongst others taken to promote recovery. Additional mitigation measures aimed at reducing the catch of winter skate, such as gear modifications (e.g., Walsh 2008; DFO 2009) and spatial closures in areas with high bycatch rates could be contemplated. However, their costs to harvesters in terms of modifying equipment, potentially decreased catch per unit effort and lost fishing opportunities would need to be considered in light of the minor benefit to reduced overall adult mortality.

In this report we have examined and evaluated the evidence concerning the extent to which bycatch of winter skate in the southern Gulf scallop fishery may be adversely affecting the current recovery potential of the species. We have not addressed the question of the extent to which bycatch mortality in this fishery contributed historically to the considerable decline in adult winter skate abundance since 1971. With the data at hand, we feel it is impossible to do so because there are many reasons to suspect that the exploitation rates estimated for 2006 to 2008 cannot be applied to the past. While it is generally accepted that fishing mortality will be proportional to fishing effort, provided that catchability of a species to a fishery is constant (e.g., Ricker 1940; Ricker 1975), past levels of effort are not well known (though assuredly higher than the present day) and catchability of winter skate has likely changed. Factors that would contribute to a change in catchability include changes in gear configuration and typical operating practices, changes in the timing (season) or location of the fishery and density dependent habitat shifts of the bycaught species (for a recent review, see Wilberg et al. 2010). All of these factors have changed over time in the southern Gulf, though their contribution to winter skate catchability change (direction and magnitude) is unknown. For example, areas closed to scallop fishing were introduced in southern Gulf nearshore waters over a number of years, including most recently to nearshore areas in the Northumberland Strait in 2005 (Fig. 6; Davidson et al. 2007). The introduction of these areas effectively concentrated fishing effort in existing fishing grounds. Winter skate occur in those closed areas, though their relative distribution and catchability between fished and closed areas are unknown and it is impossible to speculate whether the spatial shift in the fishery resulted in an overall increase, decrease of no change in catchability.

Finally, the 2005 RPA for winter skate on the Scotian Shelf also identified fishing mortality in the local offshore scallop fishery as a potential source of unaccounted human-induced mortality. At this stage it would be premature to conclude that the results for the southern Gulf of St. Lawrence also apply there. The scallop fishery on the Scotian Shelf occurs in deeper waters and different habitat compared to the southern Gulf fishery. The bycatch rate of winter skate and the potential survival of discards estimated in the Gulf may therefore not be applicable. Recent information on the incidental catch of winter skate in Scotian Shelf nearshore scallop fisheries is available elsewhere (Smith et al. 2009).

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Table 1. Summary of the observed fishing activities in the southern Gulf of St. Lawrence commercial scallop fishery (2006 to 2008) by scallop fishing area (SFA).

Date (YYYYMMDD)	SFA	Site	Observed fishing sets	Fishing effort (hours)	Winter skate (numbers)
20070626	21A	Petit-Rocher NB	22	8.6	0
20080716	21A	Petit-Rocher NB	16	4.9	0
20060711	21A	Pointe-Verte NB	22	10.0	0
20080708	21A	Pointe-Verte NB	25	8.8	0
20080728	21A	Pointe-Verte NB	21	8.6	1
20080729	21A	Pointe-Verte NB	23	9.8	3
20070704	21A	Salmon Beach NB	16	11.1	0
20070705	21A	Salmon Beach NB	13	4.9	0
20080624	21B	Miscou NB	7	5.0	0
20060727	21C	Val-Comeau NB	10	9.3	0
20060509	22	Cape Tormentine NB	31	9.8	0
20080507	22	Cape Tormentine NB	28	7.0	0
20080508	22	Cape Tormentine NB	32	8.3	3
20080515	22	Cape Tormentine NB	30	8.1	1
20080522	22	Egmont Bay PEI	19	5.5	30
20060531	22	Miminegash PEI	18	7.4	1
20080603	22	Miminegash PEI	27	7.9	4
20060516	22	West Point PEI	31	10.0	1
20070724	23	Milligan’s shore PEI	23	10.9	0
20071108	24	Pictou NS	46	10.5	1
20081125	24	Pictou NS	41	9.9	4
20081128	24	Toney River NS	56	8.8	0
20071031	24	Wood Islands PEI	48	8.2	0
20081031	24	Wood Islands PEI	19	3.2	0

Table 2. Annual number of fishing trips (2006 to 2008) in each scallop fishing area sampled in the study (i.e., SFA 21 to 24) and in other scallop fishing areas in the southern Gulf of St. Lawrence, based on records in DFO's ZIFF database.

