THE LARGER PELAGIC CRUSTACEA OF THE GULLY SUBMARINE CANYON

by

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ABSTRACT

The larger pelagic crustacean fauna of the Gully submarine canyon is described for the first time, based on three annual summer surveys. The larger Crustacea are a significant part of the Gully fauna, and are dominated by cold temperate species, in particular the northern krill *Meganyctiphanes norvegica* and the decapod *Sergestes arcticus*. In all, at least 69 species were collected from the surface to bathypelagic depths, with seventeen being new Canadian records. With the exception of *M. norvegica*, inter-annual variation in the dominant species was minor. The species assemblage varied primarily with depth surveyed and diel cycle, and not year. Comparing the larger pelagic crustaceans in the Gully and over the adjacent continental slope showed that overall species number, biomass, and abundance were all greater in the canyon, the biomass of *S. arcticus* particularly showing a positive "Gully effect".

LIST OF ABBREVIATIONS USED

CCGS	Canadian Coast Guard Ship
CTD	Conductivity, Temperature, and Depth Sensor
DVM	Diel Vertical Migration
g	Grams
IYGPT	International Young Gadoid Pelagic Trawl
Log	Logarithm
MDS	Multidimensional Scaling
NMNH	National Museum of Natural History
p	P Value
PC	Principal Component
PCA	Principal Component Analysis
ROPOS	Remotely Operated Platform for Ocean Science
SIMPROF	Similarity Profile
WoRMs	World Registry of Marine Species

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Chapter 1. Introduction

1.1. General Introduction

The living world is described and catalogued using one of the oldest fields of biology, the science of taxonomy. Taxonomy is the identification and description of species, the preservation and cataloguing of reference collections, and the organization of species into classification systems and scientific keys to their identification. Taxonomy is the principal instrument of Systematics, argueably the most encompassing of all fields of biology, studying the relationships between all forms of life as we know it, with phylogenies incorporating ecological and evolutionary relationships. The modern age of taxonomy was born by the Swedish botanist Carl Linnaeus in the mid-1700s with the introduction of binomial nomenclature for the naming of species and their arrangement in a nested hierarchy based on shared physical characteristics, eventually linked to an evolutionary hierarchy. The basic utility of this system has allowed it to endure, and the field of taxonomy is recently experiencing a renaissance of sorts following decades of neglect. Significant worldwide efforts to both increase the total number of species catalogued and construct accessible and interactive taxonomic support systems have been under way for several years now, including the Census of Marine Life, the World Registry of Marine Species (WoRMS), and the Barcode of Life project. Such interest is not purely academic, however, but the result of growing concern over loss and threats to global biodiversity through disappearing habitat and environmental change.

The nomenclature and hierarchical system of Linnaeus allowed for the proliferation of new species described and named from around the world, but the deep sea remained a largely undiscovered frontier for taxonomists. The most frequent samplers of deep-sea fauna in the time of Linnaeus were the lead-weighted sounding ropes employed by ships, which would occasionally dredge up animals. In 1818, one of the earliest basket stars was collected from a depth of 1.6 km off Baffin Island during a depth sounding in search of the Northwest Passage (Murray & Hjort 1912). Like the basket star, most early deep-sea biology was focused on benthic life, and though the first written observations of vertically migrating zooplankton were made by Cuvier in 1817 (Cushing 1951 and references therein), the existence of deep sea zooplankton was not proven by sampling until the British Challenger expedition from 1872-1876.

Benthic dredges were the main means to collect deep sea species in the 19th century, and it was not until 1910 that a large scale survey of the North Atlantic was carried out with pelagic nets by the Norwegian steamer Michael Sars. The early 20th century was an age of taxonomy and biogeography, not just for pelagic Crustacea, but a range of pelagic and deep sea animals in general. In the second half of the century, researchers began focusing on the importance of secondary production and energy flow, patterns in pelagic assemblages, persistence and variation, and the “paradox of plankton” (Hutchinson 1961, Lehman 1988 and references therein, Hopkins & Sutton 1998).

The use of dredges and later bottom trawls to study the deep sea continued from the 19th into the 20th century and are still widely used today. Working at the sea floor, researchers began to notice that pelagic and benthic species interact, with pelagic species found in the stomachs of benthic or demersal species and sediment and bottom detritus in the stomachs of pelagic species (Merret 1986, Mauchline 1986). Some pelagic species were even observed to change their lifestyle and adopt a more demersal or nektobenthic habit in areas where vertical distribution brought them into contact with the sea floor, as at continental margins (Merret 1986, Sutton et al. 2008 and references therein). And not only do pelagic species regularly come in contact and interact with the sea floor, but they often deepen the expected vertical range in order to reach bottom (Hargreaves 1985a).

