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**Gulf Region** — **Région du Golfe**

# Estimated amounts, species composition and pre-discard condition of marine taxa captured incidentally in the southern Gulf of St. Lawrence scallop fishery

# Estimation des quantités, de la composition par espèce et de la condition avant le rejet des espèces capturées en prises accessoires dans la pêche au pétoncle du sud du Golfe du Saint-Laurent

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## ABSTRACT

Catch amounts, species composition and pre-discard condition of marine taxa captured incidentally in the scallop fishery of the southern Gulf of St. Lawrence (sGSL) during 2006-2008 were estimated using data from an at-sea sampling program. A broad range of coastal fish and macro-invertebrate taxa are captured in this fishery. One of the most common species in the catches was the rock crab (*Cancer irroratus*), with an estimated 680 000 individuals captured annually (approximately one crab caught for every eleven scallop). The estimated total number of individuals captured for all fish and large decapod species, including rock crab and lobster (*Homarus americanus*), was small relative to indices of abundance from research surveys or relative to removals in directed fisheries. Furthermore, most of these individuals were in good to excellent condition prior to being discarded, which suggests that post-release survival may be good, at least for the fishes. An in-depth evaluation of bycatch mortality of endangered winter skate in the sGSL scallop fishery based on the at-sea sampling data was undertaken in 2010 (DFO Can. Sci. Advis. Sec. Res. Doc. 2010/043). In preparing the present document it became apparent that an error in tabulating the fishing effort for the 2006-2008 scallop fishing seasons in the original analysis resulted in underestimates of the number of winter skate captured. While winter skate catches in the scallop fishery were underestimated by a factor of 2.5, the conclusion of the 2010 document that mortality in the scallop fishery is a small proportion of total mortality remains valid.

## RÉSUMÉ

On a effectué des estimations sur les captures, la composition des espèces et l'état, avant leur rejet, d'espèces marines capturées accidentellement dans la pêche du pétoncle du sud du golfe du Saint-Laurent (sGSL), de 2006 à 2008, en fonction de données tirées d'un programme d'échantillonnage en mer. On a capturé un vaste éventail de poissons côtiers et d'espèces macro-invertébrées dans cette pêche. Le crabe commun (*Cancer irroratus*) constitue l'une des espèces les plus fréquemment capturées; on en recueille approximativement 680 000 chaque année (on pêche environ un crabe pour onze pétoncles). Le nombre estimatif de spécimens capturés, parmi toutes les espèces de poissons et les grandes espèces décapodes, notamment le crabe commun et le homard (*Homarus americanus*), était faible compte tenu des indices d'abondance des relevés de recherche ou des captures dans les pêches dirigées pour ces espèces. De plus, la plupart de ces spécimens étaient en bonne ou excellente condition avant d'être rejetés; par conséquent, le taux de survie après le retour en mer devrait être favorable, du moins pour les poissons. On a effectué, en 2010, une évaluation approfondie de la mortalité accessoire de la raie tachetée, une espèce en voie de disparition, dans la pêche du pétoncle du sGSL, en fonction des données d'échantillonnage en mer (MPO, Secrétariat canadien de consultation scientifique, Document de recherche 2010/043). Lors de la préparation du présent document, il est devenu évident qu'une erreur de calcul relative aux activités de pêche du pétoncle des saisons de 2006 à 2008, dans l'analyse initiale, était à l'origine de la sous-estimation du nombre de raies tachetées capturées. On a sous-estimé le nombre de raies tachetées capturées dans le cadre de la pêche du pétoncle selon un facteur de 2,5, mais la conclusion du document de 2010, selon laquelle la mortalité liée à la pêche du pétoncle constituait une faible proportion de la mortalité totale, demeure valide.

# INTRODUCTION

In February 2011, Fisheries and Oceans Canada undertook a regional assessment of the scallop fishery of the southern Gulf of St. Lawrence (sGSL). One of the terms of reference for that assessment was to evaluate the possible ecosystem-level impacts of this fishery. To that end, the present document provides an analysis of the estimated catch amounts, species composition and pre-discard condition of marine taxa captured incidentally in the fishery. The analyses are based on an at-sea sampling program that was undertaken during the 2006-2008 fishing seasons. More cryptic impacts of the fishery on benthic habitats or on the mortality of organisms that interact with but are not retained by the fishing gear are not addressed.

Winter skate (*Leucoraja ocellata*) in the sGSL has been designated as endangered by the Committee on the Status of Endangered Wildlife in Canada. A recovery potential assessment (RPA) was undertaken in 2005 to provide information on winter skate 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 RPA identified bycatch mortality in the scallop fishery as a potential unaccounted human-induced source of mortality. In 2010 a detailed evaluation of winter skate bycatch in the scallop fishery was undertaken to evaluate this mortality in light of skate abundance and total mortality (Benoît et al. 2010b; DFO 2010). It was concluded that given small incidental catches of winter skate relative to abundance and a strong potential for post-discard survival, fishing mortality in the scallop fishery represented a very small fraction of total mortality. However, it has since become apparent that an error in tabulating the fishing effort for the 2006-2008 scallop fishing seasons in the original analysis resulted in underestimates of the number of winter skate captured. A re-evaluation of winter skate bycatch is presented here to correct this error. While winter skate catches in the scallop fishery were underestimated by a factor of 2.5, the re-analysis confirms that the conclusions of the 2010 work remain valid.