SFA	2006	2007	2008
21A	210	277	172
21B	150	115	141
21C	13	20	10
22	687	701	634
23	9	13	8
24	239	186	136
other	397	340	302
total	1705	1652	1403

Table 3. Description of the codes used to qualify the vitality of captured fishes during commercial and Sentinel survey fishing trips.

Vitality	Code	Description
Excellent	1	Vigorous body movement; no or minor external injuries only
Good / Fair	2	Weak body movement; responds to touching/prodding; minor external injuries
Poor	3	No body movement but fish can move operculum; minor or major external injuries;
Moribund	4	No body or opercular movements (no response to touching or prodding)

Table 4. Description of the codes used to qualify the degree of injury of captured fishes during commercial and Sentinel survey trips.

Injury	Code	Description
None	1	No bleeding, torn operculum or noticeable loss of scales
Minor	2	Minor bleeding or minor tear of mouthparts or operculum or moderate loss of scales (i.e. bare patch)
Major	3	Major bleeding or major tearing of the mouthparts or operculum or everted stomach or bloated swim bladder

Table 5. Number (N) and percentage of observed winter skate in each of four vitality categories and three injury categories in the commercial scallop fishery sea-sampling and during experimental scallop dredging. Also presented is the percentage of skates in each vitality category that survived a 48 hr holding period following experimental bottom trawling as described by Benoît and Hurlbut (2010).

	Vitality code	N	%	48-hr survival	injury	N	%
Commercial fishery							
	1	41	83.7	100%	1	36	73.5
	2	4	8.2	100%	2	10	20.4
	3	4	8.2	62.5%	3	3	6.1
	4	0	0	42.1%			
Experimental							
	1	62	82.7		1	54	73.0
	2	10	13.3		2	20	27.0
	3	2	2.7		3	0	0
	4	1	1.3		NA	3	-
	NA	2	-				

Table 6. Estimated annual mean number of winter skate killed (95% confidence interval), population abundance (95% credibility interval) and exploitation rate for juvenile and adult southern Gulf of St. Lawrence winter skate in 2006-2008. Two estimates of exploitation rate are presented based on the ratio of the upper confidence interval for the bycatch losses of juvenile and adult winter skate and either i) the mean estimated population abundance or ii) the lower credibility interval of the estimated population abundance.

		Year	
	2006	2007	2008
Juveniles			
Bycatch loss (numbers)	396 (73-607)	402 (74-600)	356 (62-511)
Abundance (thousands)	612 (116-1,687)	275 (61-793)	311 (73-802)
Exploitation rate i)	0.10%	0.22%	0.16%
ii)	0.52%	0.99%	0.70%
Adults			
Bycatch loss (numbers)	87 (16-133)	88 (16-132)	78 (13-112)
Abundance (thousands)	179 (86-328)	205 (112-355)	174 (87-310)
Exploitation rate i)	0.07%	0.06%	0.06%
ii)	0.16%	0.12%	0.13%