The continental margins, though not as expansive worldwide as ocean ridge systems (Sutton et al 2008), are nonetheless massive, with ecological significance on a similarly massive scale. Continental margins, where the neritic meets the oceanic, are sites of upwelling deep water and downwelling shallow water and generally increased productivity. Common features of most continental margins are submarine canyons, cutting down the continental slope. Although these are sometimes large features, their role in local and regional processes is not fully understood (Hickey 1995). It is generally beleived that many canyons are areas of increased productivity, and increasingly aspects of this productivity and the possible roles of submarine canyons in deep-sea ecosystems are being discovered (DeLeo et al. 2010, Company et al. 2008).

The Gully is one of the largest submarine canyons along the eastern margin of North America, located in Atlantic Canada approximately 200km south of Nova Scotia. The canyon proper cuts sharply into the slope and shelf, is steep-sided, and reaches depths of over 2km. A wide inner trough of the Gully extends from the upper end of the canyon proper across the shelf, forming a shallower basin 30km long, 70km wide, with depths exceeding 300m, linking the canyon proper (and slope) to the inner Scotian Shelf. Because of its exceptional depth, steep relief, and reach far across the continental shelf, it is considered distinct among the canyons of Eastern Canada. Like other submarine canyons, the Gully has both observed and anecdotal indications of increased productivity relative to adjacent areas of ocean (Gordon and Fenton 2002). Foremost among these is the presence of a unique population of deep-diving toothed whales (Hooker et al. 2002). Following extensive scientific reviews (Harrison and Fenton 1998, Gordon and Fenton 2002, Rutherford & Breeze 2002), information on the pelagic component of the Gully ecosystem was noted as particularly lacking.

In this investigation I describe the complement of larger pelagic Crustacea found at a centrally located sampling station within the Gully submarine canyon. In Chapter 2, the dominant members of the fauna are characterized and the distribution of absolute and relative catch biomasses and abundances with respect to depth and time of day are summarized and discussed. The assemblage of species is analyzed to examine which factors explain most of the variation in the assemblage: Depth (of distribution), Time of Day (diel change), and Year (three years). A limited comparison is also made between the fauna inhabiting the canyon and the water column over an adjacent area of continental slope. In Chapter 3, details of nomenclature, taxonomic identification, and geographical and vertical distribution are broadly summarized for each species collected in the Gully, including species recorded from Canadian waters for the first time. Information on species vertical depth of distribution and diel changes in species biomass and abundance over the three year study are summarized.

This thesis is the first description of the larger pelagic Crustacea found within the Gully submarine canyon, the micronekton and larger macrozooplankton. It is part of a broader program with the goal of better understanding the Gully ecosystem as a whole.

1.2. The Pelagic Ecosystem

The pelagic realm of the world oceans, or any part of it that is not near the sea floor, is the single largest living space on Earth, accounting for approximately 99% of all habitable space on the planet (Herring 2002). The waters above the continental shelves, or neritic zone, are considered separate from the oceanic or open ocean, which itself is divided vertically into five zones of increasing depth: epipelagic, mesopelagic, bathypelagic, abyssopelagic and hadopelagic.

The epipelagic zone extends from the surface to 200m, below which the amount of sunlight is insufficient to permit photosynthesis. It is this productive layer that provides the food energy to nearly all depths below, both pelagic and benthic, which are largely or exclusively heterotrophic and allochthonous systems, with the isolated and overall minor exceptions of hydrothermal vents and hydrocarbon seeps (Angel 2003, Company et al. 2008, Sutton et al. 2008). Almost 95% of pelagic oceanic habitat is the deep sea: that portion below the photosynthetically productive epipelagic zone (Horn 1972 in Sutton et al. 2008). Pelagic biomass decreases exponentially in the depths below the epipelagic zone and its concentration of food energy (Angel & Baker 1982).

