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The extent and diversity of the harvest fishery bycatch in Canadian commercial fisheries and the possible rational utilization for aquaculture feed production

La portée et la diversité des prises accessoires des pêches commerciales canadiennes et la possibilité de leur utilisation rationnelle dans la production d'aliments piscicoles

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ABSTRACT

The potential to use bycatch and discards as a source of feed for the Canadian aquaculture industry was examined in two steps. The first step estimated the weight of bycatch and discards in the 2009-2010 fisheries by directed species, location, gear type and season using logbook data archived in DFO's Zonal Interchange File Format database, from data sources on groundfish, shellfish and Pacific salmon in DFO Pacific Region and from published scientific analyses of observer data. There were many gaps in the literature, very few of the studies were completed during 2009-10 and there were very few analyses of bycatch and discards in gillnets, purse seines, longlines and pot fisheries. Despite these gaps, the major source of discards appeared to be the dredge fisheries for scallop and surfclam, shrimp trawls, groundfish trawls and large pelagic longlines. The lowest and most reliable estimate of discards was 38,000 t, which was about 4% of total landings. The high estimate of 96,000 t represented about 10% of total landings. The second step examined the potential for utilizing the discarded material, a mixture of groundfish, crustaceans, molluscs and echinoderms, as an ingredient in aquafeeds. Currently, aquafeed components are created almost entirely from small pelagic fish taken from global stocks that are generally fully exploited. Discards could be used as a future source of fishmeal and fish oil but first it would be necessary to develop methods to collect and store the material that is likely landed at many widely dispersed ports. In the meantime, fishmeal and fish oil could be obtained from the large amount of waste in seafood processing, which is about 400,000 t, tenfold the weight of discards from capture fisheries.

RÉSUMÉ

La possibilité d'utiliser les prises accessoires et les rejets en tant que source d'aliments destinés à l'industrie aquacole canadienne a été examinée en deux étapes. La première consiste en l'estimation du poids des prises accessoires et des rejets des pêches pour 2009-2010 en fonction de l'espèce ciblée, de l'endroit, du type d'engin de pêche et de la saison à partir des données des journaux de bord archivées dans la base de données *Zonal Interchange File Format* (ZIFF) du MPO, de données de la région du Pacifique du MPO sur le poisson de fond, les mollusques, les crustacés et le saumon du Pacifique, et d'analyses scientifiques publiées des données des observateurs. La documentation contient de nombreuses lacunes puisque très peu d'études ont été réalisées pendant l'exercice 2009-2010 et très peu d'analyses des prises accessoires et des rejets concernent les pêches au filet maillant, à la senne coulissante, à la palangre et au casier. Malgré ces lacunes, il semble que les plus importantes sources de rejets soient la pêche du pétoncle et de la mactre à la drague, la pêche de la crevette au chalut, la pêche du poisson de fond au chalut et la pêche à la grande palangre pélagique. L'estimation des rejets la plus modeste et la plus fiable s'élève à 38 000 tonnes, soit environ 4 % du total des débarquements. L'estimation élevée est de 96 000 tonnes, ce qui représente environ 10 % du total des débarquements. La seconde étape consiste en l'évaluation de la possibilité d'utiliser les prises rejetées, un mélange de poissons de fond, de crustacés, de mollusques et d'échinodermes comme ingrédients des aliments aquacoles. À l'heure actuelle, les aliments aquacoles sont créés presque entièrement à partir de petits poissons pélagiques capturés dans des stocks mondiaux généralement en pleine exploitation. Les rejets pourraient éventuellement servir de source de farine et d'huile de poisson, mais il faudrait d'abord élaborer des méthodes pour recueillir et entreposer le matériel qui est probablement débarqué à de nombreux ports très éloignés les uns des autres. En attendant, il serait possible de produire de la farine et de l'huile de poisson à partir de la grande quantité de déchets résultant de la transformation des fruits de mer, qui s'élève à environ 400 000 tonnes, soit dix fois le poids des rejets des pêches.

INTRODUCTION

The terms of reference for this work were to determine the total volume and diversity of bycatch and discards from Canadian commercial fisheries and identify those that could be used in the production of fishmeal and/or fish oil for aquaculture (Appendix 1). This working paper should address the following:

A. What is the total volume of bycatch and discards from Canadian commercial fisheries in all regions? If possible, this information should be classified by region, area, date, season, and species.
B. Provide an analysis of the diversity of bycatch species from the Canadian harvest fishery, and an analysis regarding possible utility in aquaculture feed production or other value added uses. This may include an analysis of:
    i. Which fishery bycatch species have been utilized for aquafeed production internationally?
    ii. The nature of the nutritional composition (*e.g.*, protein, oils, vitamins), specifically as it pertains to aquafeed production requirements.
C. What proportion of this total volume represents an opportunity to make rational utilization of the discards as a raw material for use in aquaculture (feeds) or other value added uses?

BACKGROUND

Discards represent a significant proportion of global marine catches and are generally considered to constitute waste, or suboptimal use of fishery resources (Kelleher 2005). A workshop was held in June 2010 in Ottawa on bycatch management in Canada. Its purpose was to identify how bycatch is managed and to initiate discussions of objectives for the national policy (Metuzals 2010). A new bycatch policy is to be drafted as part of the Sustainable Fisheries Framework that forms the basis for implementing an ecosystem approach. The workshop concluded that there were major gaps in bycatch measures (low observer coverage, misreporting and non-reporting of bycatch) and data management.

In 2011, a report was completed on the utilization of landings from Canadian fisheries as a potential food source for aquaculture feed (MUN 2011). The report found that nearly 50% of the 894,000 t landed in wild capture fisheries was not utilized or accounted for. The majority of unutilized fisheries resources were composed of waste materials from crustaceans (~25%), pelagics (~32%) and groundfish (~26%). The report concluded that the most significant opportunity to improve resource utilization would be to collect information on product dumped at sea (discards) and the use of fishery products as bait and fishmeal production.

METHODS

Bycatch and discards in Canadian fisheries were estimated for 2009 and 2010 from Fisheries and Oceans Canada (DFO) databases and values taken from the literature. Bycatch defined as the proportion by weight of landings for non-target commercial species. Discards (or discarded catch) were defined as the portion of catch that is returned to the sea (Kelleher 2005). Discards are not a subset of bycatch because the target species is often discarded (e.g. lobster and snow crab). Catch includes all animal material retained or captured by fishing gear, whether brought on board or not (Kelleher 2005), although in this report there were no estimates of animal material not brought on board. Fish and invertebrate discards were treated separately. The years 2009 and 2010 were chosen to be representative of recent trends in the fishery and had complete data available. The two years were treated separately to allow for comparisons between them.

On the Atlantic coast, landings were available in the Zone Interchange File Format (ZIFF) database that records landings from harvester's logbooks by fishing trip. Landings in the ZIFF were summarized by the following variables: North Atlantic Fisheries Organization (NAFO) Division, quarter, gear type, directed species (species sought), species caught and year (2009, 2010). This information was extracted from the ZIFF and provided by Hugues Benoît (DFO, Gulf Region).

The Atlantic coast comprises 19 NAFO Divisions that are managed by five DFO regions and have been characterized by five biogeographic units called ecoregions (Table 1). Ecoregions are high-level spatial units based primarily on oceanographic and bathymetric similarities (DFO 2009). The > 50 gear types in the ZIFF database were grouped into 13 categories (Table 2). Note that tuck seine was combined with purse seine, and hydraulic device was combined with dredge. A description of gear types is given in Donaldson et al. (2010). Landings by gear type were compared between 2009 and 2010 for the three main types of fishery, groundfish, pelagic and shellfish. Landings from the ZIFF database were also compared to the official landings on the DFO website (http://www.dfo-mpo.gc.ca/stats/commercial/land-debarq/sea-maritimes/s2009pq-eng.htm and http://www.dfo-mpo.gc.ca/stats/commercial/land-debarq/sea-maritimes/s2010pq-eng.htm 24-01-2012).

Bycatch was estimated from the ZIFF as the proportion of non-directed commercial catch to total catch. Because all commercial groundfish species must be landed in Atlantic groundfish fisheries, it was felt that there would be less incentive to not record bycatch compared to other fisheries, where bycatch is discouraged. In pelagic fisheries, restrictions on bycatch are unclear. For example, in herring and mackerel fisheries, management plans indicate that bycatches <5% of either species may be landed; above this threshold, bycatch should be discarded; and, bycatch of salmon and tuna is not allowed. In large pelagic fisheries like swordfish, there are no restrictions on bycatch of tuna or sharks. In the surfclam fishery, bycatch of other molluscs is allowed but groundfish cannot be retained. In lobster, snow crab, rock crab, Jonah crab and scallop fisheries, bycatch is supposed to be released but it is well known that rock crab and the occasional fish species taken in lobster pots are kept for bait. In these fisheries, logbooks would not provide a reliable measure of bycatch.

Observer data were used to estimate discards. In NAFO Divisions 0AB there was 100% coverage of groundfish and shrimp trawl fisheries and therefore the estimates of discards could be considered as accurate. In other areas, observer coverage was low and uneven. Usually <5% of trips were observed (Gavaris et al. 2010), even though management plans require at least this much coverage. This low sampling rate likely results in a non-random selection of trips and the likelihood that observed vessels would behave differently from unobserved vessels (Benoît and Allard 2009).

Despite the above caveats, there have not been many studies of discards in Atlantic fisheries and few of them were done in 2009-10. Extensive publication lists are available on the CSAS (http://www.meds-sdmm.dfo-mpo.gc.ca/csas-sccs/applications/publications/index-eng.asp), NAFO (http://www.nafo.int/publications/frames/science.html) , Transboundary Resources Assessment Committee (TRAC) (http://www2.mar.dfo-mpo.gc.ca/science/trac/rd.html) and DFO's on-line catalogue, WAVES (http://waves-vagues.dfo-mpo.gc.ca/waves-vagues/) websites. The websites were combed for any discard or bycatch study over the past several decades. The few studies that were found and considered here include: discards by shrimp trawlers (Orr et al. 2010, Koeller et al. 2006, Fréchet et al. 2006, J. Gauthier pers. comm.); herring purse seiners (Wheeler et al. 2008, Stephenson et al. 1999); trawl, gillnet and longline fisheries (Benoît and Hurlbut 2010, Gavaris et al. 2010); dredge fisheries (Roddick 2007, Benoît 2010, Bourdages and Goudreau 2012, Sameoto and Glass 2012); and, a few pot fisheries (den Heyer et al. 2010). In addition, observer-based discard information was available for a number of trawl, gillnet and longline fisheries in the southern Gulf (4T) for 2009-10 (H. Benoît, unpubl. data). Other than non-commercial types and sizes of snow crab that are returned to the water unharmed, there are almost no bycatch and discards in snow crab pot fisheries (M. Moriyasu, pers. comm.). Purse seine fisheries for capelin, herring and mackerel are also able to release unwanted sizes and types of fish without harm (Wheeler et al. 2008 and Stephenson et al. 1999). Estimates of discards from pelagic gill net fisheries and groundfish handline fisheries were not available and were borrowed from international studies (Kelleher 2005) that are summarized in Table 3. There were no studies of seine or trap net fisheries but it is unlikely that they would be a significant source of discard mortality.

The above studies were used to estimate discards for the main gear types. Often the proportion of discards to total catch (discard ratio) was not easily deciphered in the scientific report and it was necessary to adjust the discards, in weight or numbers, from the observed trips to the proportion of landings for the entire year in that fishery and then to extrapolate to the years of interest, 2009-10.