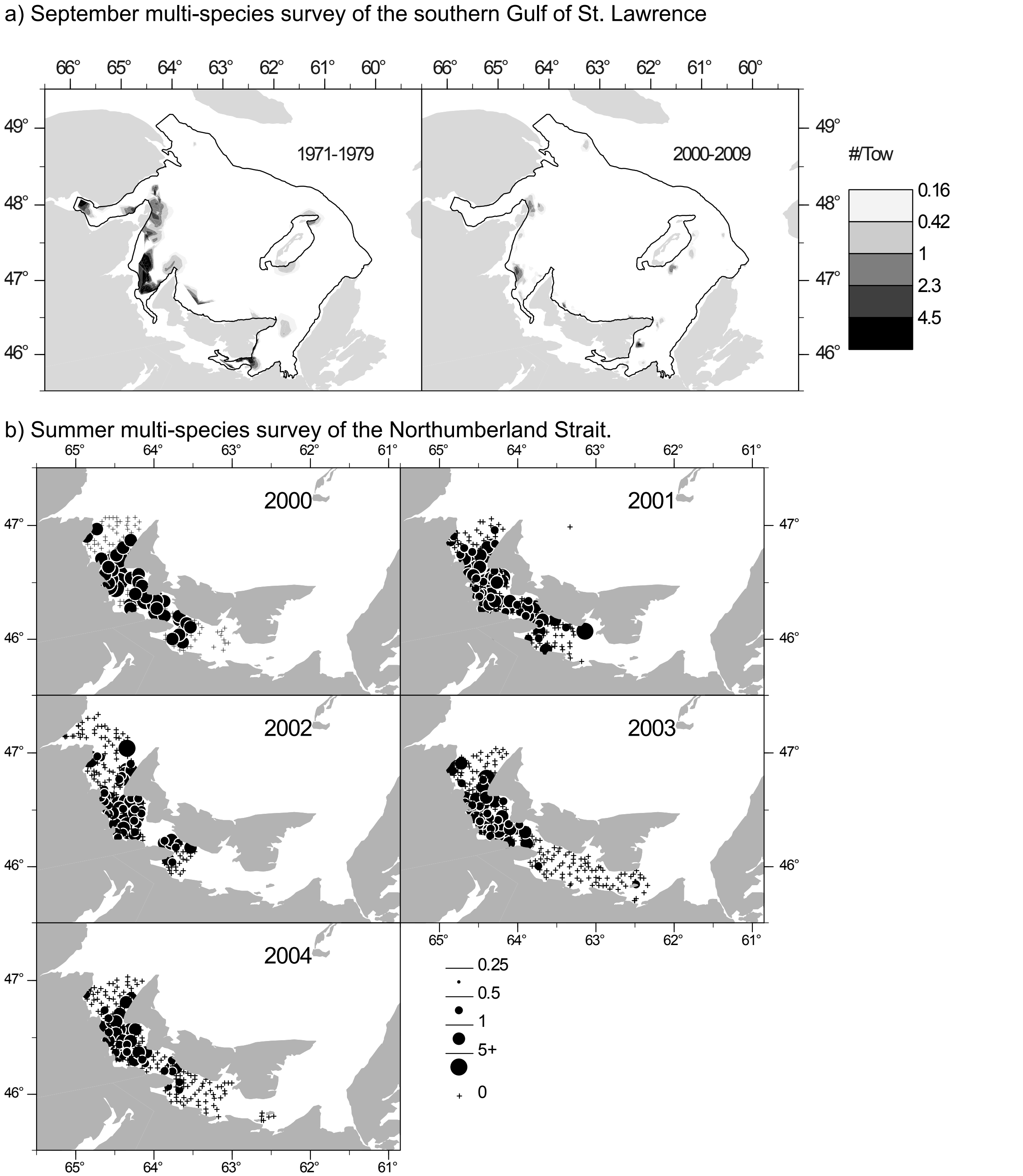

Figure 1. Catches of winter skate in multispecies surveys of a) the southern Gulf of St. Lawrence in the 1970s and the 2000s, and b) the Northumberland Strait in 2000 to 2004. Contours in (a) represent the 10th, 25th, 50th, 75th and 90th percentiles of the number of winter skate captured per tow for non-zero catches in the southern Gulf survey from 1971 to 2009. The solid line in (a) defines the survey area. The expanding circles in (b) represent the number of winter skate captured per km towed, the '+' indicate a null catch. See Swain et al. 2006b for details on the surveys.