The mesopelagic is a zone of rapidly attenuating sunlight below the epipelagic extending from 200-1000m (Angel 2003, Herring 2002). The varying levels of light in this zone cue a characteristic behaviour of the mesopelagic fauna: diel vertical migration. In what is probably an anti-predation mechanism, moderated by light intensity and modified by food abundance and temperature, animals typically move upwards into more productive depths at dusk to feed in darkness, and retreat to deeper, darker depths at dawn (Cushing 1951, McLaren 1963, Lampert 1989). An oxygen minimum zone, where the amount of dissolved oxygen or oxygen saturation is at its lowest, is also typically found in the mesopelagic, as most of the organic matter sinking from the productive epipelagic zone is consumed by aerobic bacteria in the upper 1000m (Angel 2003).

Pressure also increases constantly with depth, 1 atmosphere every 10m, so that organisms at 1000m experience approximately 100 times the pressure at the surface (Bartle date unknown).

No residual sunlight reaches the bathypelagic zone below 1000m; the only source of light is from bioluminescence of organisms (Angel 2003). Vertical migration is absent or rare and strange morphologies and life histories appear. Although total pelagic biomass decreases with depth, mainly because of a decreasing food supply with distance from the epipelagic, species diversity (richness and evenness) reach a maximum in the lower meso- or upper bathypelagic. There is also typically a widespread permanent thermocline in the lower meso- or upper bathypelagic, between the (usually) warmer epipelagic and the continually cold (4-5^{0}C) deeper sea (Angel 2003). The abyssopelagic begins at 4000m and extends to the bottom of the ocean basins at 6000m, and the hadopelagic extends to the bottom of the ocean trenches.

Chapter 2. The Larger Pelagic Crustacea of the Gully Submarine Canyon: Major Patterns and a Comparison to Adjacent Continental Slope

2.1. Introduction

The vertically migrating micronekton and zooplankton are considered central to the functioning of oceanic ecosystems (Hopkins et al. 1994, Sutton et al. 2008, Deforest & Drazen 2009 and references within). Found throughout the world's oceans, this fauna plays an important role in the transfer of primary and secondary production to higher trophic levels, as well as to the deep-sea, from more productive, shallow depths (Angel 1985, Longhurst and Harrison 1989, Longhurst et al. 1990). It is considered to be one of the largest synchronized daily movements of animals and biomass on the planet (Berge et al. 2008). Recent observations suggest that this fauna also functions to move energy upwards from some deep-sea, near-bottom habitats or benthic boundary layers with greater food resources (Gartner et al. 2008).

In contrast to three-dimensional terrestrial systems, the pelagic realm is considered to be relatively homogeneous (McFall-Ngai 1990). Most of this realm, from approximately 200m down into the deepest ocean trenches 11km below the surface, is the deep-sea pelagial. By definition, pelagic organisms do not directly interact with the bottom. However the vertical and horizontal distributions of pelagic species can be strongly influenced by bottom topography: over flat abyssal plains (Vinogradov 1999, Domanski 1986), at mid-ocean ridges (Sutton et al. 2008), seamounts (DeForest & Drazen 2009), islands and continental margins (Hargreaves 1984, Benoit-Bird & Au 2006, Gartner et al. 2008), including submarine canyons that often incise them (Youngbluth et al. 1989, Hickey 1995, Genin 2004). Regions of increased abundance and biomass of species or assemblages of species are typically reported in these areas, and these and related phenomena may be both geographically extensive and ecologically significant for both pelagic and benthic populations, affecting species interactions, feeding ecology, reproduction, and niche opportunities (Genin 2004, Gartner et al. 2008, Sutton et al. 2008).

Submarine canyons along continental margins increase the effective size of the biogeographic boundaries between the neritic, over the continental shelves, and oceanic, and introduce steep slopes and heterogeneous substrates atypical of comparable depths along the undissected continental shelf edges (Hickey 1995, Levin and Gooday 2003). Compared with areas of adjacent continental slope, some canyons support higher benthic biomass and productivity (Hecker et al. 1983, De Leo et al. 2010), show enhanced concentrations of pelagic species, and greater biomass or abundance of higher trophic level predators (Whitehead et al. 1998, Hooker et al. 2002, Bosely et al. 2004, Genin 2004). They can be areas of greatly elevated mixing and act as upwelling and downwelling conduits between the shelf and deep-sea (Allen & de Madron 2009), which may have significant effects on deep-sea populations (Company et al. 2008). Despite this, information about the effects of submarine canyons on deep-sea ecosystems is sparse, and their role in both regional and local processes has been largely speculative (Hickey 1995, Gordon and Fenton 2002, De Leo et al. 2010).