Landings from the Pacific coast for 2009-2010 were provided from different sources for salmon, groundfish and shellfish fisheries. Numbers of the six species of Pacific salmon that were kept or released were available by fishery (troll, gillnet and seine) and licence area (L. Biagini unpubl. data). Troll was included in the longline gear category (Table 2) and seine in the purse seine category. Licence areas were divided into North (A, C, F) and South (B, D, E, G, H). North overlapped two ecoregions, British Columbia (BC) Northern Shelf and BC Offshore. South overlapped the two other ecoregions, Strait of Georgia and BC Southern Shelf. Numbers of salmon were converted to weight using mean weights available by fishery, year and type of salmon (Y. Lui unpubl. data). No observer program or scientific studies of discards and bycatch were available for BC salmon fisheries and numbers of kept and released salmon were estimated by DFO managers (B. Patten pers. comm.). Estimates of discards from Pacific large pelagic longline fisheries were borrowed from Kelleher (2005). Landings from other pelagic fisheries were obtained from the Integrated Fisheries Management Plans (IFMPs) for Pacific herring, Pacific sardine and albacore (http://www.pac.dfo-mpo.gc.ca/fm-gp/ifmp-eng.htm).

Landings in Pacific groundfish were available by fishery, each one with 100% observer or on-board video/electronic coverage and providing information on species landed and released by Pacific Fisheries Management Area (G. Workman and K. Rutherford unpubl. data). The following fisheries and gear types were examined separately: groundfish trawl and longline fisheries for halibut; combined halibut and sablefish; lingcod; rockfish inside (within the Strait of Georgia); rockfish outside (outside the strait); sablefish; and, dogfish. Bycatch and discard estimates were available for each fishery except for trawl fisheries where there was no single directed species . Management areas were divided into ecoregions as follows: PFMAs 3 -11 and 102 - 111 in BC Northern Shelf; PFMAs 12 - 29 in Strait of Georgia; PFMAs 101, 130 and 142 in BC Offshore; and, PFMAs 121 – 127 in BC Southern Shelf.

Landings from BC shellfish fisheries were available from harvester's logbooks for the Dungeness crab pot fishery, the prawn pot fishery and the shrimp trawl fishery (G. Gillespie and J. Dunham pers. comm.). Due to low numbers, landings of the two kinds of prawn (spot and humpback) and the two kinds of shrimp (pink and sidestripe) were combined by management area (PFMA) for each year. Landings were sorted into ecoregions as with groundfish. All bycatch from the shrimp pot fishery is released live at sea. There is some bycatch of juvenile rockfish in the shrimp trawl fishery (G. Gillespie pers. comm.). Landings from the above sources were compared to the official landings as reported on the DFO website.

The incidence of bycatch and discards has been related to the density and diversity of organisms in the fishing environment (Murawski 1996). Indicators of diversity and biomass were calculated for each ecoregion using information from research vessel groundfish surveys in recent years (2008-10). A Shannon-Weiner diversity index was calculated from the mean weight per tow of fish species taken in each of the surveys. Biomass was estimated for all fish species in t km^{-2} for the survey area. Finally, the percent invertebrate biomass and the proportions of the six most abundant fish species to total fish biomass were calculated for each survey. Groundfish survey data were available for the BC Northern Shelf and Southern Shelf ecoregions in 2010 (Bryan et al. 2010; G. Workman unpubl data; Olsen et al. 2009 a, b, c). Results of the RV trawl survey in the Eastern Arctic ecoregion were available for 2008 (M. Treble unpubl. data). Results of the RV fall surveys in the Newfoundland and Labrador Shelves ecoregion (NAFO Divisions 2J3KLMNO) were available for 2009 (M. Koen-Alonzo unpubl. data). Survey information in 2009-2010 were available for 4T (Hurlbut et al. 2011), 4VWX (Clarke et al. 2010) and 5Z (Stone and Gross 2012) and unpublished information from H. Benoît.

Based on the above, bycatch and discards were summarized by gear type, main species group, including groundfish, small pelagic, large pelagic, crustacean, and other shellfish (scallop, surfclam and whelk), and ecoregion. Information was combined for the Newfoundland and Labrador Shelves (NLS), Gulf of St. Lawrence (GSL) and Scotian Shelf (SS) ecoregions and for the BC ecoregions. Except in cases were bycatch and discards were known because of 100% observer coverage, low and high estimates were taken from the summarized harvester logbooks and scientific studies. Studies of pot fisheries indicate that there can be discarding of about 6% fish and 14% invertebrates in lobster fisheries (den Heyer et al. 2010) but all discards are returned to the water live and healthy or used as bait. The above observations were supported by the harvesters’ logbooks, which do not record any bycatch in these fisheries.

For the remaining fisheries, scientific studies were used to estimate discard rates. But again, it is noted that these studies were only available for shrimp and groundfish fisheries in the southern Gulf, Scotian Shelf and Gulf of Maine. None of these studies was done for the 2009 and 2010 fisheries and it was necessary to extrapolate discard rates from other years.

RESULTS

LANDINGS

The official commercial landings of marine species are summarized for 2009 in Table 4. In general, the amount of landings from groundfish, pelagic and shellfish fisheries is similar between 2009 and 2010. Note that these landings do not include marine plants and aquaculture species such as mussels on the Atlantic coast, oysters on the Pacific coast and Atlantic salmon on both coasts.

The total Atlantic landings from the ZIFF are provided in Table 5. The ZIFF total for 2009 was about 1,000 t more than the official data. The ZIFF shellfish landings were 6,400 t less and groundfish landings 9,000 t more than the official numbers. The latter because the ZIFF and the official data had underestimated catches in NAFO Divisions 0AB. The same problem was also true In 2010, where because of missed groundfish landings in 0AB, the adjusted ZIFF had about 10,000 t more than the official data. It should be noted that species and area were not identified for a small proportion of landings, which is why the totals differ between Tables 4 and 5. Most landings in both years were from the Newfoundland and Labrador Shelves and Gulf of St. Lawrence ecoregions (about 30% in each). The proportion of landings by area was similar between 2009 and 2010, with the exception that most landings were from 4T in 2009 and from 4X in 2010 (Fig. 1).

In 2009, the Pacific landings (Table 5) were about 12,000 t less than the official data (Table 4), mostly in groundfish. In 2010, the Pacific landings were about 12,000 t more than the official data, mostly in pelagic fish. In both years, shellfish landings were 4,000-5,000 t less than the official landings because the predominantly dive-fisheries for sea cucumber, sea urchin, clams, geoducks and other shellfish do not have bycatch or discards and were not included in this report.

Species caught

On the Atlantic coast, a total of 61 species were recorded with landings. The species name was not known for 11,652 t of landings in 2009 and 18,867 t in 2010. More than 95% of landings were from 17 species (shown in Fig. 2) and the analysis was largely restricted to them. The five most abundant species were herring, shrimp, snow crab, scallop and lobster. The ninth to fourteenth most abundant species were groundfish. The proportions of species caught were similar in 2009 and 2010 (Fig. 2). There was considerable overlap in the landings of abundant species in the five Atlantic ecoregions (Table 6). Herring and shrimp predominated in four ecoregions. Turbot, cod, snow crab and scallop predominated in three ecoregions.

On the Pacific coast, Pacific hake comprised 65% of groundfish landings; and Pacific ocean perch, yellowtail rockfish and walleye pollock comprised another 15% of these landings. Pacific salmon species, sardine and herring comprised almost all pelagic landings; and shrimp and Dungeness crab comprised all shellfish landings shown in Table 5.

Gear type

There were 50 gear types recorded in the ZIFF that were grouped into 13 categories. The predominant gears were pot, purse seine, shrimp trawl, purse seine and trawl (Fig. 3). For the Atlantic coast, trawl, gillnet, longline and hand line were the predominant gear types in groundfish fisheries (Table 7); purse seine, gillnet and trap net were the main gears used in pelagic fisheries; and, pot, dredge and shrimp trawl were the main gears used to catch shellfish. Although not shown in Table 7 because of small catches (<1%), longlines were the main gear used to catch large pelagic fish and trap nets were also used to prosecute groundfish.

Pacific fisheries were harvested predominantly by trawl for groundfish, by purse seine for pelagic fish and by pot for shellfish.

Diversity

Diversity indices and species compositions from research trawl surveys suggested that ecoregions could be categorized by low, medium and high fish diversity (Table 8). The Eastern Arctic had a low diversity of fish species, where one species, turbot, comprised two-thirds of the biomass (Table 9). The Eastern Arctic also had a low pooled biomass and a low percentage of benthic invertebrates. By contrast, the BC ecoregions had high fish diversity and a low biomass of invertebrates. The three central Atlantic ecoregions (NLS, GSL and SS) had medium values for fish diversity and invertebrates comprised about 30% of biomass. These ecoregions also shared a similar fish fauna. Turbot, cod, yellowtail, redfish and plaice dominated the research surveys (Table 9). Species compositions in the landings data were also similar (Table 6). Based on their large-scale similarities and the lack of information available on bycatch and discards, results of analyses were shared among the three ecoregions (NLS, GSL and SS).

Except for the low biomass of invertebrates, George's Bank was also similar to the other Atlantic ecoregions (Table 8)

BYCATCH

Observer coverage was 100% in Eastern Arctic and the BC ecoregions, which were the areas of lowest and highest fish diversity. In the Eastern Arctic, bycatch in turbot trawl fisheries was 6% in 2009 and 8% in 2010 (Table 10). In British Columbia, bycatch estimates were available only for groundfish longline fisheries (Table 11). Average values and ranges were similar to those for the same gear and type of fishery on the east coast, see below:

	BC Longline (%)
2009	26 (0 – 78)
2010	20 (0 – 76)

On the Atlantic coast, observations of bycatch were more numerous in gillnet, longline and trawl groundfish fisheries (Table 10); their average values and ranges in percentages were as follows:

	Gillnet (%)	Longline (%)	Trawl (%)
2009	23 (0 – 56)	28 (6 – 61)	20 (0 – 65)
2010	20 (3 – 59)	23 (9 – 37)	31 (4 – 100)

The average values for 2009 and 2010 in the table above were used as minimum and maximum estimates of bycatch for the three gear types. The few observations of bycatch for Danish seines ranged from 16% to 67%. Bycatch in handline fisheries was <5% (Table 10).

Bycatch of non-target salmon species ranged between 1 and 14% in gillnet and purse seine fisheries and between 4 and 18% in troll (longline) fisheries.

Bycatch was not recorded in dredge, pot, purse seine, seine, shrimp trawl and trap net fisheries and assumed to equal discards. This assumption was also made for small pelagic gillnet and purse seine fisheries on the Atlantic coast. There would have been no incentive (regulation or market) to record bycatch in these fisheries.

There was little difference between 2009 and 2010 for any of the estimates of bycatch (Tables 10 and 11) summarized below:

Year	Low estimates of bycatch (t)			High estimates of bycatch (t)		
	Fish	Invertebrates	Total	Fish	Invertebrates	Total
2009	34,831	17,469	52,300	60,057	56,316	116,823
2010	35,999	16,463	52,463	61,861	53,045	114,906

DISCARDS

The groundfish trawl fisheries of the Eastern Arctic and the BC ecoregions had 100% observer coverage and likely provided the most reliable estimates of discards. In the Eastern Arctic, the ecoregion of lowest fish diversity, discards were 1.9% (Table 12). This value was about one-third the value for bycatch (Table 10). By contrast in BC, where ecoregions had the highest fish diversity, discards from groundfish trawls ranged from 11% to 16% (Table 13). Thus, discard rates in Canadian groundfish trawl fisheries might fall between 1.9% and 16%. Note that bycatch is not recorded in BC groundfish trawl fisheries (Table 11).