# METHODS

## AT-SEA SAMPLING

Prior to 2006 there had been no at-sea observer program that quantified incidental catches in the scallop fishery in the sGSL scallop fishing areas (SFA) 21 to 24. 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. 1; Table 1). Further details on the project are available in Benoît et al. (2010b).

Vessels for observation in each SFA were selected randomly from the list of fish harvesters in each SFA that were both active in the fishery and 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 and lobster captured (see Appendix I for the protocol used). For the majority of fishing sets (depending on the time available), observers also collected information on the number of individuals of other incidentally captured taxa. Fish and large crustaceans were generally identified to species, while other invertebrates were identified to the lowest practical taxonomic level. For some abundant small-bodied invertebrates, the number captured in a fishing set was estimated by subsampling and adjusting by the total mass of the taxon in the set.

In all but one set over the 3-year study, observers also undertook detailed sampling of individual captured fishes and large crustaceans, measuring their length (fish, in cm) or carapace dimension (crustaceans, in mm), visually assessing their vitality on a four level ordinal scale (Table 2) and visually assessing degree of injury on a three level ordinal scale (fish, Table 3; crustaceans, Table 4). Semi-quantitative assessment of vitality (and injury) has been shown to correspond well with eventual relative survival of discarded fish (e.g., Hueter and Manire 1994; Richards et al. 1995; Kaimmer and Trumble 1998; Benoît et al. 2010a). In addition, observers noted whether crabs and lobster were missing appendages (claws and legs) that appeared to be recently lost. It was not possible however to confirm whether these appendages had been lost during the fishing set in question, and some may have been lost shortly prior and not necessarily as a result of an encounter with scallop fishing gear.

## DISCARD ESTIMATION

Design-based estimation was used to calculate the annual total number of individuals discarded for each incidentally captured taxon, 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 point estimate for total discards was based on 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 average annual total number discarded for each taxon ( $\hat{D}$ ) was calculated as:

Eqn 1. $$\hat{D} = \sum_{s}^{S}\left(\left(\sum_{y=2006}^{2008} T_{sy} \big/ 3\right) \cdot \frac{\sum_{y=2006}^{2008}\sum_{j=1}^{o_{sy}} \rho_{jsy}^{-1} \cdot \sum_{i=1}^{I_j} w_{ijsy}}{\sum_{y=2006}^{2008} o_{sy}}\right)$$

for $$y \in (2006, 2007, 2008)$$ $$s \in (21\text{A}, 21\text{B}, 21\text{C}, 22, 23, 24)$$

$T_{sy}$ is the total number of scallop fishing trips in SFA *s* and year *y* (Table 5) obtained from DFO's zonal interchange file format database (ZIFF; database which combines landings and logbook data), $w_{ijsy}$ is the total number of the taxon observed in sampled set *i* during trip *j* in *s* and *y*, $\rho_{jsy}$ is the proportion of fishing sets during trip *jsy* in which bycatch sampling was undertaken (recall that for winter skate and lobster, bycatch sampling was undertaken for all fishing sets during all trips), and $o_{sy}$ is the total number of observed trips in *s* and *y*. The average discard rate (number caught per trip, $\hat{d}$ ) for the fishery during 2006-2008 was calculated as:

Eqn 2. $$\hat{d} = \hat{D} \cdot \frac{3}{\sum_{y=2006}^{2008} \sum_{s}^{S} T_{sy}}$$

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. If a bias exists, it is likely to be due to an under-reporting of $T_{sy}$ which would translate to an underestimate of $\hat{D}$ for each taxon.

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 (Table 1). The standard error for $\hat{D}$ was estimated using a two-stage unrestricted bootstrap (Efron and Tibshirani 1993), first of sampled sets within observed trips, and then of the observed trips themselves. In this manner, the estimated error includes the sampling error contributions related to sampling of both sets within trips and trips within the fishery. Because of the dearth of sampling in certain SFAs, resampling of trips was done without regard for SFA (i.e., sampling with replacement from the entire pool of observed trips). Based on prior simulations of the stability of estimated standard error as a function of the number of bootstrap iterations, 5000 iterations were deemed amply sufficient to properly characterize the standard error (Benoît et al. 2010b).

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 harvesters was in practice random with respect to other fishing trips and harvesters in the SFA. Furthermore, we cannot determine whether the presence of observers affected fishing operations during sampled trips. The impact of these possible departures from the model assumptions on the discard estimates cannot be quantified with the data at hand.