The Gully is one of the largest submarine canyons on the eastern margin of North America, 110km long, cutting both far onto the continental shelf and down the slope, ranging from 10-70km wide, with sections over 2000m deep (Fenton 1998, Rutherford & Breeze 2002). It is also Atlantic Canada’s first Marine Protected Area under the Oceans Act (established in 2004), with particular ecological relevance for higher trophic levels, serving as a year-round home to a relatively rare population of large carnivores: deep-diving northern bottlenose whales, *Hyperoodon ampullatus*, feeding at great depth within the canyon (Hooker et al. 2002, Rutherford & Breeze 2002). There is also evidence of enhanced demersal fish biomass and diversity and possibly enhanced spawning of some fish species; it is recognized for its high diversity and abundance of deep-sea corals, and euphausiids and mesopelagic fish are abundant (Harrison and Fenton 1998, Gordon & Fenton 2002). Despite the perceived ecological significance of the Gully, even after extensive review, explanations of its enhanced productivity, and the possible mechanisms for transfer of energy to the canyon depths, are still lacking (Gordon & Fenton 2002). Data on organisms and pelagic processes, in particular the midwater pelagic ecosystem, are at best preliminary.

This investigation is part of a larger program with an overall goal of better understanding the Gully ecosystem, both as an aid to management and as a study of deep-sea and submarine canyon ecosystems in general (Kenchington et al. 2009, 2011). Principal objectives were to describe and understand the major patterns of distribution in biomass and abundance of individual species and assemblages of species present, and to identify possible ecological processes that may explain these patterns. The objectives also included a limited comparison to the same fauna over an area of adjacent continental slope outside of the canyon. Analyses of additional pelagic sampling stations, including other faunal components (fish and cephalopods), and an overarching program on the entire Gully system are in progress.

2.2 Materials and Methods

2.2.1. Overall Program

The first deep pelagic trawl surveys of the Gully submarine canyon (Figure 2.1) were run out of the Bedford Institute of Oceanography by the Canadian Department of Fisheries and Oceans with one of three Canadian Coast Guard stern trawlers: the CCGS *Wilfred Templeman* (2007-08), *Alfred Needler* (2009) and *Teleost* (2010). Biological data and other information for this investigation are only a subset of those collected during a series of surveys carried out during the late summer over a three-year period from 2007-2009 (Table 2.1). Several sampling methods were employed in an attempt to map the pelagic fauna and their physical environment, and extensive details of the methodology and other results are reported elsewhere (Kenchington et al. 2009, 2011), with more details on sample processing relevant to this work presented in Chapter 3. The present investigation deals with faunal samples from two sampling stations: the Gully Main and an adjacent Slope Station (Figure 2.1).

2.2.2. Study Area

The waters above the Gully are largely Gulf of St. Lawrence outflow, stratified in the summer with a warm surface layer and a cold intermediate layer (Hachey 1942). Offshore, two large ocean currents meet to the south of Nova Scotia and Newfoundland (Figure 2.2), the cold Labrador Current and the warm Gulf Stream (McLellan et al. 1953, McLellan 1957, Csanady & Hamilton 1988). The Gulf Stream is a deep, warm current originating in the Gulf of Mexico and Caribbean, which together with the North Atlantic Drift, Canary Current, and North Equatorial Current, form a large subtropical oceanic gyre (Figure 2.3), encircling the Sargasso Sea and Central North Atlantic. The Labrador