Discards of fish and invertebrates in Atlantic fisheries are summarized in Table 12. With few exceptions, these estimates were based on low observer coverage, generally <5%, and were made prior to 2009-2010 (Table 12). Discards can be large in pot fisheries because all non-commercial types and sizes of the target species are returned to the water.

Values for BC salmon fisheries were of uncertain accuracy (B. Patten pers. comm.) and values for pot and shrimp trawl fisheries in this province were taken from scientific studies (Rutherford et al. 2010, Olsen et al. 2000).

Only calculations for 2009 are shown in Tables 14 and 15. Discards in Canadian fisheries ranged from 38,000 t to 96,000 t. Total landings were 902,733 t in 2009 and the ratio of discards to landings ranged from 4% to 10%. Again, there was little difference between 2009 and 2010, summarized below by the main species categories:

Year	Low estimates of discards (t)			High estimates of discards (t)		
	Fish	Invertebrates	Total	Fish	Invertebrates	Total
2009	20,183	17,469	37,652	38,969	56,316	95,284
2010	21,996	16,463	38,459	40,743	53,045	93,788

The low and high estimates of discards are shown below for four gear types, dredge, pot, shrimp trawl and trawl. In the high estimates, 42% of discards were from pot fisheries, where the release of undersized and female snow crab and lobster were considered as discards. The low estimates were considered the most reliable; 85% of these discards were from five fisheries, scallop dredge, surfclam dredge, crustacean pot, crustacean trawl and groundfish trawl (Table 15). The remaining 15% of discards are summarized on the next page.

Gear	Species group	Ecoregion	Proportion of total discards	
			Low estimate	High estimate
Dredge	Scallop	NLS+GSL+SS	0.05	0.04
		GB	0.21	0.08
	Surfclam	NLS+GSL+SS	0.18	0.10
Pot	Crustacean	NLS+GSL+SS	0.01	0.42
Shrimp Trawl	Crustacean	NLS+GSL+SS	0.07	0.04
Trawl	Groundfish	NLS+GSL+SS	0.06	0.08
		BC	0.27	0.11
Total			0.85	0.85

All estimates need to be validated. For example, the discard rates for dredge fisheries were based on only a few studies that varied widely among regions. In the northern Gulf of St. Lawrence discards recorded in harvester logbooks were 8.3% compared to 77.1% for research surveys using a hydraulic dredge with a 20mm liner (Bourdages and Goudreau 2012).

UTILIZATION OF DISCARDS

The type of material available from the main discard fisheries are shown below:

Fishery	Amount of discards (t)	Type of material	Reference	Locations
Scallop dredge	1,800	59% molluscs and echinoderms 36% crustaceans 5% fish	Benoît 2011	Digby
	8,000	Likely as above		Factory freezer at sea, Lunenburg
Surfclam dredge	6,700	95% echinoderms 4% molluscs	Roddick et al. 2011	Factory freezer at sea, Lunenburg
Shrimp trawl	2,500	90% fish 10% invertebrates	Orr et al. 2010	Factory freezer at sea, various ports
Groundfish trawl	2,200	70% fish 30% invertebrates	M. Koen-Alonzo, pers. comm	Various ports
	10,000	99% groundfish 1% other	G. Workman pers. comm.	Prince Rupert, Vancouver
Groundfish trawl (shrimp)	862	70% fish 30% invertebrates	Proportion assumed from RV survey	
Groundfish gillnet	862	100% groundfish		
Groundfish longline	815	100% groundfish		
Large pelagic longline	1,144	100% sharks	Campana et al. 2011	
Other	5,376	Wide variety of species		

The proportion of landings by season are shown on the next page for the main discard fisheries. Except for yellowtail flounder, more than 60% of landings occurs in the spring and summer fisheries. The most temporally aggregated fishery is swordfish, where over 80% of landings occurs in the summer. The temporal distribution of fisheries appears to present less of a logistical problem than the widely-dispersed spatial distribution.

Species	Spring (Q2)	Summer (Q3)	Fall (Q4)	Winter (Q1)
Scallop	0.33	0.31	0.18	0.18
Surfclam	0.35	0.30	0.23	0.12
Shrimp	0.30	0.42	0.15	0.13
Cod	0.11	0.54	0.25	0.11
Haddock	0.12	0.45	0.21	0.22
Turbot	0.41	0.51	0.08	0.00
Yellowtail	0.45	0.07	0.37	0.11
Swordfish	0.06	0.82	0.12	0.00

Bycatch in Aquafeed Production

In 2009, Canada's capture fisheries landed about 914,000 t of fish and shellfish. Approximately, 37,650 t of this material might have been discarded; however, if it had been collected, it could have produced at most 7,530 t of fishmeal and 2,260 t of fish oil (using ratios from Tacon et al. 2006), depending on a number of variables (see next section).

Up to now, the inclusion of bycatch and discards in the manufacture of aquaculture feeds (aquafeeds) has not been pursued. Fishmeal and fish oil, the main ingredients in aquafeed, are generally made from the reduction of small pelagic fishes. Reduction is a process in which catch is brought to a processing plant where it is cooked, then the oil is pressed out and the remainder dried to make fishmeal (Anon, 2007). The yield in weight after reduction is about 20% fishmeal and 6% fish oil (Tacon et al. 2006) but this average value can range widely as explained in the next section. Landings in reduction fisheries have fluctuated between 20 and 30 Mt yr^{-1} over the last 30 years. About 30% of the 93 Mt yr^{-1} of landings in capture fisheries are used for aquafeed (Tacon and Metian 2009).

Global production of aquafeed in 2008 was 30 Mt, after doubling twice over the past two decades (Tacon and Metian 2009). The main constituent species in aquafeeds are shown below.

Species	Percent of global average (Huntington 2004)	Percent used in commercial feed (EWOS 2010)
Anchovy	57	44
Mackerel	10	8
Capelin	10	
Herring	1	10
Menhaden	5	6
Sardine	2	
Sandeel/Sandlance	5	8
Whiting	7	8
Sprat	2	
Other	1	16

FAO (2009) reports that most reduction fisheries are fully exploited, with some considered as overexploited. Fully-exploited fisheries are producing catches at or near the maximum sustainable level and overexploited stocks risk depletion if catches are not reduced (Anon. 2007).

The use of discards and seafood by-products has potential for reducing aquaculture's dependence on international forage fisheries and pressures from competing users. Discards from fisheries and wastes from seafood processing are estimated to be about 25–30 Mt yr^{-1} (Naylor et al. 2009, Hall & Mainprize 2005). Although none of this material is easily available, if collected together, it would be equal in weight to the landings of forage fish currently used to produce fishmeal and oil (Naylor et al. 2009).

Bycatch and discards in Canadian fisheries from this study were a mixture of demersal fish, crustaceans, molluscs, echinoderms and sharks. These species would likely produce a lower yield of fishmeal and fish oil than pelagic fish. Nevertheless, as explained above, the harvests of small pelagic fish appear to have plateaued worldwide while the aquaculture industry continues to grow. Thus, any increases in aquaculture will require other sources of protein and oil (Olsen 2011); perhaps, discards could help fill this void.

Tacon (2009) summarized a number of negative environmental and social impacts that could result from the use of bycatch/discards (called trash fish in his article) in aquaculture feeds:

- increased environmental pollution resulting from the use of highly perishable trash fish-based feed items;
- increased biosecurity and disease risks of feeding unpasteurized trash-fish products back to cultured fish and/or wild fish through bait use;
- increased fishing pressure on wild juvenile target species for fattening and on pelagics for feeding/bait use; and
- increased use of trash fish may also include the captured juveniles of higher-value commercial food-fish species and consequent risk of overfishing on available fish stocks (FAO 2004).

Tacon (2009) also suggested that high demand for trash fish for use in aquafeeds might raise prices and place these fish out of reach for direct human consumption, particularly the poor. Nevertheless, bycatch and discards could become an important component in aquafeeds if the above difficulties could be overcome.

Nutritional Composition of Aquafeed

Atlantic salmon is the second most valuable cultured aquatic species in the world (FAO 2009) and its production is based entirely on commercial feeds. Global production of salmon was 2.0 Mt in 2008 and consumed 500,000 t of fishmeal and nearly 300,000 t of fish oil (Tacon et al. 2011).

Two-thirds of Canada's aquaculture production is Atlantic salmon (http://www.dfo-mpo.gc.ca/stats/aqua/aqua09-eng.htm). In 2009, production was 100,000 t, or 5% of the global total. Canadian aquaculture feed manufacturers produce from 150,000 t to 200,000 t of feed annually (Tacon and Metian 2008); they also import 40% of feed ingredients, including 50,000 t of fish meal and 35,000 t of fish oil, about 10% of global production (Tacon et al. 2011).

Although it is the smallest portion of major farmed animal feeds (Anon. 2007), aquaculture globally consumes 46% of the world's fishmeal and 81% of the world's fish oil (Tacon et al. 2006). These ingredients are particularly important dietary components for carnivorous species like salmon, which need fishmeal and fish oil for their easily-digestible essential nutrients and fatty acids, which are not present in oils from higher plants (Olsen 2011).

Global fishmeal production has plateaued at 6-7 Mt (FAO 2011). About 90% of fishmeal is from pelagic fish, 4% from demersal fish and <1% from crustaceans (Tacon et al. 2006). Worldwide fish oil production is 1.0 Mt (FAO 2011). About 40% of fish oil comes from pelagic fish and 50% from other fish (Tacon et al. 2006). Fishmeal and fish oil can be produced from a wide variety of fishes (anchovy, capelin, grenadier, hake, herring, mackerel, menhaden, pilchard, sandeel, sardine, sardinella, saury, shad, sprat, whiting), crustaceans (marine shrimps, squilla), and molluscs (clams, mussels, squid) (Tacon et al. 2011). It should be noted that in Canada, meal made from crustaceans is registered by CFIA as crustacean meal and meal from molluscs is registered as molluscan meal (A. Dumas pers. comm.). A more precise composition of these products is unknown because only 18% of global fishmeal and 45% of fish oil production is reported at a species-specific level (Tacon et al. 2006).

Using values from 2007, the main countries involved with the production, export and import of fishmeal and fish oil are shown below (Tacon et al. 2011). Canada is a minor producer of fishmeal and oil on a global basis. It is a net importer of fishmeal and oil to meet the needs of domestic aquafeed production. Canadian production data are currently unavailable.

Country	Production (%)		Export (%)		Import (%)	
	Fishmeal	Fish oil	Fishmeal	Fish oil	Fishmeal	Fish oil
Peru	25	30	41	37		
China	19				30	3
Chile	13	18	16	8		10
Thailand	8		3			
US	5	7	3	6		3
Japan	4	6			11	3
Denmark	3	12	5	15	5	18
Norway	3	5	1	7	7	26
Iceland	2	6	4	7		
Canada	N/A	N/A	N/A	N/A	1	3
Global Mt	*6.1*	*1.1*	*3.1*	*0.9*	*3.3*	*0.9*

Seven corporations currently produce aquaculture feeds in Canada, namely Skretting North America, EWOS Canada, Martin Mills, Corey Feed Mills, Northeast Nutrition, Taplow Feeds and Viterra Feed Products. Together, they operate nine aquaculture feed mills located in British Columbia, Ontario, New Brunswick, and Nova Scotia (Bureau 2010). A small proportion of this production is exported to the United States, Mexico, and different countries in Asia. Canadian aquaculture operations also import small amounts of aquaculture feeds from the United States, Europe and Asia (Bureau 2010). Canada sent 200,00 t of herring for reduction in 2003 (Tacon et al. 2006) and has the capacity to produce several hundred tons of meal from each of herring, capelin, shrimp, rock crab and snow crab, mostly in New Brunswick (MUN 2011). In addition, Newfoundland and Nova Scotia have capacities to produce fishmeal and other meals derived from marine species.