# RESULTS AND DISCUSSION

## SCALLOP CATCHES

Based on the at-sea sampling, an estimated 7.7 million (± 0.7 million, S.E.) scallops were caught in the fishery annually during 2006-2008 (Table 6). Assuming an average count of 40 scallop meats (muscle, no shell) per 0.5 kg landed in the fishery (Davidson and Biron, MS in prep), the estimated number corresponds to approximately 96 tonnes of scallop meat annually. This estimate is in line with the mean annual declared catches for 2006-2008 of around 110 tonnes. Though the scallops observed at sea include some undersized individuals that are normally discarded, the general correspondence between estimated and landed scallop catches nonetheless lends credibility to the observer sampling and catch/bycatch estimation processes.

## FISH BYCATCH

Winter flounder were the most commonly incidentally captured fish species, with an average of around twelve individuals captured per fishing trip, resulting in an estimate of around 34,500 (± 10,200 SE) captured annually in the fishery (Table 6). Other commonly encountered fish species (mean catch rate >1 per trip) were yellowtail flounder, winter skate, cunner, shorthorn sculpin and windowpane flounder. On average, there was one fish captured for every 65 scallops.

The scallop fishery captured a broad range of fish sizes, both within and between species (e.g., range from 5 cm windowpane flounder and 7 cm moustache sculpin, to a 68 cm ocean pout) (Fig. 2). For winter skate, shorthorn sculpin, and winter, yellowtail and windowpane flounders, the length frequency distributions of incidentally captured individuals were comparable to those observed in the annual bottom-trawl survey of the southern Gulf (Fig. 2) (Hurlbut and Clay 1990; Benoît 2006). In contrast, cunner, longhorn sculpin, sandlance, and sea raven captured in the scallop fishery tended to be smaller than those observed in the survey. For some species, this result may have to do with the relative depths of the annual survey (20-350 m) and of the scallop fishery (15-35 m), since mean body length of individuals within species generally increases with water depth (MacPherson and Duarte 1991).

In general, incidentally captured fish were in good condition just prior to being discarded (Table 7). Most individuals were assessed into vitality classes 1 and 2 and had generally sustained only minor injuries, though moribund individuals were nonetheless observed in a number of species (composing between 3-17% of discarded individuals). For winter flounder, winter skate and the large sculpins at least, individuals scored into vitality classes 1 and 2 have a very high likelihood of post-release survival (Benoît et al. 2010a; Benoît et al., MS in prep). Furthermore, across a diversity of taxa a portion of moribund individuals, are actually not dead and survive at least 48 hrs once released to water (Benoît et al. 2010a).

To quantify the impact of incidental capture and discarding in the scallop fishery on the population dynamics of southern Gulf winter skate, Benoît et al. (2010b) estimated the number captured each year from 2006-2008 in SFAs 21-24 and adjusted this number for fishing trips occurring in other areas of the southern Gulf (e.g., Magdalen Islands, around the Gaspé peninsula). Based on the revised number of fishing trips used here, an average of 14% of southern Gulf of St. Lawrence scallop fishing trips occurred outside of SFAs 21-24 during 2006-2008. Assuming a post-release survival rate of 90% (Benoît et al. 2010b), the estimated number of juvenile winter skate (i.e., individuals <42 cm) killed in the scallop fishery in 2006, 2007 and 2008 were respectively 949 (87-1475, 95% confidence interval), 994 (84-1424) and 902 (74-

1253) (Table 8). Based on estimates of winter skate population size from modeling results provided in Benoît et al. (2010b), these estimated bycatch losses represent an exploitation rate that varies between 0.24-2.33%, depending on the year and method of calculation (Table 8). Likewise, the estimated number of adult winter skate (i.e., individuals ≥42 cm) killed in the scallop fishery in 2006, 2007 and 2008 were respectively 208 (19-324), 218 (96-312) and 198 (16-275), resulting in an exploitation rate that varies between 0.15-0.38%, depending on the year and method of calculation (Table 8). In comparison, 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 (Benoît et al. 2010b). The bycatch mortality of both juvenile and adult winter skate in the southern Gulf scallop fishery therefore appears to be very small relative to mortality from other causes, as concluded by Benoît et al. (2010b).

Applying the sort of detailed analysis undertaken for winter skate to other species is beyond the scope of this report, as it requires having population models for the species of interest. Nonetheless, estimated bycatch amounts for the various fish species can be compared to estimates of trawlable abundance from the multispecies bottom-trawl survey of the southern Gulf to provide an indicator of a possible adverse impact of mortality in the scallop fishery. The annual survey which has been conducted each September since 1971 covers most areas of the sGSL with depths ≥20 m (Fig. 3; Hurlbut and Clay 1990), but misses a number of nearshore areas into which extend the distributions of most species considered. Failure to cover all the occupied habitats, combined with the fact that most of the fish taxa are unlikely to be efficiently sampled by the survey gear (Harley et al. 2001), means that abundance of most taxa was very likely underestimated, perhaps by a large amount. Bearing this in mind, bycatch of all fishes other than winter skate represents ≤1% of their respective mean trawlable abundances for the 2006-2008 period (Table 6). High likelihoods of post-release survival (Benoît et al. 2010a; Benoît et al., MS in prep) further suggest that bycatch in the scallop fishery likely represents a minor contribution to the mortality of the incidentally-captured fish species.