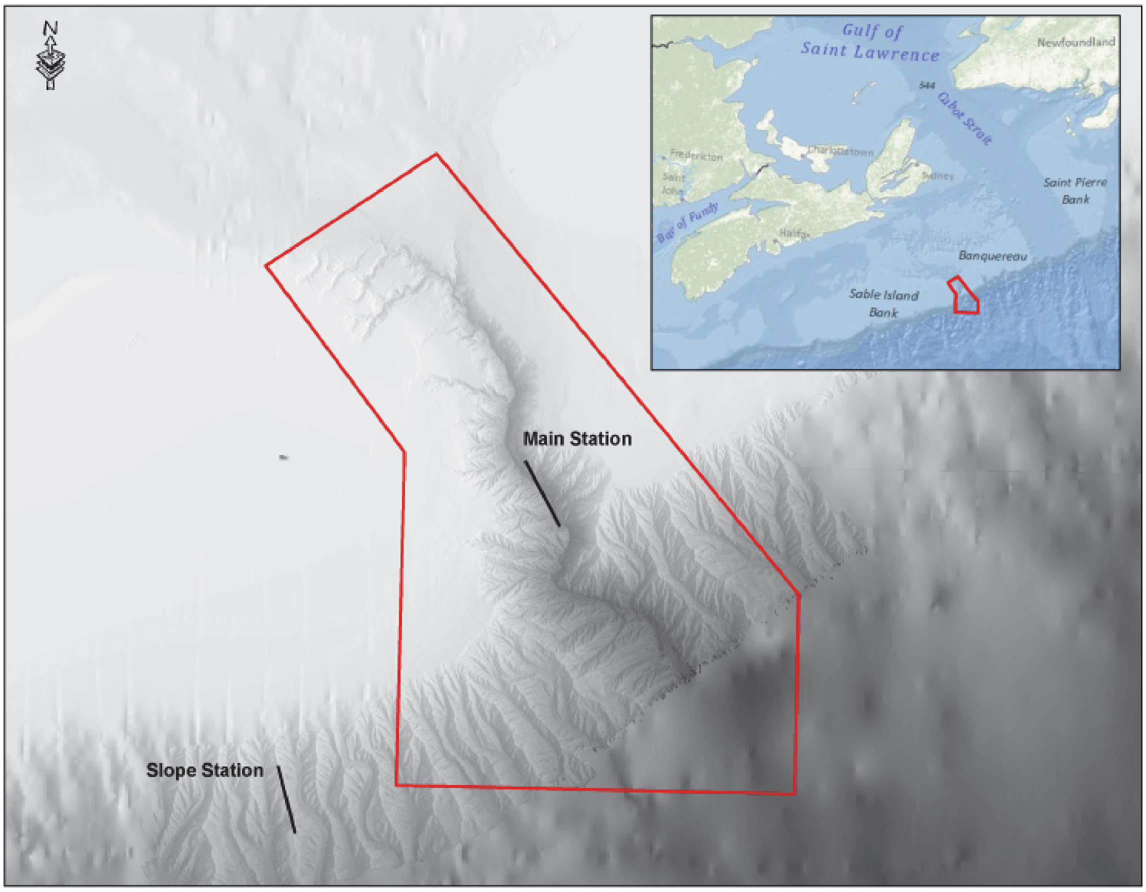

Figure 2.1. A map showing the location of the Gully submarine canyon and the location of fixed trawl stations.

Table 2.1 Survey dates (based on Kenchington et al. 2009, 2011)

Year	Month and Day
2007	September 7 – September 19
2008	August 30 – September 6
2009	August 13 – August 21