Crab and shrimp meal are used primarily as dietary feeding attractants and a natural source of carotenoid pigments (Villarreal et al., 2004). These products generally have lower protein quality than fishmeal (due to higher exoskeleton and chitin content) and variable quality (depending upon fishing season and species processed). As with krill and squid, crustacean meals are good dietary sources of cholesterol, phospholipids and minerals (Hertrampf and Pascual 2000).

Fish meal and fish oil provide an excellent source of animal protein, essential amino acids, omega-3 fatty acids, vitamins and minerals, and energy (Hertrampf and Pascual 2000). The levels of essential amino acids, essential fatty acids, minerals, and vitamins to which feeds are formulated can vary several-fold within species. Differences exist in the nutritional requirement of fish of the same species at different life stages thereby requiring aquafeed manufacturers to formulate feeds following widely different nutritional specifications depending on life stage (Tacon and Metian 2008). The digestible energy (DE) content of feeds manufactured for salmonids may vary as much as 60% (e.g. 14 MJ DE/kg to 24 MJ DE/kg). Feeds of different DE content will result in different feed intakes and different feed conversion ratios (FCRs). In general, Canadian FCRs range between 1.2-1.4, and feeds comprise 30% meal and 18% fish oil (Tacon and Metian 2008).

Aquafeed usually represents the highest cost of operating a salmon farm, with feeds and feeding representing 50 to 60 percent of total costs (A. Dumas, pers. comm.). Because fishmeal and fish oil comprise the main ingredients of feed, any increases in their price will lead to increased costs and decreased profitability (Tacon 2005). Despite substantial efforts to substitute fishmeal with other protein sources, success has been limited by growth and performance constraints (Huntington 2004). The fishmeal content of salmonid feeds is unlikely to fall by more than 25%, although the ability to replace up to 50% of fish oil with vegetable substitutes is technically possible (Huntington 2004). Another viable option is the rapid expansion in species used for marine aquaculture (Duarte et al. 2009). These innovations in domestication and breeding would suggest that a wider variety of protein and oil could be utilized as a feed source. FAO (2011) notes that fishmeal production has stopped increasing and alternatives will need to be found if aquaculture is to continue growing.

There appears to be potential to using the wide-range of discards from Canadian fisheries in the manufacture of fishmeal and fish oil because most material (demersal fish, sharks, crustaceans and molluscs) could be used (Tacon et al. 2011). No information could be found for echinoderms, which are a major component of discards in the surfclam dredge fishery. The International Fishmeal and Fish Oil Organization list of approved materials for use in fish meal includes a wide range of demersal and pelagic fish, elasmobranchs, scallops and lobster shell (http://www.iffo.net/default.asp?contentID=755).

In the view of Jón Árnason (Matis Ltd., Iceland http://www.matis.is/english/about/), discards from Canadian fisheries would have a combination of nutrients that could be utilized in aquafeeds but there are no published results at present. There is work in Iceland to use molluscs and crustaceans as ingredients in aquafeeds but there is no work on the potential utilization of echinoderms or elasmobranchs.

In Iceland, there are several issues regarding the use of discards (J. Árnason pers. comm.). First, the conservation of raw material prior to processing for any extended period of time might require acidification with organic acids (e.g., formic acid), although this method is not a common practice in Iceland. Second, some raw materials might contain undesirable toxins, particularly if the organisms are filter feeders. Finally, due to the geographically widely-dispersed landings of bycatch there may be a need for small-scale fishmeal processing units. An Icelandic company called Hedinn has developed units that can process about 7 Mt per day. Processing units of similar size are also available from China. Up to now, Iceland has shown little interest in utilizing discards, except for the 20-30% that are used to feed fur animals.

Canadian aquafeed production is currently about 200,000 Mt. About 150,000 Mt is used domestically primarily for salmon and trout production (Tacon and Metian 2008). Canadian aquafeed contains about 15% fishmeal and 5-10% fish oil. As stated above, if Canadian discards were equivalent in quality to small pelagic fish, they might have produced about a third of fishmeal and 15% of fish oil requirements for the aquaculture industry. A major obstacle to the utilization of discards from Canadian fisheries would be the collection and storage of fresh material to be used in processing.

Before considering discards, it would appear more logical to begin utilizing the > 400,000 t of materials that are being discarded at fish processing plants (MUN 2011). This material is already available in a concentrated form and more amenable for transport to reduction plants than discards from widely-dispersed capture fisheries. This solution would help to alleviate pollution problems in coastal waters caused by seafood processing plants (Morry et al. 2003) and would be consistent with the ecosystem approach to aquaculture, where waste products from one activity serve as inputs to another (FAO 2011).

DISCUSSION

One conclusion of this study would be that there is very little concrete information on discards in Canadian fisheries. Considering the usual requirement for annual advice on the more than 500 stocks or management units in Canada (DFO 2001), it is surprising to find that there has been only a handful of studies on discards over the past decade or so and that discards are mentioned only infrequently in stock assessments. The latter is also surprising, considering global interest in ecosystem-based fishery management and the plea to develop community and system-level standards and control rules that would account for ecosystem components such as non-target species (Rosenberg et al. 2006, Pikitch et al. 2004). In addition, the supposed commitment to the Oceans Act and integrated oceans management would seem to require an accounting of all removals and discards within ocean management areas. A clearly-designated section on discards under ecological considerations would be a useful improvement to stock assessments.

The previous comprehensive study of discards in Canadian fisheries was made by Kelleher (2005). Part of the source material for this analysis was from Duthie (1997). Kelleher found that the overall discard rate for Canada was 10.2% of the 789,000 t of landings; he concluded that major discards were from scallop dredges (23,000 t), Atlantic groundfish trawls (11,000 t), Pacific groundfish trawls (9,000 t) and lobster and crab pot fisheries (25,000 t). Minor discards were from the swordfish longline fishery (9%).

In the current study, the discard ratio for all Canadian fisheries combined ranged from a low estimate of 4% to a high estimate of 10%. The upper value was close to Kelleher's estimate. This study also found the same gear types with high discards as listed by Kelleher (2005) but with the addition of shrimp trawls and surfclam dredges. A paper by the World Wildlife Fund estimated that 8.1% of Canada's annual landings was bycatch (Davies et al. 2009). Although the data are weak, there appeared to be some agreement among the different Canadian estimates.

In contrast, a comprehensive study of discards recently completed in the US has found higher discard ratios than those above (NMFS 2011). This study found that 17% of all landings in the US were discarded and the highest discard ratios were in bottom trawl and longline fisheries. Discard ratios in north-eastern fisheries were estimated to be 5% for purse seine, 23-44% for otter trawl, 8% for handline, 17-32% for gillnet, 9-13% for scallop dredge and 11-22% for longline. These values were generally higher than what were found here.

The major source of discard information is the extensive observer database, which again seems to be used only infrequently. The lack of interest in the database stems from several issues, one of them being that observer data cannot be matched by trip to the ZIFF database. Other issues are the low number of fishing trips that are actually observed and the statistical problems of deployment bias and non-randomness (Benoît and Allard 2009). There seems to be little interest in improving the situation. For example, the DFO management plan for surfclams stated that the need for at-sea observers was considered to be low because “there is an absence of groundfish bycatch and data for scientific purposes will be collected under research programs” (http://www2.mar.dfo-mpo.gc.ca/fisheries/res/imp/98srfclm.htm#5.2 Issue:). Consequently, the year-round surfclam fishery has been observed on only 7 trips since 1995, a period of 17 years (Roddick et al. 2011).

Another issue is the assumption that bycatch and discards are unimportant in small pelagic and pot fisheries. Regarding the former, purse seine fisheries, as a rule, fish in well-defined locations where aggregations of the target species, usually herring, have occurred routinely over many years and the chance of bycatch is very low (FRCC 2009); however as Stephenson et al. (1999) point out, there can be occasional large bycatches that are episodic and not predictable. Gillnets are also a selective gear but their widespread use increases the likelihood of bycatch. Apart from herring fisheries in the Gulf of St. Lawrence that are focused on herring spawning beds, it would be useful to increase observer coverage of gillnet fisheries. Pot fisheries can have sizeable discards, although none would be practicably available for processing. One issue is the safe release of animals to the water. The survival of discarded undersized snow crab is related to time of exposure on deck and distance dropped to the water (FRCC 2005). The Fisheries Resources Conservation Council (FRCC) noted that discarding was a conservation issue that could be improved with a strictly enforced code of practice (FRCC 2005). In general, discards of undersized lobsters and berried females from lobster fisheries are not an issue (M. Comeau pers. comm.). The bycatch of groundfish in these fisheries is small (L. Savoie, pers. comm.).

Discards could be used in aquaculture feed but there will be many obstacles related to collecting the material at sea and transporting it to a reduction plant. These issues might best be overcome by beginning with the reuse of wasted material at seafood processing plants, where > 400,000 t of material, or 48% of landings, are currently being wasted (MUN 2011). This number is an order of magnitude greater than the potential unutilized discards in Canadian fisheries.

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Table 1. Summary of Atlantic coast commercial landings (t) 2009-10 by ecoregion, DFO region and NAFO Division. These numbers include landings where the species name was not known, making the numbers slightly higher than in Table 4.

Ecoregion	DFO Region	NAFO	2009	2010
Eastern Arctic (EA)	Central	0A	6,813	10,036
	Central	0B	10,216	12,676
Newfoundland and Labrador Shelves (NLS)	Newfoundland	2G	11,643	13,457
	Newfoundland	2H	9,706	12,769
	Newfoundland	2J	31,269	35,948
	Newfoundland	3K	60,109	77,267
	Newfoundland	3L	63,263	58,307
	Newfoundland	3M	13	12
	Newfoundland	3N	8,391	10,246
	Newfoundland	3O	7,079	6,212
	Newfoundland	3P	34,927	35,929
Gulf of St. Lawrence (GSL)	Newfoundland	4R	68,432	57,361
	Quebec	4S	37,033	37,558
	Gulf	4T	128,584	111,799
Scotian Shelf (SS)	Maritimes	4V	42,240	42,637
	Maritimes	4W	39,590	35,606
	Maritimes	4X	117,367	126,825
	Maritimes	5Y	9,669	9,338
Georges Bank (GB)	Maritimes	5Z	67,995	64,503
Total			756,348	760,496

Table 2. Summary of categories of gear used in this report.

Gear category	Types of gear included
Danish Seine	Danish Seine, Scottish Seine
Dredge	Dredge (Boat), Drag Rake, Hydraulic Device, Mechanical Digger
Gillnet	Gillnet (drift), Gillnet (fixed), Gillnet (unspecified)
Handheld Tools	Electric Harpoon, Hand and Hand-held Tools, Harpoon, Rakes and Tongs, Spear
Hand Line	Handline
Longline	Longline, Troll, Line, Mechanical Jigger
Purse Seine	Pair Seine, Purse Seine, Tuck Seine
Seine	Beach and Bar Seine
Shrimp Trawl	Shrimp Trawl, Shrimp Beam Trawl
Pot	Conical Trap, Eel Pot, Lobster Trap, Pot (Unspecified), Japanese Trap, Pyramidal Trap, Mixed Trap-Crab, Standard Trap-Pot
Trap Net	Box Net, Fyke Net, Square Net, Trap Net, Lift Net, Weir
Trawl	Otter Trawl (Side), Otter Trawl (Stern) and Unspecified, Midwater Trawl
Uncategorized	Hagfish barrel, Hunting, Diving, Rod and Reel, Rope, Unspecified, Blank

Table 3. Summary of discard rates used in earlier reports.