## DECAPOD BYCATCH

Rock crab were the most commonly incidentally captured large crustacean, with an average of over 242 individual captured per trip, or 683,000 (± 97,600) per year (Table 6). This implies a fairly elevated bycatch intensity of around one rock crab for every 11 scallops caught. Hermit crabs and the toad crabs were the second and third most frequently captured decapods, with mean catch rates of 28.1 and 6.5 individuals per trip respectively (Table 6). An average of 1.9 lobsters were captured per trip for an estimated 5,430 captured annually.

Most rock crab captured had a carapace width >60 mm (Fig. 2). The minimum legal size of rock crab in the fishery directed on them is 102 or 108 mm, depending on the geographic area (DFO 2008). Approximately 32% of rock crab captured in the scallop fishery had carapace widths at or above the limit of 102 mm. The frequency distribution of carapace widths for incidentally captured toad crab was skewed towards larger sizes than observed during the multi-species bottom-trawl survey (Fig. 2), but was comparable to that observed in the commercial fishery (DFO 1996). The legal minimum size of lobster in the commercial fishery directed on them ranges from 70 to 76 mm, depending on the fishing area (DFO 2007). Approximately 80-84% of lobsters incidentally captured in the scallop fishery would be considered to be of legal size.

Most incidentally-captured rock crab and lobster were in good to excellent vitality when they were discarded, with the majority (76-82%) having an intact carapace (Table 7). For toad crab, one quarter of captured individuals were scored as moribund, though most had intact carapaces. It is not known however to what extent the vitality scoring criteria (Table 2) are sensitive to the actual physical state for this species (i.e., lack of movement may not be a good indicator of death in freshly captured toad crabs). Around 29% of rock crabs were missing a pincer claw and 26% were missing at least one walking leg (Table 9). For toad crab these numbers were respectively around 38% and 31%. Few captured lobster were missing either a crusher (2%) or pincer claw (8%), and none were missing walking legs. In all cases of missing appendages, it is not possible to establish whether they were lost as a result of capture in the scallop dredge or during catch handling. Furthermore, it is not presently known how vitality and degree of injury affect survival in these decapod species.

To place the incidental catches of rock crab in context, annual landings in directed and bait fisheries have varied around 5,000 tonnes during the 2000s (DFO 2008). Assuming an individual average weight of 150 g (corresponding roughly to a 100 mm individual), the scallop fishery captured an average of 102 tonnes, all of which was released to the water and much of which was composed of individuals in good condition (Table 2). The impact of incidental mortality in the scallop fishery was therefore likely to be small compared to mortality in the directed commercial fishery.

Incidental catches of lobster can also be viewed in the context of mortality in the directed fishery. Assuming an individual lobster weight of 700 g, the estimated bycatch of lobster in the scallop fishery translates to 3.8 tonnes, which is very small relative to declared annual landing during the 2000s that were generally >15,000 tonnes in the directed fishery (DFO 2007). Furthermore, all lobster captured incidentally in the scallop fishery were to be returned to the water, and most of those individuals were in good condition prior to discarding (Table 2).

### BYCATCH OF OTHER INVERTEBRATES

Other commonly discarded invertebrates included mollusks, such as horse mussel, whelks and moonshells, echinoderms such as starfish, sand dollars and urchins, as well as anemones and sponges (Table 6). No attempt is made here to relate estimated bycatch amounts to possible population abundance for these invertebrate taxa.

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

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

*Table 2. Description of the codes used to qualify the vitality of captured fish and crustaceans.*

| 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, opercular or gill movements (no response to touching or prodding) |

*Table 3. Description of the codes used to qualify the degree of injury of captured fishes.*

| 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 4. Description of the codes used to qualify the degree of injury to the carapace of captured crabs and lobsters*

| Code | Description |
|---|---|
| 1 | No injury to carapace |
| 2 | Minor carapace fractures – animal expected to live |
| 3 | Major carapace fracture – part of the carapace has been severely crushed, animal could reasonably die from injury |

*Table 5. Annual number of fishing trips (2006 to 2008) in each scallop fishing area, based on records in DFO's ZIFF database.*

| SFA | 2006 | 2007 | 2008 |
|---|---|---|---|
| 21A | 285 | 339 | 188 |
| 21B | 55 | 58 | 94 |
| 21C | 42 | 28 | 13 |
| 22 | 1568 | 1697 | 1554 |
| 23 | 10 | 5 | 14 |
| 24 | 1046 | 776 | 692 |