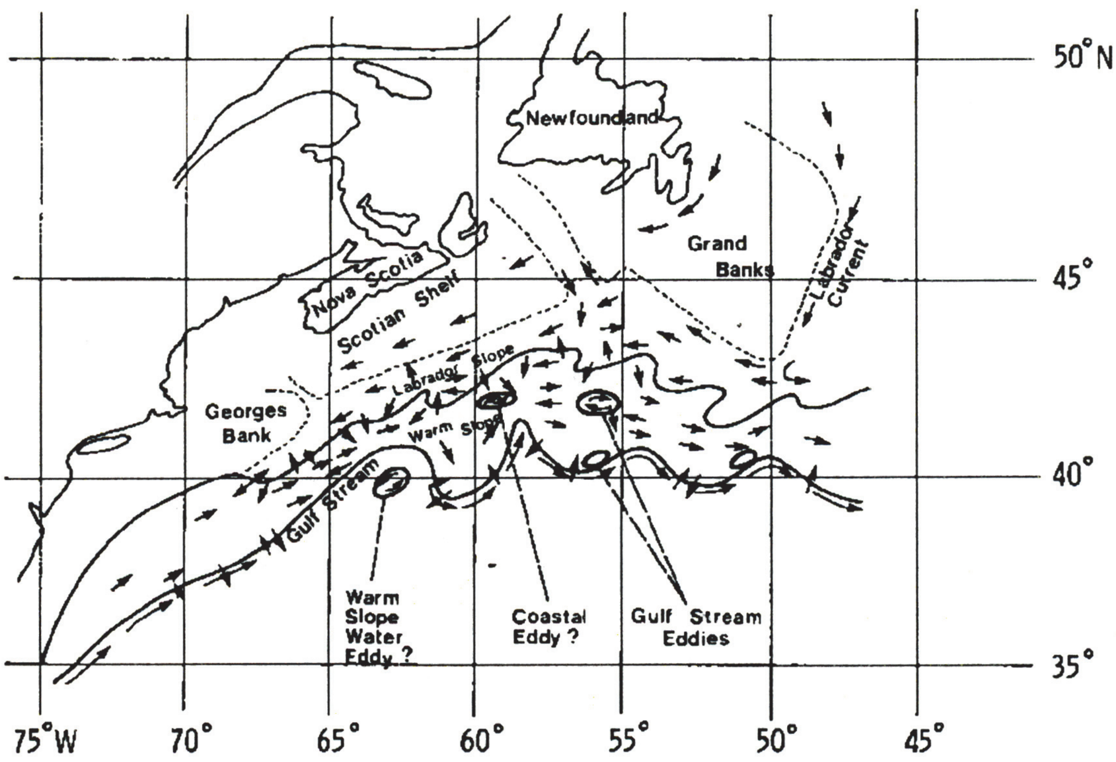

Figure 2.2. A diagram showing the general horizontal structure of currents and water masses (from Gatien 1976).

Current, originating in the Labrador Sea, largely flows around the Grand Banks to reach Nova Scotia (Sutcliffe et al. 1975 and references therein). In the ocean area between these two massive currents sits the slope water (Figure 2.3), with identifiable cold slope water to the north and warm slope water to the south (McLellan et al. 1953, Gatien 1976), both sitting above North Atlantic Central Water (Figure 2.4). It is a dynamic area, with sharp physical and chemical oceanographic boundaries, characteristic of the western side of an ocean basin with a clockwise ocean gyre.

2.2.3. Oceanographic Sampling

Periodic conductivity/temperature/depth profiles (Sea-Bird Electronics CTD, Washington, U.S.A.) were made most days, some corresponding to trawl stations, others not. A Star-Oddi centi-ex depth / temperature recorder (Star-Oddi, Vatnagardar 14, 104 Reykjavik, Iceland) was also attached to the net. Both provided physical-oceanographic data throughout the Gully and other sampling stations in order to monitor the stability of environmental conditions while sampling, compare years, and investigate other phenomena (Kenchington et al. 2009, 2011). For the present investigation, these data were simply used to broadly characterize the physical conditions in the Gully for each year.

2.2.4. Trawl sampling

Biological data for the present investigation were selected from surveys with an International Young Gadoid Pelagic Trawl (IYGPT): a mid-sized trawl with a net opening of approximately $60m^2$ when being towed (T. Kenchington personal communication). It is larger than many nets used in such surveys, with larger nets generally able to catch both larger and less common species (Krygier & Pearcy 1981).