Gear category	Discard rates from earlier studies (%)	
	Kelleher 2005	Duthie 1994 and Alverson et al. 1994
Danish Seine		
Dredge	28	25
Gillnet	1-20	20-30
Handheld Tools		
Hand Line	2	
Longline	8-29	
Purse Seine	1	0.2-1
Seine		
Shrimp Trawl	62	6
Pot	23	20-22
Trap Net		
Trawl	10	6-35

Table 4. Summary of official landings (see Methods) in Canada's Atlantic and Pacific commercial marine fisheries

Year	Total		Groundfish		Pelagic & Other Fish		Shellfish	
	Atlantic	Pacific	Atlantic	Pacific	Atlantic	Pacific	Atlantic	Pacific
2009	755,408	158,625	105,635	98,229	239,994	46,219	409,779	14,176
2010	748,238	150,852	103,843	87,135	221,171	52,241	423,226	11,476

Table 5. Summary of landings in commercial marine fisheries from ZIFF and other sources (see Methods).

Year	Total		Groundfish		Pelagic & Other Fish		Shellfish	
	Atlantic	Pacific	Atlantic	Pacific	Atlantic	Pacific	Atlantic	Pacific
2009	756,730	146,003	114,956	86,276	238,405	50,136	403,370	9,194
2010	758,830	162,249	113,882	89,289	221,127	63,212	423,820	7,427

Table 6. Most important species shown in proportions of total 2009 landings for the five Atlantic ecoregions. The shaded squares are for species that comprise > 95% of total landings for a given ecoregion. The colours in the species column identify groundfish (grey), pelagic fish (blue) and shellfish (red). The value 0.00 indicates that the proportion of landings was <0.005.

Species	Ecoregion				
	EA	NLS	GSL	SS	GB
Turbot	0.45	0.03	0.02	0.00	
Cod		0.05	0.01	0.02	0.01
Yellowtail		0.03	0.00		
Silver hake				0.06	
Redfish		0.01	0.00	0.05	0.01
Haddock		0.00		0.03	0.24
Pollock				0.03	0.01
Hagfish				0.01	0.00
Herring		0.03	0.30	0.33	0.11
Mackerel		0.05	0.12	0.01	0.00
Capelin		0.10	0.05		
Alewife			0.01	0.00	
Shrimp	0.55	0.40	0.16	0.02	
Snow crab		0.24	0.14	0.06	
Lobster		0.01	0.09	0.15	0.00
Rock crab		0.00	0.03	0.00	0.00
Oyster			0.01		
Scallop		0.00	0.01	0.06	0.62
Whelk		0.02	0.01		
Surfclam		0.01	0.00	0.13	
Cucumber		0.00	0.00	0.01	0.00
Total proportion	1.00	0.95	0.96	0.95	0.97

Table 7. Percentage of landings by major gear type for each group of Atlantic commercial fisheries, 2009-10.

Year	Groundfish				Pelagic & Other Fish			Shellfish		
	Trawl	Gillnet	Long-line	Hand Line	Purse Seine	Gillnet	Trap Net	Pot	Dredge	Shrimp Trawl
2009	63	22	13	2	66	27	4	42	23	35
2010	67	21	10	1	69	26	4	39	21	40

Table 8. Surface area, 2009 landings, survey biomass and diversity indices of fish species for 2009-10 research surveys in the five Atlantic and two Pacific ecoregions.

Characteristic	Ecoregion						
	Eastern Arctic	NL Shelves	Gulf of St. Lawrence	Scotian Shelf	Georges Bank	BC Northern Shelf	BC Southern Shelf
Area (000s km^2)	88[1]	448	73[2]	172	60	13	13
Landings (000s t)	16	226	235	213	68	62	62
Biomass (t km^{-2})	1.67[1]	4.60	2.40	3.15	2.85	2.24	4.32
% invertebrates	8	30	31	32	<1	<1	<1
Diversity Index	1.091	2.477	2.352	2.008	1.608	2.925	2.737

[1] Division 0A only
[2] Southern Gulf only

Table 9. Proportions of the six most dominant fish species from 2009-10 research surveys in the five Atlantic ecoregions.

Species	Ecoregion				
	EA	NLS	GSL	SS	GB
Turbot	0.69	0.09	0.06		
Cod		0.10	0.30	0.09	0.11
Yellowtail		0.11	0.03	0.02	0.19
Silver hake					
Redfish	0.01	0.27		0.37	
Haddock				0.28	0.53
Pollock				0.04	0.02
Hagfish					
Plaice		0.13	0.11		
Skates	0.03	0.07			0.08
Sharks	0.19			0.04	
W. flounder			0.08		
Other	0.04				0.01
Herring			0.19		

Table 10. Landings for Atlantic Canada and the percent bycatch (catch of non-directed commercial species) from logbooks in 2009 and 2010.

Gear	Eco-region	Directed species	Landings 2009 (t)	Percent bycatch	Landings 2010 (t)	Percent bycatch
Danish Seine	GSL	Cod	1	0	1	0
		Redfish	120	21	157	16
		Yellowtail	102	66	196	67
	SS	Haddock	1	0	0	
		Pollock	1	0	0	
		Redfish	1	0	1	0
	GB	Pollock	1	0	0	
Dredge	NLS	Scallop	442	0	860	0
		Surfclam	1,076	0	542	0
	GSL	Scallop	1,931	0	1,323	0
		Surfclam	894	0	911	0
	SS	Scallop	12,164	0	12,983	0
		Surfclam	25,978	0	23,992	0
	GB	Scallop	48,066	0	44,529	0
Gillnet	EA	Turbot	3,744	18	2,449	25
	NLS	Cod	6,219	10	6,205	5
		Haddock	40	46	0	
		Pollock	12	56	50	35
		Redfish	46	54	6	59
		Turbot	3,488	4	3,432	4
		Herring	432	0	61	0
		Mackerel	20	0	95	0
	GSL	Cod	1,822	3	1,684	3
		Redfish	22	0	0	
		Turbot	4,375	4	4,112	4
		Herring	46,228	0	42,548	0
		Mackerel	2,888	0	2,300	0
	SS	Cod	184	40	137	39
		Haddock	4	38	0	
		Pollock	1,362	23	1,092	28
		Herring	9,925	0	5,763	0
		Mackerel	275	0	1,178	0
	GB	Cod	153	27	59	30
		Pollock	16	27	370	10
		Mackerel	286	0	0	
Hand Line	NLS	Cod	1,345	0	925	0
		Mackerel	6	0	71	0
	GSL	Cod	209	1	266	1
		Herring	61	0	7	0
		Mackerel	3,084	0	2,370	0
	SS	Cod	28	0	16	4
		Mackerel	46	0	16	0
		Pollock	44	2	50	5
	GB	Cod	9	1	4	23

Table 10. continued

Gear	Eco-region	Directed species	Landings 2009 (t)	Percent bycatch	Landings 2010 (t)	Percent bycatch
Longline	EA	Turbot	102			
	NLS	Cod	3,369	12	2,103	12
		Haddock	2	61	0	
		Redfish	8	0	0	
		Turbot	8	44	69	16
		Mackerel	1	0	0	
	GSL	Cod	1,380	6	960	9
		Redfish	62	6	0	
		Turbot	12	10	0	
		Mackerel	2	0	0	
	SS	Cod	2,075	38	2,756	27
		Haddock	908	39	1,328	37
		Pollock	28	16	7	29
		Swordfish	821		968	
		Turbot	2	50	0	
	GB	Cod	219	33	120	36
		Haddock	2,700	22	2,864	15
		Swordfish	359		414	
Pot	NLS	Cod	3	0	12	0
		Lobster	1,403	0	1,574	0
		Rock crab	72	0	89	0
		Snow crab	53,171	0	52,464	0
		Whelk	5,147	0	5,252	0
	GSL	Lobster	21,239	0	22,346	0
		Rock crab	6,228	0	6.089	0
		Snow crab	32,171	0	17,948	0
		Whelk	1,273	0	1,495	0
	SS	Lobster	29,683	0	36,258	0
		Rock crab	209	0	185	0
		Shrimp	4	0	2	0
		Snow crab	11,563	0	13,983	0
	GB	Lobster	255	0	488	0
		Rock crab	5	0	0	
Purse Seine	NLS	Capelin	18,636	0	12,983	0
		Herring	4,581	0	3,520	0
		Mackerel	11,215	0	17,767	0
	GSL	Capelin	9.136	0	8,746	0
		Herring	21,794	0	23,178	0
		Mackerel	21,464	0	13,469	0
	SS	Herring	53,282	0	48,176	0
	GB	Herring	8,455	0	8,453	0
Seine	NLS	Capelin	599	0	291	0
		Herring	2,076	0	1,760	0
		Mackerel	681	0	1,095	0
	GSL	Capelin	141	0	0	

Table 10. continued

Gear	Eco-region	Directed species	Landings 2009 (t)	Percent bycatch	Landings 2010 (t)	Percent bycatch
Shrimp Trawl	EA	Shrimp	4,813	0	9,507	0
	NLS	Shrimp	89,460	0	113,190	0
	GSL	Shrimp	2,914	0	2,582	0
	SS	Shrimp	3,355	0	5,098	0
Trap Net	NLS	Cod	35	1	15	0
		Capelin	3,180	0	2,023	0
		Herring	541	0	1,153	0
		Mackerel	410	0	279	0
	GLS	Cod	1	0	0	
		Capelin	2,786	0	2,058	0
		Herring	1,805	0	810	0
		Mackerel	512	0	579	0
	SS	Mackerel	754	0	299	0
Trawl	EA	Turbot	8,370	8	2,146	6
	NLS	Cod	760	12	1,490	22
		Pollock	17	35	0	
		Redfish	1,387	10	1,856	8
		Turbot	3,025	18	4,078	20
		Yellowtail	6,690	40	9,364	14
	GSL	Cod	8	0	4	75
		Redfish	528	19	429	9
		Yellowtail	228	65	391	68
		Shrimp	33,147	0	33,838	0
	SS	Cod	851	39	1,004	41
		Haddock	4,540	15	4,528	16
		Pollock	3,406	15	2,873	14
		Redfish	9,837	10	10,676	7
		Silver hake	11,059	4	8,468	4
		Yellowtail	3	0	16	100
		Herring	2	0	0	
		Shrimp	21	0	0	
	GB	Cod	34	42	119	54
		Haddock	15,785	3	14,770	5
		Pollock	136	35	261	27
		Redfish	784	13	287	15

Table 11. Landings for Pacific Canada and the percent bycatch (catch of non-directed commercial species) from observers in groundfish fisheries and logbooks in salmon and shellfish fisheries, 2009 and 2010.