*Table 6. Summary of the 2006-2008 at-sea observer sampling for incidentally captured fish, crustaceans, mollusks, echinoderms and others : total number of individuals observed, estimated average catch rate (mean number per trip), and the estimated average and standard error (S.E.) of the number captured per year in the fishery. Also presented for most fish taxa is the average trawlable abundance for 2006-2008 and associated S.E., estimated from the annual multispecies survey of the sGSL.*

| Name | Taxonomy | # counted | Mean #/trip | Mean #/year | S.E. #/year | Trawlable abundance | S.E. |
|---|---|---|---|---|---|---|---|
| Sea scallops | *Placopecten magellanicus* | 49,220 | 2,727.97 | 7,697,000 | 741,900 | | |
| *Fish* | | | | | | | |
| Winter flounder | *Pseudopleuronectes americanus* | 243 | 12.23 | 34,510 | 10,190 | 5.614 E7 | 1.091 E7 |
| Yellowtail flounder | *Limanda ferruginea* | 77 | 3.82 | 10,770 | 4586 | 3.898 E7 | 6.367 E6 |
| Winter skate | *Leucoraja ocellata* | 49 | 3.52 | 9,923 | 3964 | 4.477 E4 | 2.375 E4 |
| skate purse (empty) | Rajiformes | 88 | 6.98 | 19,690 | 8901 | | |
| skate purse (full) | Rajiformes | 65 | 5.69 | 16,060 | 8129 | | |
| Cunner | *Tautogolabrus adspersus* | 37 | 3.42 | 9,660 | 3534 | 1.752 E6 | 8.437 E5 |
| Shorthorn sculpin | *Myoxocephalus scorpius* | 35 | 1.66 | 4,691 | 1819 | 6.313 E5 | 1.278 E5 |
| Windowpane | *Scophthalmus aquosus* | 22 | 1.83 | 5,157 | 1706 | 3.648 E5 | 1.204 E5 |
| Longhorn sculpin | *M. octodecemspinosus* | 21 | 0.80 | 2,243 | 1261 | 3.190 E6 | 1.056 E6 |
| Northern sand lance | *Ammodytes dubius* | 19 | 0.26 | 727 | 2129 | 3.209 E6 | 2.639 E6 |
| Sea raven | *Hemitripterus americanus* | 18 | 0.48 | 1,346 | 1270 | 2.165 E5 | 5.436 E4 |
| Ocean pout | *Zoarces americanus* | 8 | 0.33 | 937 | 779 | 5.287 E4 | 2.438 E4 |
| Snakeblenny | *Lumpenus lumpretaeformis* | 8 | 0.10 | 271 | 930 | 4.493 E5 | 1.287 E5 |
| Alligatorfish | *Aspidophoroides monopterygius* | 5 | 0.17 | 466 | 909 | 2.492 E6 | 4.263 E5 |
| Moustache sculpin | *Triglops murrayi* | 2 | 0.16 | 459 | 468 | 8.382 E5 | 1.663 E5 |
| Banded gunnel | *Pholis fasciata* | 3 | 0.13 | 369 | 431 | | |
| Sculpin (unidentified) | *Myoxocephalus* sp. | 1 | 0.09 | 263 | 245 | | |
| Lumpfish | *Cyclopterus lumpus* | 2 | 0.02 | 68 | 342 | 2.274 E5 | 6.316 E4 |
| White hake | *Urophycis tenuis* | 1 | 0.01 | 34 | 191 | 8.594 E6 | 3.416 E6 |
| Rainbow smelt | *Osmerus mordax mordax* | 1 | 0.01 | 34 | 211 | 1.901 E8 | 8.518 E7 |
| Eelpouts | *Lycodes* sp. | 1 | 0.01 | 34 | 184 | 2.265 E6 | 3.957 E5 |
| American plaice | *Hippoglossoides platessoides* | 1 | <0.01 | 10 | 218 | 2.179 E8 | 1.868 E7 |

*Table 6 (continued).*

| Name | Taxonomy | # counted | Mean #/trip | Mean #/year | S.E. #/year | Trawlable abundance | S.E. |
|---|---|---|---|---|---|---|---|
| *Crustaceans* | | | | | | | |
| Atlantic rock crab | *Cancer irroratus* | 4311 | 242.11 | 683,100 | 97,580 | | |
| Toad crab | *Hyas* sp. | 212 | 6.54 | 18,450 | 19,930 | | |
| Hermit crabs | Paguridae Family | 513 | 28.09 | 79,250 | 31,290 | | |
| American lobster | *Homarus americanus* | 51 | 1.92 | 5,431 | 2,196 | | |
| lobster shell | | 14 | 1.12 | 3,151 | 1,295 | | |
| Snow crab | *Chionoecetes opilio* | 1 | 0.02 | 68 | 448 | | |
| *Mollusks* | | | | | | | |
| Horse mussels | *Modiolus modiolus* | 919 | 81.37 | 229,600 | 122,700 | | |
| Whelks | *Buccinum* sp. | 1,238 | 19.93 | 56,240 | 105,000 | | |
| Moonshell | *Euspira heros* | 153 | 11.00 | 31,040 | 7,545 | | |
| Astarte sp. | *Astarte* sp. | 78 | 7.01 | 19,780 | 5,887 | | |
| Quahaug | *Arctica islandica* | 138 | 4.32 | 12,190 | 13,200 | | |
| Limpet | Archaeogastropoda Order | 35 | 3.26 | 9,188 | 6,047 | | |
| Bar,surf clam | *Spisula solidissima* | 41 | 1.69 | 4,762 | 10,870 | | |
| Blue mussels | *Mytilus edulis* | 64 | 1.76 | 4,979 | 5,977 | | |
| Northern propellor clam | *Cyrtodaria siliqua* | 33 | 0.36 | 1,014 | 7,288 | | |
| Iceland scallop | *Chlamys islandica* | 18 | 0.20 | 561 | 1,952 | | |
| *Echinoderms* | | | | | | | |
| Starfish | Asteroidea Sub-Class | 4,561 | 206.75 | 583,300 | 138,100 | | |
| Sand dollars | Clypeasteroida Order | 4,182 | 66.08 | 186,400 | 404,400 | | |
| Sea urchins | *Strongylocentrotus* sp. | 1,081 | 14.12 | 39,850 | 116,050 | | |
| Brittle star | Ophiuroidea Sub-Class | 95 | 3.64 | 10,270 | 11,960 | | |
| Sea cucumbers | Holothuroidea Class | 219 | 6.61 | 18,660 | 23,330 | | |
| *Other* | | | | | | | |
| Sea anemone | Anthozoa Class | 502 | 31.81 | 89,750 | 20,150 | | |
| Sponges | Porifera Phyllum | 509 | 18.75 | 52,910 | 51,110 | | |