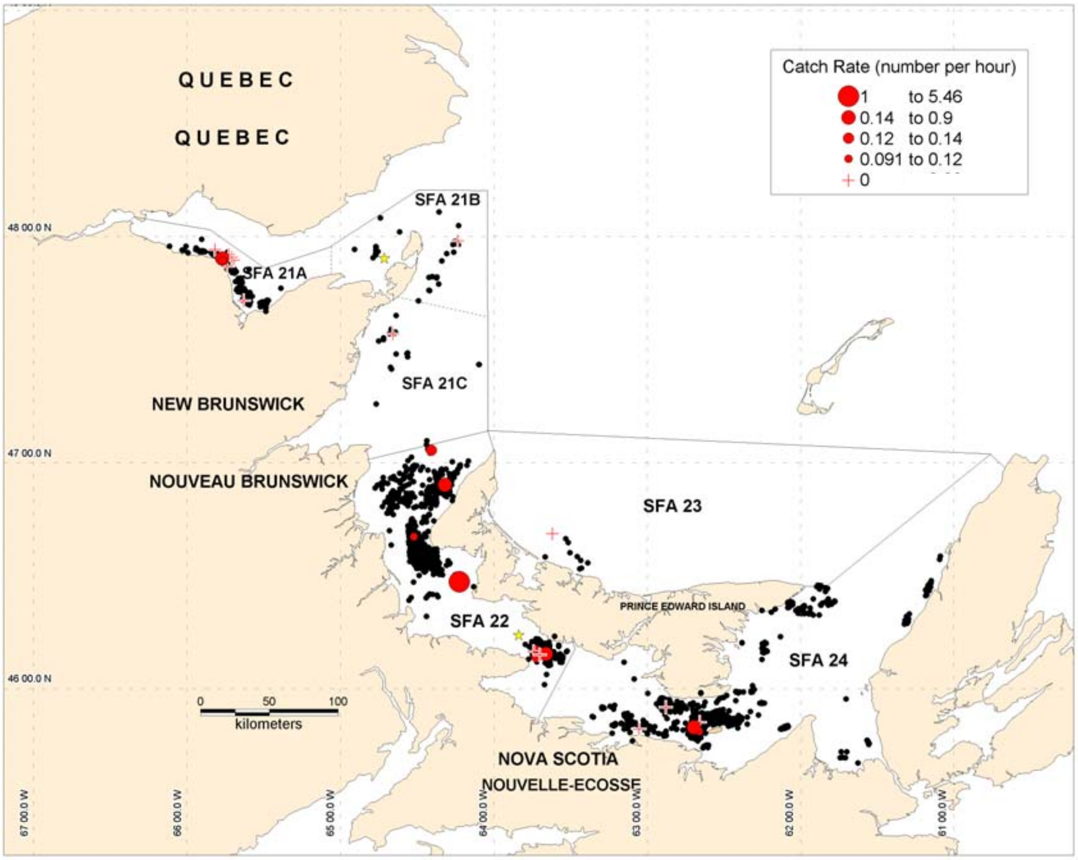

Figure 2. Location of commercial scallop fishing trips (2006 to 2008) from fish harvesters' logbooks (black dots), location of sampled fishing trips (red circles and crosses) and location of experimental fishing sites (yellow stars). The relative size of the red circles corresponds to the winter skate catch rate (individuals/hour of fishing) during individual observed commercial fishing trips, crosses indicate null catches. Solid lines delineate the six scallop fishing areas (SFA) that were sampled.

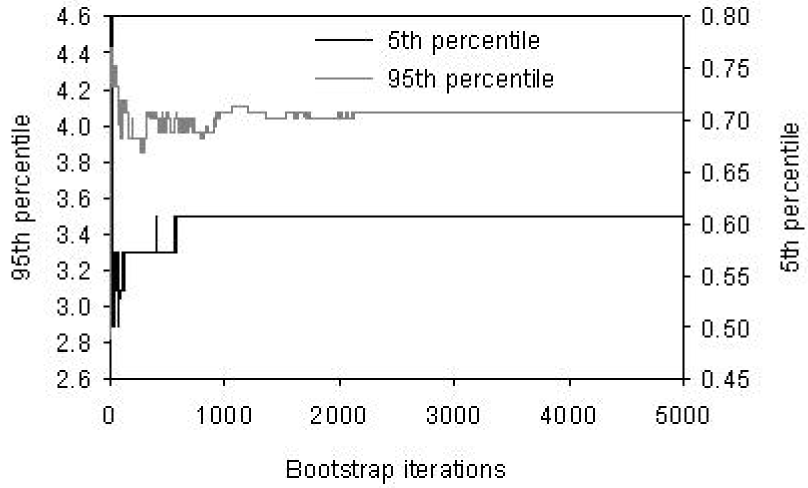

Figure 3. Estimate 5th and 95th percentiles of the distribution of winter skate bycatch rate (individuals/trip) from bootstrap simulations, as a function of the number of bootstrap iterations in a simulation. The 5th and 95th percentiles were chosen for computational simplicity in the simulation, whereas the 2.5th and 97.5th percentiles were used to calculate the confidence intervals for the actual discard estimates in the study.