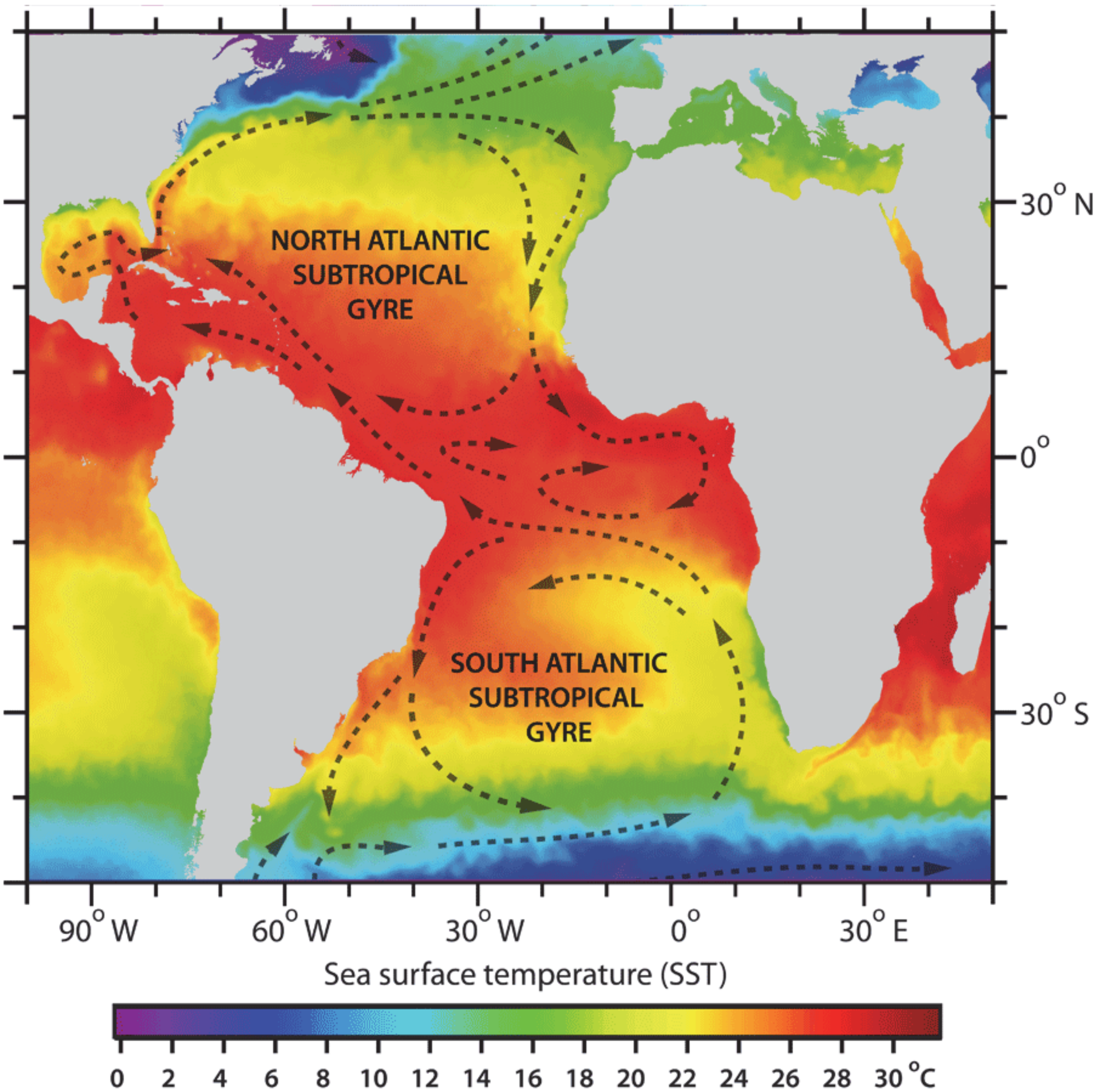

Figure 2.3. A representation of the Atlantic Subtropical Gyres with cold an warm water indicated (EURO-ARGO date unknown)