Gear	Eco-region	Directed species	Landings 2009 (t)	Percent bycatch	Landings 2010 (t)	Percent bycatch
Gillnet	BCNS	Herring	1,286	0	1,010	0
		Salmon	1,258	5	571	14
	St.of G	Herring	3,937	0	3,244	0
		Salmon	1,137	1	9,483	1
Longline	BCNS	Dogfish	26	30	110	29
		Groundfish	270		236	
		Halibut	1,934	25	2,000	20
		Halibut-Sablefish	595	25	579	23
		Lingcod	153	4	113	3
		Sablefish	12	54	317	5
		Salmon	1,345	18	1,053	15
	St.of G	Dogfish	374	30	308	14
		Groundfish	259	0	32	0
		Halibut	13	43	18	56
		Lingcod	1	0	1	0
	Offshore	Groundfish	191		294	
		Halibut	187	43	244	37
		Halibut-Sablefish	125	42	112	35
		Lingcod	36	8	26	4
		Sablefish	237	15	681	6
	Southern	Albacore	397		2321	
		Dogfish	2,454	8	427	19
		Groundfish	113		139	
		Halibut	138	78	133	76
		Halibut-Sablefish	212	36	313	43
		Lingcod	227	5	255	4
		Sablefish	157	16	518	8
		Salmon	648	11	1,519	4
Purse Seine	BCNS	Herring	713		474	
		Salmon	13,622	5	1,011	6
	St.of G	Herring	5,685		4,540	
	Offshore					
	Southern	Salmon	3,826	4	17,399	1
		Sardine	15,334		22,223	
Pot	BCNS	Crab	2,455		2,288	
		Shrimp	393		325	
	St.of G	Crab	2,441		2,155	
		Shrimp	2,617		1,326	
	Offshore					
	Southern	Crab	297		388	
		Shrimp	386		440	

Table 11. continued

Gear	Eco-region	Directed species	Landings 2009 (t)	Percent bycatch	Landings 2010 (t)	Percent bycatch
Shrimp Trawl	BCNS	Shrimp	110		68	
	St.of G	Shrimp	325		415	
	Offshore					
	Southern	Shrimp	170		22	
Trawl	BCNS	Groundfish	27,124		16,590	
	St.of G	Groundfish	13,790		1,849	
	Offshore	Groundfish	1,598		6,301	
	Southern	Groundfish	36,050		57,693	

Table 12. Percentage of total landings by weight of fish and invertebrates discarded in Atlantic fisheries from available scientific studies of observer data. The % observer coverage and years analyzed are shown.

Gear	Eco-region	Directed species	Percent discarded Fish	Invert	Reference for discard estimate	Year	Obs. %
Danish Seine	GSL	Cod	1.5	1.2	Benoît and Hurlbut 2010	1991-09	˜5
		Redfish					
		Yellowtail	11.5	5.6	Benoît and Hurlbut 2010	1991-09	˜5
	SS	Haddock					
		Pollock					
		Redfish					
	GB	Pollock					
Dredge	NLS	Scallop					
		Surfclam	0.1	35.0	Roddick et al. 2011, survey	2007	<1
	GSL	Scallop	0.6	11.8	Benoît 2011, unpubl. data	2006-08	<1
		Surfclam		8.3 77.1[1]	Bourdages and Goudreau 2012 [1]with 20mm liner	2009	0
	SS	Scallop		7.8	Sameoto and Glass 2012	2009	3-9
				22.9	Gavaris et al. 2010	2006	2
		Surfclam	0.1	24.0	Roddick et al. 2007, survey	2004	<1
	GB	Scallop	1.0		Eekhaute and Gavaris 2006,	2005	1
				15.7	Gavaris et al. 2010	2006	6
Gillnet	EA	Turbot	1.8		Treble unpubl. observer data	2009-10	High
		Turbot	2.2		Treble unpubl. observer data	2009-10	High
	NLS	Cod	0.2		Benjamins et al. 2010, sharks only	2001-03	<1
		Haddock					
		Pollock					
		Redfish	4.0		Benjamins et al. 2010, sharks only	2001-03	1.5
		Turbot	0.6		Benjamins et al. 2010, sharks only	2001-03	1.5
		Herring	trace		Reddin et al. 2002, from survey	2001	
		Mackerel					
	GSL	Cod	3.3	1.6	Benoît and Hurlbut 2010	1991-09	˜5
		Redfish					
		Turbot	9.5	6.5	Benoît and Hurlbut 2010	1991-09	˜5
		Herring					
		Mackerel					
	SS	Cod					
		Haddock	9.0		Gavaris et al. 2010	2005	2
		Pollock	17.6		Stone et al. 2009	2008	2
		Herring					
		Mackerel					
	GB	Cod	0.5		Gavaris et al. 2010	2002	12
		Pollock					
		Mackerel					

Table 12. Continued.

Gear	Eco-region	Directed species	Percent discarded		Reference for discard estimate	Year	Obs. %
Hand Line	NLS	Cod					
		Mackerel					
	GSL	Cod	0.6		Benoît and Hurlbut 2010	1991-09	~5
		Herring					
		Mackerel					
	SS	Cod					
		Mackerel					
		Pollock					
	GB	Cod					
Longline	EA	Turbot					
	NLS	Cod					
		Haddock					
		Redfish					
		Turbot					
		Mackerel					
	GSL	Cod	9.9		Benoît and Hurlbut 2010	1991-09	~5
		Redfish					
		Turbot	14.8	0.4	Benoît and Hurlbut 2010 (for halibut)	1991-09	~5
		Mackerel					
	SS	Cod	13.4		Gavaris et al. 2010	2002	1
		Haddock	13.4		Gavaris et al. 2010	2002	1
		Pollock	13.4		Gavaris et al. 2010	2002	1
		Swordfish	97.0		Campana et al. 2011	1996-10	5
		Turbot	7.6		Gavaris et al. 2010	2002	6
	GB	Cod	6.4		Gavaris et al. 2010	2002	10
		Haddock	6.4		Gavaris et al. 2010	2002	10
Pot	NLS	Cod					
		Lobster					
		Rock crab					
		Snow crab					
		Whelk					
	GSL	Lobster					
		Rock crab					
		Snow crab					
		Whelk					
	SS	Lobster	5.8	19.5	den Heyer et al. 2010	2006	0.01
		Rock crab					
		Shrimp					
		Snow crab	0.001	0.001	Choi and Zisserson 2007	2004-06	4
					Gavaris et al. 2010	2006	
				20.2			8
	GB	Lobster					
		Rock crab					

Table 12. Continued.

Gear	Eco-region	Directed species	Percent discarded		Reference for discard estimate	Year	Obs. %
Purse Seine	NLS	Capelin					
		Herring	100		Wheeler et al. 2008, not used	1996-07	
		Mackerel					
	GSL	Capelin					
		Herring					
		Mackerel					
	SS	Herring	0.1		Stephenson et al. 1999	1990s	<1
			0		Gavaris et al. 2010	2002	8
	GB	Herring	23.6		Gavaris et al. 2010	2002	4
Seine	NLS	Capelin					
		Herring					
		Mackerel					
	GSL	Capelin					
Shrimp Trawl	EA	Shrimp	2.0		Siferd 2010	2008-09	100
	NLS	Shrimp	2.3	0.3	Orr et al. 2010	2008-09	100
	GSL	Shrimp	1.2		Fréchet et al. 2006	1999-05	˜5
	SS	Shrimp	3.6		Koeller et al. 2006	2004-06	<1
Trap Net	NLS	Cod					
		Capelin					
		Herring					
		Mackerel					
	GLS	Cod					
		Capelin					
		Herring					
		Mackerel					
	SS	Mackerel					
Trawl	EA	Turbot	1.9	0.2	Treble unpubl. observer data	2009-10	100
	NLS	Cod	6.5		Kulka 1997	1980-94	˜5
		Pollock					
		Redfish	5.0		Pavlenko et al. 2010	1980-09	
		Turbot	4.3		Ibarrola and Paz 2011	2008-09	˜18
		Yellowtail	3.2		Morgan 2008, cod only	2000-07	
			5.0		Shelton and Morgan 2005, plaice only	2001-03	
	GSL	Cod	1.5	1.2	Benoît and Hurlbut 2010	1991-09	˜5
		Redfish					
		Yellowtail	11.5	5.6	Benoît and Hurlbut 2010	1991-09	˜5
		Shrimp	1.2		Fréchet et al. 2006	1999-05	˜5
	SS	Cod					
		Haddock					
		Pollock	4.3		Stone et al. 2009	2006-07	˜2
		Redfish	13.3		Stone et al. 2009	2006-08	˜3
			3.1		Gavaris et al. 2010		7
		S. hake	4.0		Gavaris et al. 2010	2002	10
			0.9		Showell et al. 2010	2000-09	9
		Yellowtail					
		Herring					
		Shrimp					
	GB	Cod					
		Haddock					
		Pollock	0.8		Stone et al. 2009	2006-08	˜10
		Redfish					

Table 13. Percentage discards of fish and invertebrates for landings in Pacific fisheries by major gear type, 2009-10.

Gear	Eco-region	Directed species	2009 Percent discarded		2010 Percent discarded	
			Fish	Inverts	Fish	Inverts
Gillnet	BCNS	Herring				
		Salmon	5.0		16.3	
	St.of G	Herring				
		Salmon	1.1		0.7	
Longline	BCNS	Dogfish	3.8		0	
		Groundfish	0.4		0	
		Halibut	1.1		0.6	
		Halibut-Sablefish	1.8		0	
		Lingcod	0.7		0	
		Sablefish	0		1.3	
		Salmon	21.9		18.0	
	St.of G	Dogfish	4.8		4.2	
		Groundfish	0		0	
		Halibut	0		0	
		Lingcod	0		0	
	Offshore	Groundfish	0		0	
		Halibut	0.5		0.4	
		Halibut-Sablefish	15.2		0	
		Lingcod	0		3.8	
		Sablefish	0.8		4.8	
	Southern	Albacore				
		Dogfish	0.7		1.9	
		Groundfish	0		0.7	
		Halibut	3.6		6.8	
		Halibut-Sablefish	7.1		8.9	
		Lingcod	0.9		3.8	
		Sablefish	6.4		5.6	
		Salmon	12.7		3.7	
Purse Seine	BCNS	Herring				
		Salmon	5.5		6.7	
	St.of G	Herring				
	Offshore					
	Southern	Salmon	3.7		1.2	
		Sardine				
Pot	BCNS	Crab				
		Shrimp*	0.2		0.2	
	St.of G	Crab				
		Shrimp*	0.2		0.2	
	Offshore					
	Southern	Crab				
		Shrimp*	0.2		0.2	

Table 13. Continued.