*Table 7. Summary of the information on individual pre-discard vitality and degree of injury for species for which ≥8 individuals where sampled. Indicated are the total number of individuals sampled (N), the percentage occurring in each of 4 vitality classes (Table 2) and the percentage occurring in each of 3 injury classes (fish, Table 3; crabs and lobster, Table 4).*

| | | Vitality class | | | | Injury class | | |
|---|---|---|---|---|---|---|---|---|
| Species | N | 1 | 2 | 3 | 4 | 1 | 2 | 3 |
| Yellowtail flounder | 75 | 46.7 | 18.7 | 17.3 | 17.3 | 61.6 | 27.4 | 11 |
| Winter flounder | 225 | 82.2 | 12.4 | 1.8 | 3.6 | 64.1 | 31.4 | 4.5 |
| Cunner | 30 | 93.3 | 0 | 3.3 | 3.3 | 90.0 | 10.0 | 0 |
| Windowpane | 22 | 77.3 | 13.6 | 4.5 | 4.5 | 85.7 | 9.5 | 4.8 |
| Winter skate | 49 | 87.8 | 8.2 | 4.1 | 0 | 73.5 | 20.4 | 6.1 |
| Longhorn sculpin | 21 | 100.0 | 0 | 0 | 0 | 90.5 | 9.5 | 0 |
| Shorthorn sculpin | 35 | 82.9 | 17.1 | 0 | 0 | 94.3 | 5.7 | 0 |
| Sea raven | 18 | 72.2 | 27.8 | 0 | 0 | 61.1 | 33.3 | 5.6 |
| Sand lance | 18 | 5.6 | 22.2 | 55.6 | 16.7 | 94.4 | 5.6 | 0 |
| Snakeblenny | 8 | 50.0 | 50.0 | 0 | 0 | 37.5 | 62.5 | 0 |
| Ocean pout | 8 | 87.5 | 0 | 0 | 12.5 | 100 | 0 | 0 |
| Atlantic rock crab | 4073 | 68.8 | 13.3 | 5.4 | 12.5 | 82.1 | 4.3 | 13.5 |
| Toad crab | 207 | 40.6 | 17.9 | 16.4 | 25.1 | 91.3 | 1.4 | 7.2 |
| American lobster | 50 | 84 | 12 | 0 | 4 | 76.1 | 19.6 | 4.3 |

*Table 8. 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. Both the original calculations (regular font; taken from Table 6 in Benoît et al. 2010b) and the revised calculations (bold and italic font) made here based on the correct number of fishing trips, are presented. In both cases, 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) |
| Bycatch loss (numbers) | ***revised*** | ***949 (87-1475)*** | ***994 (84-1424)*** | ***902 (74-1253)*** |
| Abundance (thousands) | | 612 (116-1,687) | 275 (61-793) | 311 (73-802) |
| Exploitation rate i) | | 0.10% | 0.22% | 0.16% |
| | ***revised*** | ***0.24%*** | ***0.52%*** | ***0.40%*** |
| ii) | | 0.52% | 0.99% | 0.70% |
| | ***revised*** | ***1.27%*** | ***2.33%*** | ***1.72%*** |
| Adults | | | | |
| Bycatch loss (numbers) | | 87 (16-133) | 88 (16-132) | 78 (13-112) |
| Bycatch loss (numbers) | ***revised*** | ***208 (19-324)*** | ***218 (96-312)*** | ***198 (16-275)*** |
| Abundance (thousands) | | 179 (86-328) | 205 (112-355) | 174 (87-310) |
| Exploitation rate i) | | 0.07% | 0.06% | 0.06% |
| | ***revised*** | ***0.18%*** | ***0.15%*** | ***0.16%*** |
| ii) | | 0.16% | 0.12% | 0.13% |
| | ***revised*** | ***0.38%*** | ***0.28%*** | ***0.32%*** |