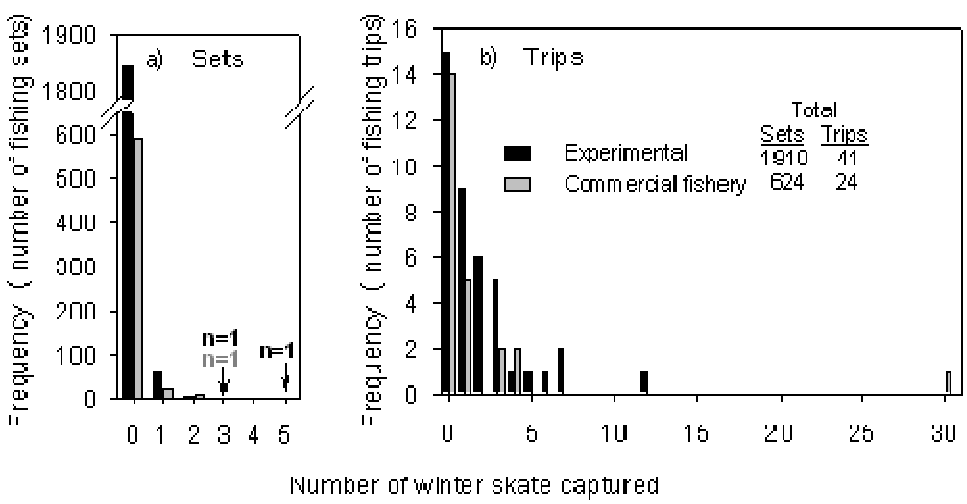

Figure 4. The frequency distribution by a) set and b) trip of winter skate catches during observed commercial fishing activities (grey bars) and during experimental dredging (black bars). A day of experimental dredging was considered a 'trip'.

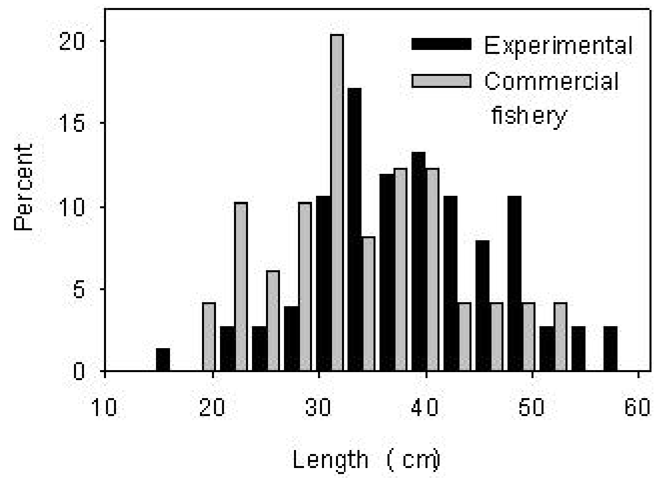

Figure 5. The length frequency distribution of winter skate captured during observed commercial fishing activities (grey bars) and during experimental dredging (black bars).