Gear	Eco-region	Directed species	2009 Percent discarded		2010 Percent discarded	
			Fish	Inverts	Fish	Inverts
Shrimp Trawl	BCNS	Shrimp**	29.6	2.2	29.6	2.2
	St.of G	Shrimp**	29.6	2.2	29.6	2.2
	Offshore					
	Southern	Shrimp**	29.6	2.2	29.6	2.2
Trawl	BCNS	Groundfish	15.5		20.7	
	St.of G	Groundfish	12.4		12.8	
	Offshore	Groundfish	15.8		9.9	
	Southern	Groundfish	10.7		6.5	

* estimates from Rutherford et al. 2010
**estimates from Olsen et al. 2000

Table 14. Calculation of bycatch for Canadian fisheries in 2009, low and high estimates

Gear	Sp. group	Ecoregion	Catch 2009	Proportion fish		Proportion invert		Bycatch(t)	
				Low	High	Low	High	Low	High
Danish Seine	Groundfish	NLS+GSL+SS	226	0.16	0.67	0.012	0.06	39	165
		GB	1					0	0
Dredge	Scallop	NLS+GSL+SS	14,537	0.006	0.006	0.118	0.229	1,803	3,416
		GB	48,066	0.01	0.01	0.157	0.157	8,027	8,027
	Surfclam	NLS+GSL+SS	27,948	0.001	0.001	0.24	0.35	6,735	9,810
Gillnet	Groundfish	EA	3,744	0.18	0.25			674	936
		NLS+GSL+SS	17,574	0.2	0.23	0.016	0.065	3,796	5,184
		GB	169	0.1	0.3			17	51
	S. Pelagic	NLS+GSL+SS	59,768	0.01	0.01			598	598
		GB	286	0.01	0.01			3	3
		BC	7,618	0.01	0.05			76	381
Hand Line	Groundfish	NLS+GSL+SS	1,626	0.01	0.05			16	81
		GB	9	0.01	0.23			0	2
	S. Pelagic	NLS+GSL+SS	3,197	0.001	0.001			3	3
Long-line	Groundfish	EA	102	0.02				2	0
		NLS+GSL+SS	7,854	0.23	0.28	0.004	0.004	1,838	2,231
		GB	2,919	0.23	0.28			671	817
		BC	7,714	0.2	0.26			1,543	2,006
	S. Pelagic	NLS+GSL+SS	3	0.001				0	0
		BC	1,993	0.11	0.18			219	359
	L. Pelagic	NLS+GSL+SS	821	0.97	0.97			796	796
		GB	359	0.97	0.97			348	348
		BC	397	0.29	0.29			115	115
Pot	Groundfish	NLS+GSL+SS	3	0.01	0.01			0	0
	Crustacean	NLS+GSL+SS	155,743	0.001	0.058	0.001	0.202	311	40,493
		GB	260	0.001	0.058	0.001	0.202	1	68
		BC	8,589	0.002	0.002			17	17
	Whelk	NLS+GSL+SS	6,420	0.001	0.001			6	6
Purse Seine	S. Pelagic	NLS+GSL+SS	130,981	0.001	0.001			131	131
		GB	8,455	0.001	0.236			8	1,995
		BC	39,180	0.001	0.001			39	39
Seine	S. Pelagic	NLS+GSL+SS	3,497	0.001	0.001			3	3
S. Trawl	Crustacean	EA	4,813	0.02	0.02			96	96
		NLS+GSL+SS	95,729	0.023	0.036	0.003	0.003	2,489	3,733
		BC	605	0.296	0.296			179	179
Tr. Net	Groundfish	NLS+GSL+SS	36	0.001	0.001			0	0
	S. Pelagic	NLS+GSL+SS	9,988	0.001	0.001			10	10
Trawl	Groundfish	EA	8,370	0.06	0.08			502	670
		NLS+GSL+SS	42,339	0.2	0.31	0.012	0.056	8,976	15,496
		GB	16,739	0.2	0.31	0.008	0.012	3,482	5,390
		BC	78,562	0.107	0.158			8,406	12,413
	S. Pelagic	NLS+GSL+SS	2					0	0
	Crustacean	NLS+GSL+SS	33,168	0.023	0.036	0.003	0.003	862	1,294

Table 15. Calculation of discards for Canadian fisheries in 2009, low and high estimates. Highlighted values from Kelleher (2005).

Gear	Sp. group	Ecoregion	Catch 2009	Proportion fish		Proportion invert		Discards (t)	
				Low	High	Low	High	Low	High
Danish Seine	Groundfish	NLS+GSL+SS	226	0.015	0.115	0.012	0.06	6	40
		GB	1					0	0
Dredge	Scallop	NLS+GSL+SS	14,537	0.006	0.006	0.118	0.229	1,803	3,416
		GB	48,066	0.01	0.01	0.157	0.157	8,027	8,027
	Surfclam	NLS+GSL+SS	27,948	0.001	0.001	0.24	0.35	6,735	9,810
Gillnet	Groundfish	EA	3,744	0.02	0.02			75	75
		NLS+GSL+SS	17,574	0.033	0.095	0.016	0.065	861	2,812
		GB	169	0.005	0.005			1	1
	S. Pelagic	NLS+GSL+SS	59,768	0.01	0.01			598	598
		GB	286	0.01	0.01			3	3
		BC	7,618	0.01	0.01			76	76
H. Line	Groundfish	NLS+GSL+SS	1,626	0.006	0.006			10	10
		GB	9	0.02	0.02			0	0
	S. Pelagic	NLS+GSL+SS	3,197	0.001	0.001			3	3
L. Line	Groundfish	EA	102	0.02				2	0
		NLS+GSL+SS	7,854	0.076	0.148	0.004	0.004	628	1,194
		GB	2,919	0.064	0.064			187	187
		BC	7,714	0.016	0.021			123	162
	S. Pelagic	NLS+GSL+SS	3	0.001				0	0
		BC	1,993	0.11	0.18			219	359
	L. Pelagic	NLS+GSL+SS	821	0.97	0.97			796	796
		GB	359	0.97	0.97			348	348
		BC	397	0.29	0.29			115	115
Pot	Groundfish	NLS+GSL+SS	3	0.01	0.01			0	0
	Crustacean	NLS+GSL+SS	155,743	0.001	0.058	0.001	0.202	311	40,493
		GB	260	0.001	0.058	0.001	0.202	1	68
		BC	8,589	0.002	0.002	0.01	0.01	17	17
	Whelk	NLS+GSL+SS	6,420	0.001	0.001	0.01	0.01	6	6
Purse Seine	S. Pelagic	NLS+GSL+SS	130,981	0.001	0.001			131	131
		GB	8,455	0.001	0.236			8	1,995
		BC	39,180	0.006	0.023			235	901
Seine	S. Pelagic	NLS+GSL+SS	3,497	0.001	0.001			3	3
S. Trawl	Crustacean	EA	4,813	0.02	0.02			96	96
		NLS+GSL+SS	95,729	0.023	0.036	0.003	0.003	2,489	3,733
		BC	605	0.296	0.296			179	179
Tr. Net	Groundfish	NLS+GSL+SS	36	0.001	0.001			0	0
	S. Pelagic	NLS+GSL+SS	9,988	0.001	0.001			10	10
Trawl	Groundfish	EA	8,370	0.019	0.019			159	159
		NLS+GSL+SS	42,339	0.04	0.115	0.012	0.056	2,202	7,240
		GB	16,739	0.008	0.04	0.008	0.012	268	870
		BC	78,562	0.098	0.128			10,056	10,056
	S. Pelagic	NLS+GSL+SS	2					0	0
	Crustacean	NLS+GSL+SS	33,168	0.023	0.036	0.003	0.003	862	1,294

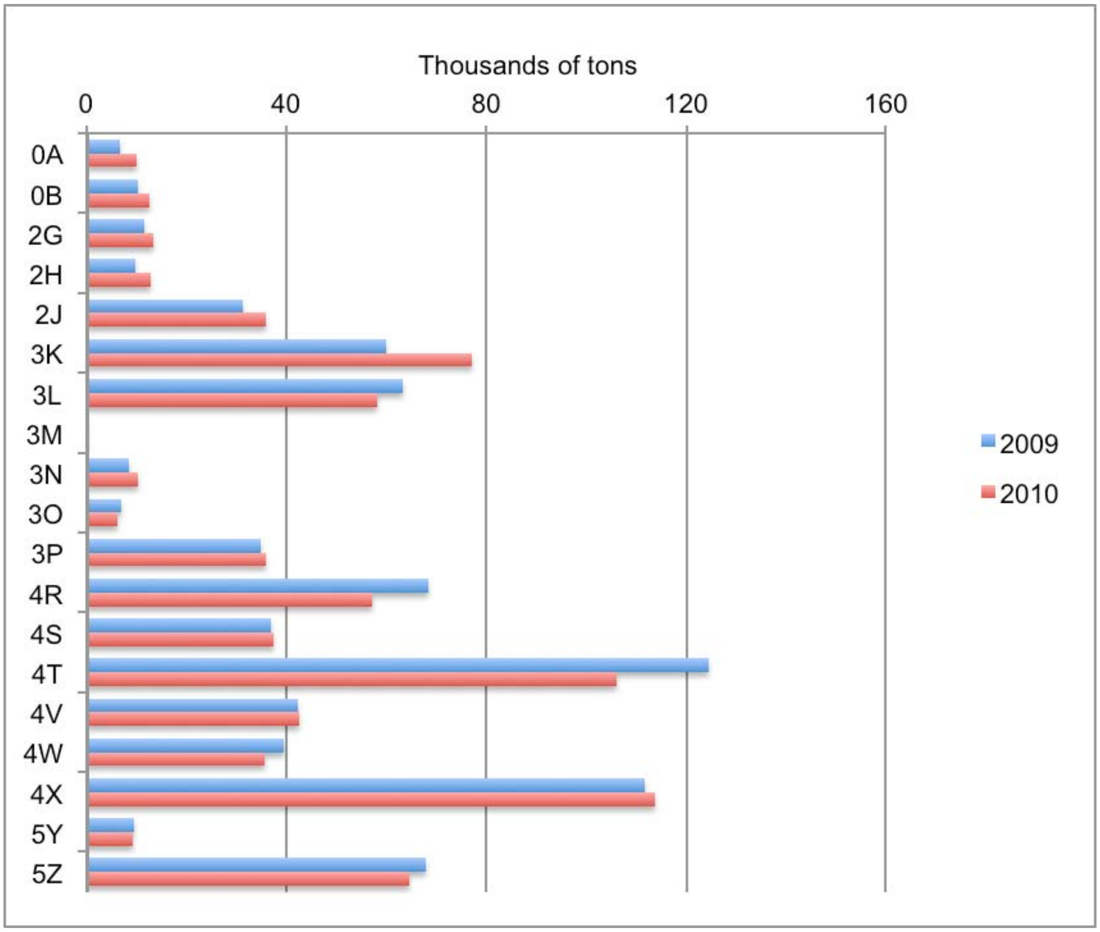

Figure 1. Landings in Atlantic commercial marine fisheries by NAFO Division, 2009-10.

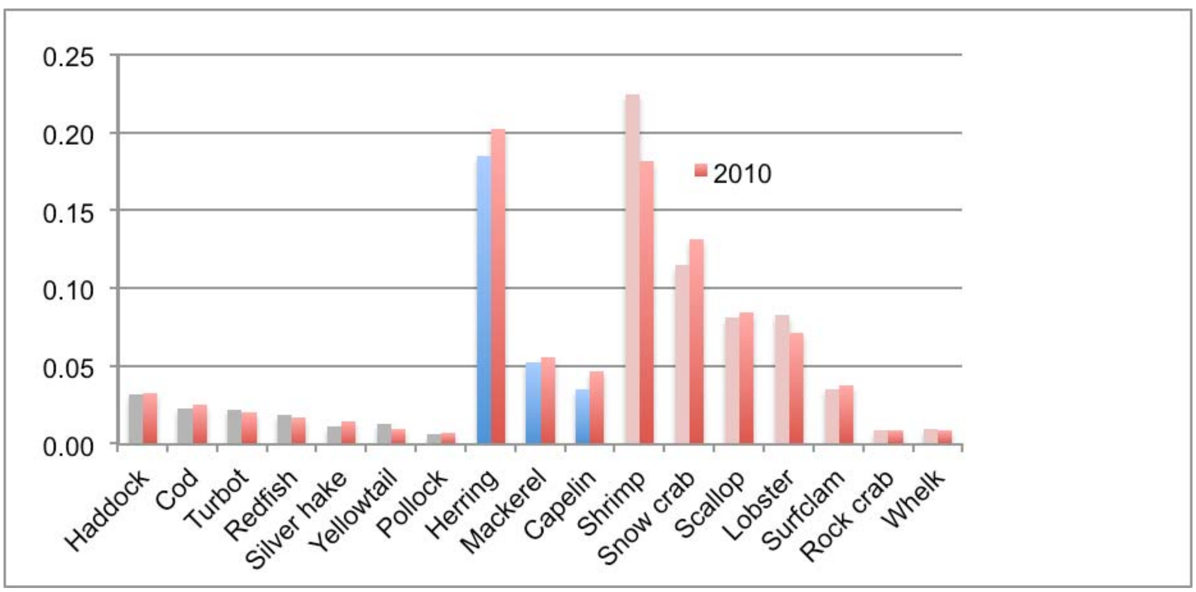

Figure 2. Proportion of Atlantic commercial landings by the 17 most abundant species in 2009-10, organized from left to right where 2009 is shown in grey for groundfish, blue for pelagic fish and pale red for shellfish.