*Table 9. Summary of the information on freshly lost appendages for crabs and lobster. Indicated are the total number of individuals sampled (N), the percentage missing crusher or pincer claws, and the percentage of sampled individuals missing a particular number of walking legs. Note that missing appendages for which the wound had healed-over are not included in this summary.*

| | | Claws | | Number of missing walking legs | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | N | Crusher | Pincer | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Rock crab | 4073 | | 28.9 | 14.0 | 6.0 | 3.0 | 1.4 | 0.5 | 0.3 | 0.2 | 0.1 |
| Toad crab | 207 | | 37.7 | 20.8 | 6.3 | 2.9 | 1.0 | 0 | 0 | 0 | 0 |
| Lobster | 50 | 2.0 | 8.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

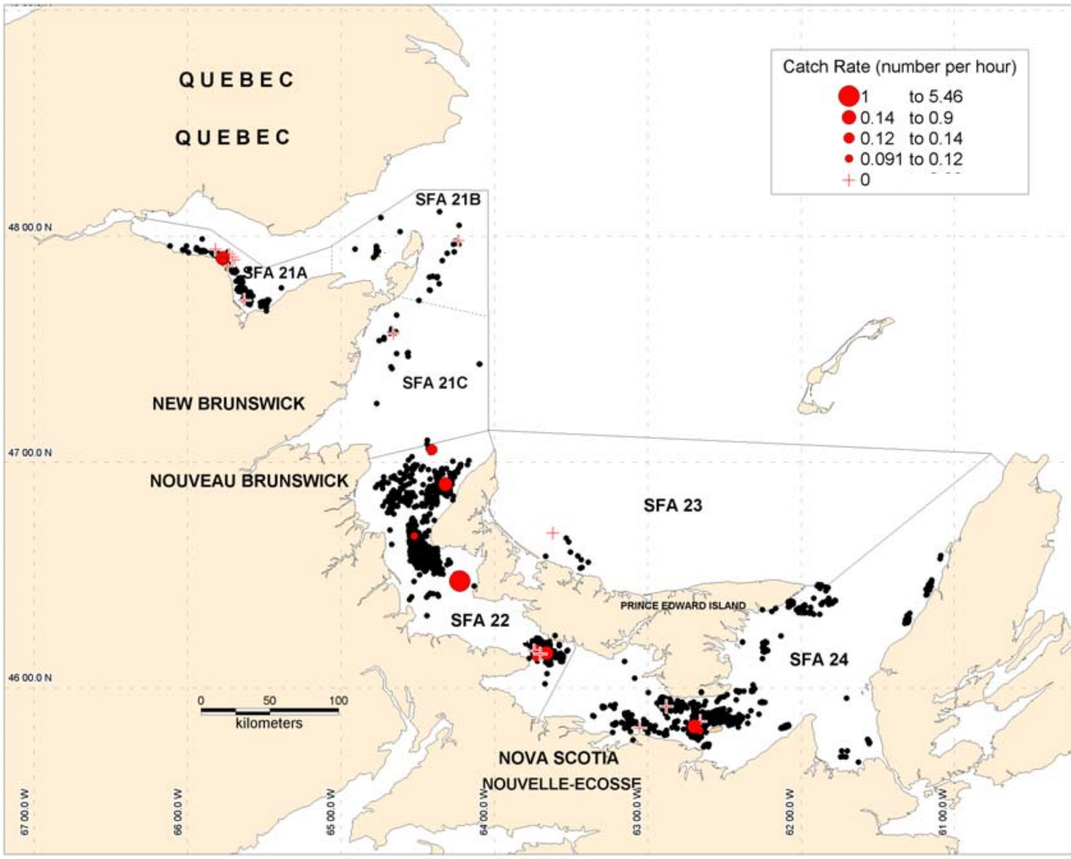


*Figure 1. Location of commercial scallop fishing trips (2006-2008) from fish harvesters' logbooks (black dots), location of sampled fishing trips (red circles and crosses). In the present figure, the relative size of the red circles corresponds to the winter skate catch rate (individuals/hour of fishing) during individual observed commercial fishing trips, crosses indicate null catches (from Benoît et al. 2010b). Solid lines delineate the six scallop fishing areas (SFA).*