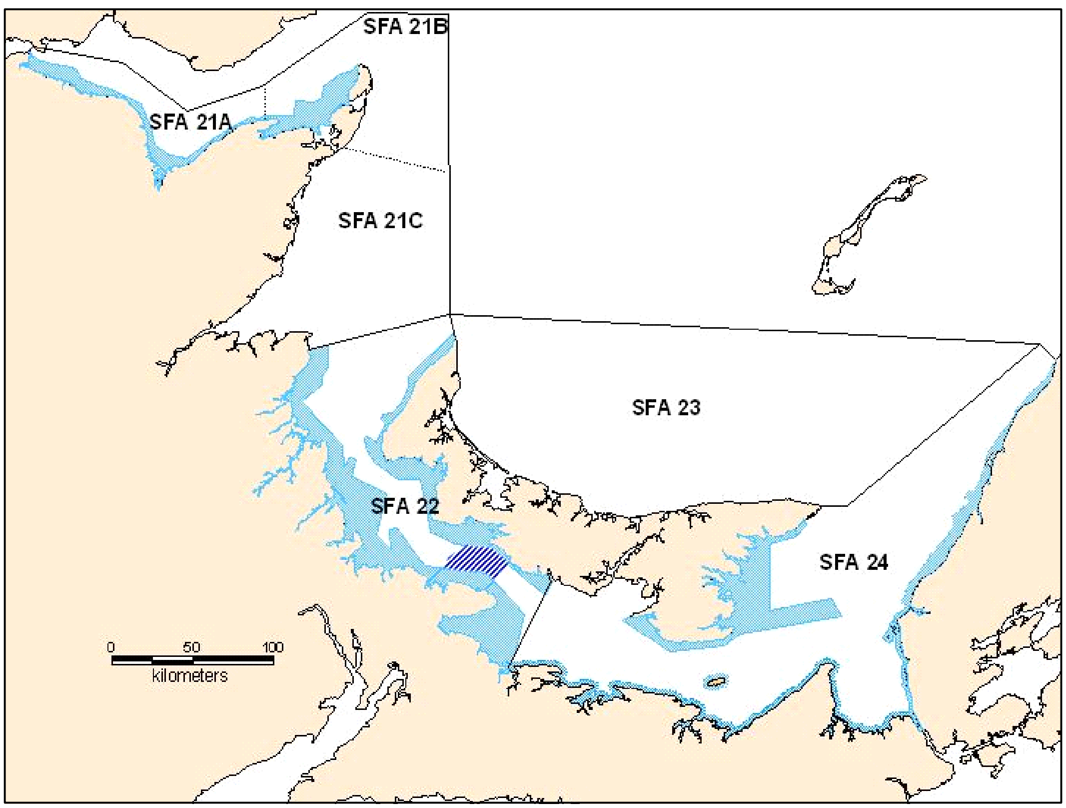

Figure 6. The location of areas presently closed to scallop fishing (lightly shaded areas) in SFAs 21 to 24. The area identified by dark (blue) hatching in the Northumberland Strait was temporarily closed, starting in 2005.

Appendix I. Protocol for the at-sea multi-species sampling of scallop dredge catches (2006-2008).

Purpose:
To obtain quantitative samples of the biota captured and retained by scallop dredges during commercial fishing activities. The intention is to be able to scale-up those catches from sampled trips to all commercial scallop fishing trips for the southern Gulf of St. Lawrence to arrive at global estimates of catches and discards.

Frequency of trips sampled:
The aim is to sample a small number of scallop fishing trips in scallop fishing areas within the southern Gulf:

i. SFA 22 (Eastern Northumberland Strait): May 1- early June 3.
ii. SFA 21a, b (Baie des Chaleurs): late June - early August 6.
iii. SFA 21c (Miramichi) : mid June – early September.
iv. SFA 23 (Northern P.E.I.): a summer and fall season
v. SFA 24 (Western Northumberland Strait-Gulf Nova Scotia) : November-December.

In principle, the vessel and dates sampled in each SFA should be chosen randomly from all possible scallop fishing trips. *In practice*, at-sea samplers should try and sample throughout the fishing season in each SFA and should cover a number of different vessels from the major fishing ports. While it should be the target, simple random sampling of trips is not possible as not all fish harvesters will be willing to take a sampler aboard and logistical constraints will restrict where and when at-sea samplers are available to go aboard vessels.

Sampling:
For the purpose of this protocol, a dredge set is the activity from the time the dredge is deployed in the water, dragged along the bottom to harvest scallops, brought back aboard the vessel and the contents emptied on deck prior to redeploying.

For each dredge set, the at-sea sampler should record the following information on the waterproof “ACTIVITY AND CATCH FORM” provided:

1. Vessel number (CFVN)
2. Date
3. Sampler’s name
4. Time for the beginning of the set (when it is deployed from the vessel) and at the end (using a 24h00 clock)
5. Latitude and longitude at both the start and end of the set (in decimal degrees)
6. Vessel speed during dredging (in knots)
7. Depth fished, if available
8. Set number (numbering should begin at 1 for the first set of the day)

Once it is brought aboard, the at-sea sampler should sort the contents of the catch by species (or to the lowest taxonomic classification possible), also separating rocks, wood and miscellaneous inorganic matter (e.g. garbage). Taxonomic guides will be provided for the identification of the biota. Rocks should be separated roughly into three categories:
(1) boulder; >256 mm,
(2) cobble; 64-256 mm,
(3) gravel; 4-64 mm.

Empty shells should be separated into the major taxonomic groups and recorded separately (e.g., “empty scallop shells”).