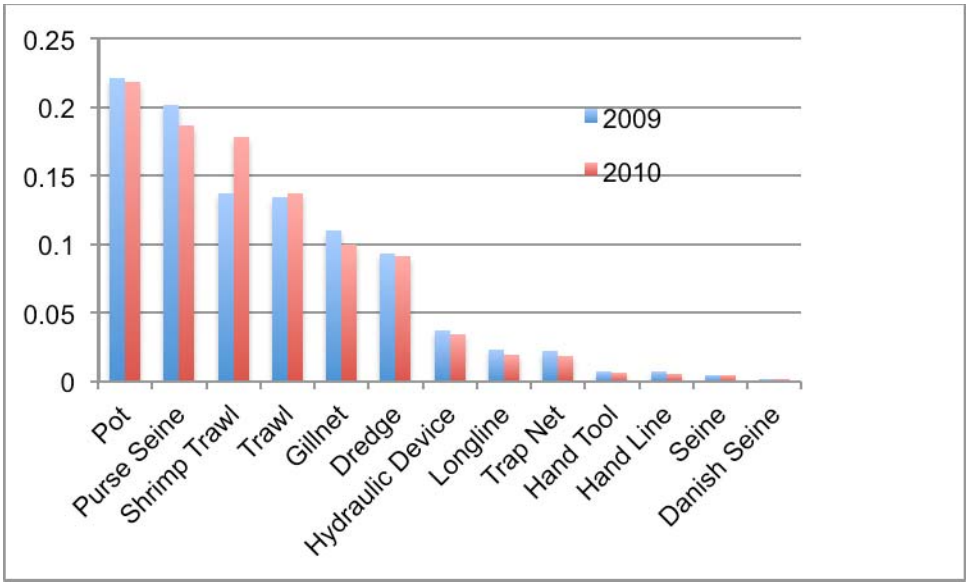

Fig. 3. Proportion of commercial landings in Atlantic Canada by gear category, 2009-10

APPENDIX 1:
Guidance related to Bycatch and Discards in Canadian Commercial Fisheries

Utilization of the harvest fishery bycatch in Canadian aquaculture feed production

National Science Advisory Process

1. Scope of Work

The contract encompasses a writing project targeted for scientific peer review as part of a Canadian Science Advisory Secretariat (CSAS) process focusing on bycatch (see attached terms of reference) and ultimately for management and technical audiences. The working paper should include, but not be limited to, the analysis of published scientific papers, government reports, and 'grey' literature.

This working paper should address the following:

D. What is the total volume of bycatch and discards from Canadian commercial fisheries in all regions? If possible, this information should be classified by region, area, date, season, and species.

E. Provide an analysis of the diversity of bycatch species from the Canadian harvest fishery, and an analysis regarding possible utility in aquaculture feed production or other value added uses. This may include an analysis of:

   a. Which fishery bycatch species have been utilized for aquafeed production internationally?

   b. The nature of the nutritional composition (*e.g.*, protein, oils, vitamins), specifically as it pertains to aquafeed production requirements.

F. What proportion of this total volume represents an opportunity to make rational utilization of the discards as a raw material for use in aquaculture (feeds) or other value added uses?

1.1. Statement of Work (Working Paper)

This statement of work serves as the basis for technical support and advice on a proposed working paper. The consultant/contractor will provide writing and editing support as needed in order to publish the materials.

Proposed Title
The extent and diversity of the harvest fishery bycatch in Canadian commercial fisheries and the possible rational utilization for aquaculture feed production.

1.2. Specific Tasks of Working Papers

The contractor shall conduct literature and data searches and data mining as appropriate to satisfy required information for each subject area. When such a search is required, the contractor shall conduct computerized and manual literature searches, retrieve pertinent articles, and provide abstracts, summaries, and data and analysis documentation as indicated below.

a. Search the periodicals.

b. Search for information in domestic and internationally non-periodical literature such as books, technical reports, monographs, and conference and symposium proceedings.

c. The contractor shall prepare an abstract for the proposed article. The abstract shall include the purpose of the working paper, summarize major findings, and provide principal conclusions and recommendations.

d. Provide copies of all literature cited and metadata for all data evaluated.

e. Provide documentation of data mining efforts, including analyses and results.

During examination of the identified literature, the contractor shall place primary emphasis upon the adequacy of study design, quality control, and interpretation of results of each study, and determine the article's relevance to the objectives of the Terms of Reference (ToR).

The consultants/contractors will be directly responsible for ensuring the accuracy, timeliness and completion of all tasks assigned under this Statement of Work contract.

2. Require Skills and Proficiencies

2.1. Skills

The contractor must have the following basic writing and editing abilities:

- The ability to write and edit technical and non-technical documentation.
- The ability to demonstrate a complete understanding of language grammatical standards as well as sentence structure requirements for this type of writing.
- Extensive experience in the document review process, which includes draft reviews, reviewing comments, comment resolution, draft updating, and final document development.
- The ability to lead a document development effort from the initial inception through final publication.
- Experience in developing, writing, and editing material for scientific and technical reports, and related technical procedures.
- Ability to check references for accuracy through various materials.
- Ability to conduct research to obtain information needed to write and/or edit the report. This research might take the form of interviewing key persons and companies for additional information about a specific topic, data and review other appropriate literature from electronic or hard copy sources.
- Demonstrated ability to provide appropriate advice and guidance regarding graphics and layout of the report.
- Demonstrated ability to produce professional-grade, articulate, accurate, and compelling documents for consumption of a range of audiences---from technical experts to the general public.

2.2. Format

The contractor must be able to provide products to DFO in electronic (*i.e.*, word processing source and PDF formats) and hard copy formats. Electronic copies provided must be compatible with Microsoft Word and/or computer-based desktop publishing applications such as rich text format (rtf). The contractor must be able to accept and send document files electronically.

3. Deliverables and Deliverable Schedule

1) Early in the development of the working paper, an outline of the working paper will be shared with Jay Parsons, Aquaculture Science Branch, Fisheries and Oceans Canada.
2) A draft working paper needs to be provided by February 21, 2012. The final draft working paper will be completed by February 29, 2012.
3) The contractor will participate in the peer review workshop, March 6−8, 2012 in Montréal, PQ. They will respond to reviewers' comments and provide a final research report (research document) within 15 days of receiving those comments.

In fulfillment of this effort, the Consultant/Contractor shall provide the following deliverables. All deliverables shall be submitted to DFO, unless otherwise agreed upon.

Unless otherwise specified, DFO will have a maximum of ten (10) working days from the day the final draft research report deliverable is received to review the document, provide comments back to the contractor, and approve or disapprove the deliverable(s). The contractor will also have a maximum of 15 working days from the day comments are received to incorporate all changes and submit the final deliverable to DFO. All days identified below are intended to be workdays unless otherwise specified.

3.1. Working Paper Plan

The contractor shall prepare a Plan describing the technical approach, organizational resources to meet the cost, performance and schedule requirements for this effort. The Plan shall detail the products, methods for developing the products and other resources necessary to produce the products and a revised timeline for producing the products, if necessary. DFO shall receive the revised Plan in both hard copy and electronic form, Microsoft Word*.* Based on the Plan, DFO will provide approval to move forward on activities planned. The contractor shall request prior approval on all activities not included in the plan or any modifications to the plan after approval has been given.

3.2. Monthly Status Reports

Reporting requirements for the monthly status reports will be outlined at the initial kick-off meeting. Monthly Status Reports will be provided on the 1st of each month. It is expected that these will include, but not be limited to:

- Paper status, to include objectives met, work completed and work outstanding
- Notable achievements
- Issues or obstacles impeding progress and recommended solutions

- Status of deliverables/milestones
- Issues and resolutions
- Topics or issues identified by DFO
- Description of work completed and plans for next month
- Summarize the efforts of each primary task in SOW

3.3. Financial Requirements

Reporting requirements for the financial reports will be outlined at the initial kick-off meeting. It is expected that these will include, but not be limited to:

- Budgeted total and budgeted monthly hours
- Actual hours expended for the reporting period
- Actual hours expended to date by task
- Actual costs to date and for the reporting period (based on actual hours)
- Estimated Cost to Completion
- Estimated Cost at Completion
- Task/cost variances (for >10% variance include explanation/analysis)

3.4. Final Report

The contractor shall provide a final report, to DFO no later than May 15, 2012. The report will fulfill the Statement of Work and any changes or modifications as recommend by a peer review process.

3.5. Deliverable Schedule

Reference	Milestone/Deliverables	Responsibility	Dates
1.0	Scope of Work/Briefing /Kickoff	DFO/ Consultant	
1.1	Statement of Work	DFO	
3.1	Work Plan	Consultant	
3.	Draft working paper		February 21 draft
2.1, 3.	Review/edit/update draft working paper	DFO/Consultant	February 29 final draft
3.2	Monthly Status Reports	Consultant	
3.3	Financial Status	Consultant	
3	Workshop (Montréal)	Consultant	March 6-8
3	Complete updated draft research report from workshop review	Consultant	March 29
3	Review final draft	DFO	April 12
3.4	Final Research Report	Consultant/DFO	May 15

3.6. Inspection and Acceptance Criteria

Final inspection and acceptance of all work performed, reports and other deliverables will be performed at the place of delivery by DFO.

3.7. General Acceptance Criteria

General quality measures, as set forth below, will be applied to each work product received from the contractor under this statement of work.

- Accuracy - Work Products shall be accurate in presentation, technical content, and adherence to accepted elements of style.
- Clarity - Work Products shall be clear and concise. Any/All diagrams and graphics shall be easy to understand and be relevant to the supporting narrative.
- Consistency to Requirements - All work products must satisfy the requirements of this statement of work.
- File Editing - All text and diagrammatic files shall be editable by the DFO.
- Format - Work Products shall be submitted in hard copy (where applicable) and in media mutually agreed upon prior to submission.
- Timeliness - Work Products shall be submitted on or before the due date specified in this statement of work or submitted in accordance with a later scheduled date determined by the DFO

3.8. Quality Assurance

DFO will review, for completeness, preliminary or draft documentation that the Contractor submits, and may return it to the Contractor for correction. Absence of any comments by DFO will not relieve the Contractor of the responsibility for complying with the requirements of this work statement. Final approval and acceptance of documentation required herein shall be by letter of approval and acceptance by DFO. The Contractor shall not construe any letter of acknowledgment of receipt material as a waiver of review, or as an acknowledgment that the material is in conformance with this work statement. Any approval given during preparation of the documentation, or approval for shipment shall not guarantee the final acceptance of the completed documentation.