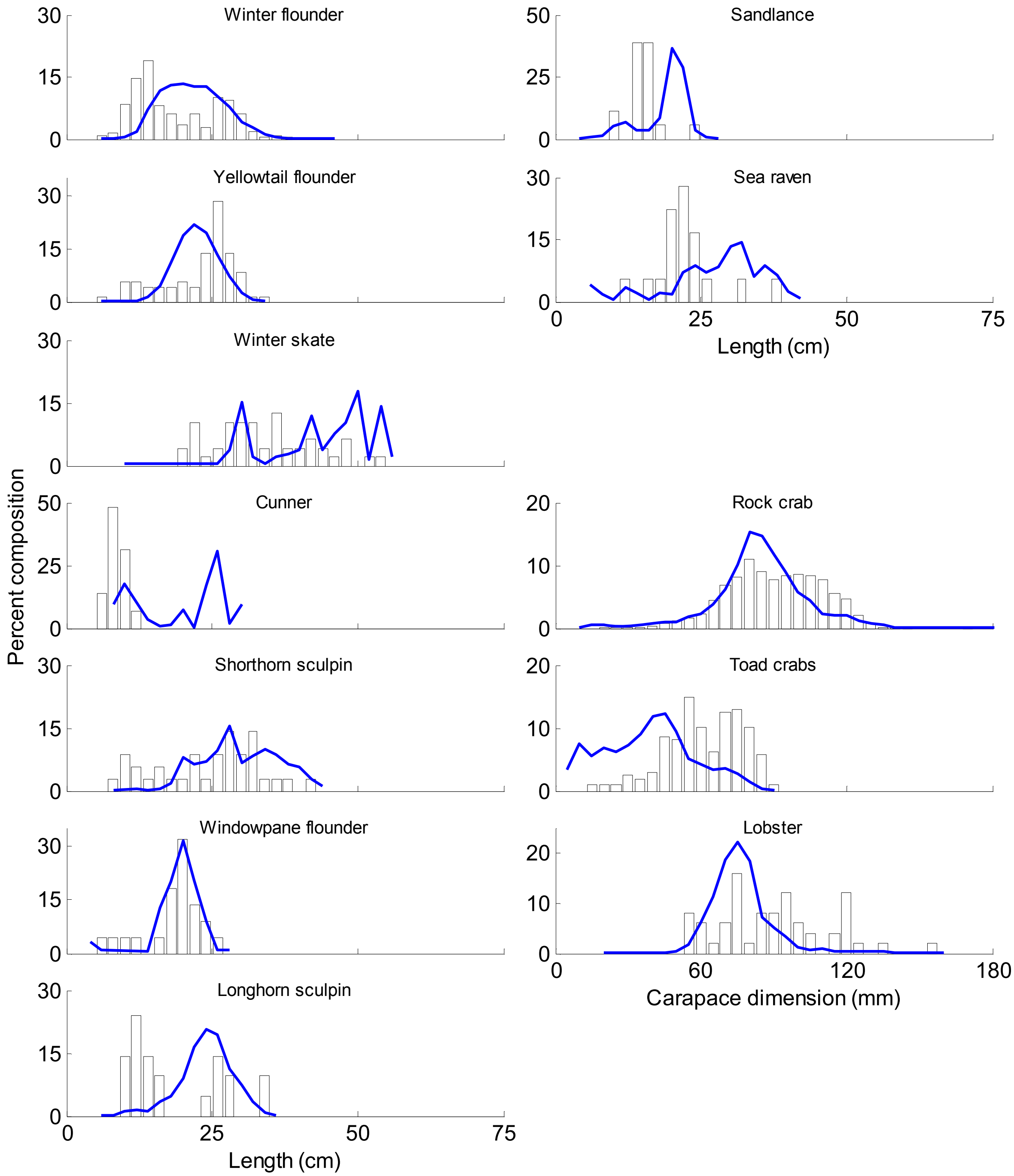


*Figure 2. Frequency distributions of fish lengths, crab carapace widths and lobster carapace lengths for individuals measured during at-sea sampling of scallop drag catches (bars) and in the annual bottom-trawl survey of the southern Gulf of St. Lawrence, 2006-2008 (line). Plots are presented only for species for which ten or more individuals were measured during the at-sea sampling.*

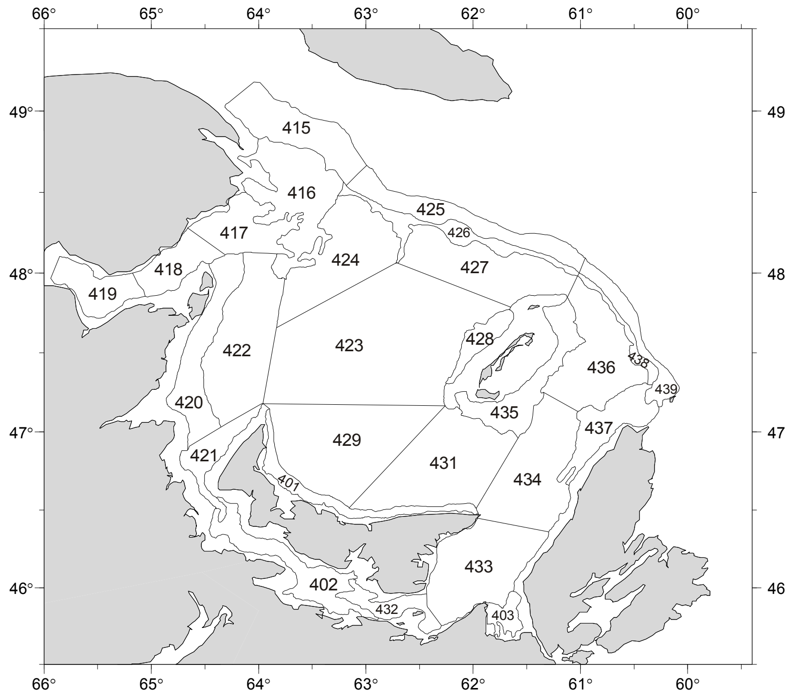


*Figure 3. Stratum boundaries for the September bottom-trawl survey. All strata, from 401 to 439, were used to estimate species trawlable abundances.*

*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.