Each taxon or other component of the catch should be recorded on a separate line of the ACTIVITY AND CATCH FORM. Up to 35 separate species from a single set can be recorded on one form. If more than 35 species are captured in a set, an additional form should be used.

Once the species are separated, the sampler should obtain the total catch weight for each species using a basket or bucket and a properly tared spring scale. Weights of small catches (<0.5 kg) may not be accurately measured using a spring scale, and the sampler should estimate the catch weight and check-off the box in the following column. Where fewer than 50 individuals of a species were captured, they should be counted and recorded. For catches with more than 50 individuals, the number caught can be estimated and the box in the following column should be checked-off. Samplers need only record the observed or estimated weight of rocks, wood or miscellaneous inorganic matter. For rocks, samplers should weigh one bucket or basket full of rocks and visually estimate the weight of all rocks (e.g. if the basket weighs 25 kg and there are approximately 6 baskets worth of “gravel” the sampler should record 150 kg). A similar estimate of total weight can be used for empty shells as it may not be practical to sort these from amongst the rocks.

For lobster, as well as all fish and crab species (excluding hermit crabs), detailed individual sampling will be undertaken in addition to recording catch weights and numbers. For up to twenty-five randomly selected individuals of a species (depending on the number caught), the following information should be obtained and recorded on the DETAILED SAMPLING FORM (see Appendix II):

1. Measurement of body size:
    - Fish: Using an offset measuring board, the fish is laid flat, snout abutted against the headpiece. The first number (cm) visible after the tail is recorded
    - Crabs: the width (side to side, not front to back) of the carapace, measured in mm using calipers, is recorded, and
    - Lobster the length of the cephalothorax, measured in mm using calipers, is recorded

2. Assess the vitality of the individual, on a scale of 1-4, by examining the body, gill or spiracle (for skates) movements for up to 10 seconds

Vitality	Code	Description
Excellent	1	Vigorous body movement; no or minor external injuries only
Good / Fair	2	Weak body movement; responds to touching/prodding; minor external injuries
Poor	3	No body movement but fish can move operculum, skate can move spiracles or bubbles are formed near the mouth of crustaceans; minor or major external injuries;
Moribund	4	No body or opercular movements (no response to touching or prodding)

3. For fish, assess the degree of injury, on a scale of 1-3, based on the following scale.

Injury	Code	Description
no injury	1	No bleeding, torn operculum or noticeable loss of scales
minor	2	Minor bleeding or minor tear of mouthparts or operculum or moderate loss of scales (i.e. bare patch)
major	3	Major bleeding or major tearing of the mouthparts or operculum or everted stomach or bloated swim bladder

4. For crustaceans, evaluate carapace condition and missing appendages as follows:

Crab and lobster carapace condition

Code	Description
1	No injury to carapace
2	Minor carapace fractures – lobster should live
3	Major carapace fracture – part of the carapace has been severely crushed, lobster could die from injury
*	Newly missing body parts have to be written in the proper box on the data sheet. This refer to missing claws and walking legs or part of the telson, abdomen or cephalothorax

Missing appendages lobster and crab:

Code	Description
CN or CO	Crusher claw missing; New injury (from this tow or within the season) or Old already calcifying injury.
PN or PO	Pincher claw missing; New injury (from this tow or within the season) or Old already calcifying injury.
WN# or WO#	Walking legs missing; New injury (from this tow or within the season) or Old already calcifying injury; and the number of walking legs missing (max of 8).

Time management:

The priorities for sampling are the following:

1. Obtain the activity information located at the top of the ACTIVITY AND CATCH FORM for all sets
2. Obtain the weights and numbers caught for each taxon or catch category from as many sets as possible. However it is important that all items in a catch are sorted and recorded from a given set (i.e., if the sampler sorts and weighs some of the taxa in the catch of a particular set, they need to complete the work for all taxa in that set).

The only exceptions to (2.) are for winter skate and lobster, for which all individuals should at least be counted in each set.

3. Obtain the detailed length, vitality and injury sampling for as many taxa and as often as possible.

Processing of the set's catch can occur while the fish harvester undertakes their following set. If there is insufficient time between sets to process the catch as described in the previous section, the sampler should forgo doing the detailed length and condition sampling and focus on recording the catch weights and numbers only. If detailed sampling can only be done for some species because of time constraints, the sampler should try and obtain at least one detailed sample per species for the day.