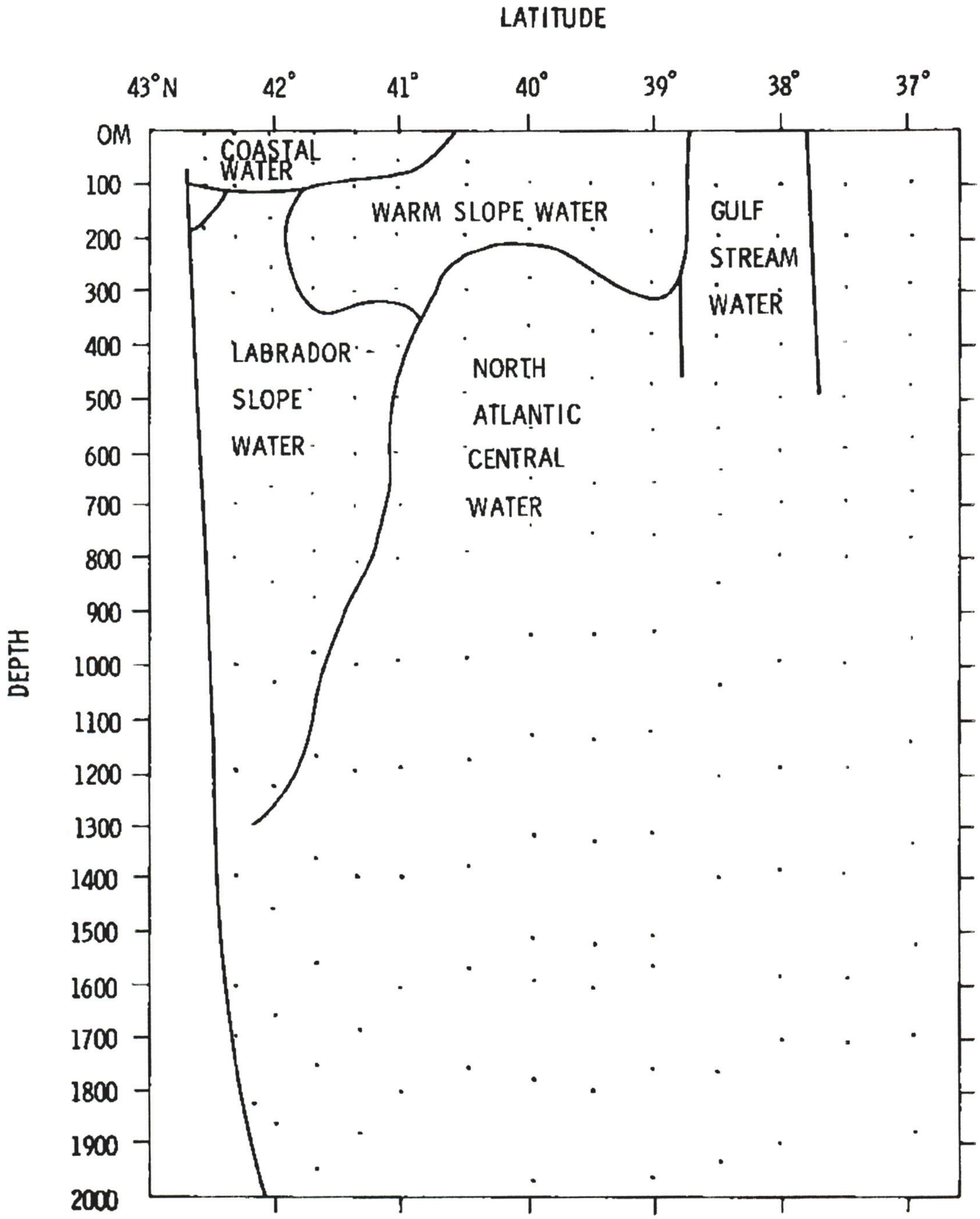

Figure 2.4. A diagram showing the general vertical structure of currents and water masses (from Gatien 1976) along an idealized line south of Halifax, Nova Scotia

It is also an open net, fishing continuously, rather than at discrete depth ranges. It is reportedly well-suited for collecting micronekton (Themelis 1996, Moore et al. 2003, 2004) with a net mesh size graded from 100mm at the headline through 80, 40, 20 and 12.7mm mesh in the cod end (Holden MJ. 1981, Koelller et al. 1986, Potter et al. 1990) and an estimated smallest size of retention of 25-26mm (Potter et al. 1990). The main considerations for using the IYGPT were to both effectively target the micronekton and to facilitate comparison with extensive mesopelagic surveys off Atlantic Canada in the 1980's (Halliday et al. 1995, Themilis 1996, Vecchione & Pohle 2002) as well as recent surveys off the north-eastern United States (Moore et al. 2003, 2004).

The IYGPT survey was primarily a fixed-station, depth-stratified design replicated both day and night (Table 2.2). In order to avoid periods of most active migration by a large portion of the pelagic fauna being targeted there was no fishing one hour before or after sunrise or sunset (Kenchington et al. 2009, 2011). Towing speed was approximately 2-3 knots, over a fixed station distance of 4 nautical miles or 7.5 km, with net depth and net configuration monitored in real-time with Scanmar instrumentation (Seatronics Inc., 10801 Hammerly Boulevard, Suite 220, Houston, Texas, 77043, United States). At the Gully Main Station, the depths fished with replicated tows were 0-250m, 0-750m and 0-1250m, and although the open net fished continuously, three nominal depth strata were used to target discrete depth ranges of interest: 0-250m, 250-750m and 750-1250m. The net fished for a total of sixty minutes within a target depth stratum, with the intent that the resulting catch would most resemble the actual fauna in the nominal stratum. The shallow 0-250m depth stratum allowed for the separation of the epipelagic zone. The division at 750m divided the water column at the approximate point where

Table 2.2 IYGPT trawl sets at the Gully Main and Slope Stations used in the present investigation

Year	Trawl Station	Time of Day	Depth	Set Numbers*
2007	Main	Day	0-250m	24, 31, 36
			0-750m	21, 23, 30
			0-1250m	22, 29, 35
			0-1500m	80
		Night	0-250m	19, 41, 43
			0-750m	27, 33, 42
			0-1250m	26, 28, 34
2008	Main	Day	0-250m	22
			0-750m	15, 39
			0-1250m	14, 53
		Night	0-250m	21, 38
			0-750m	19, 36
			0-1250m	20, 37
2009	Main	Day	0-250m	34
			0-750m	31, 35, 40
			0-1250	46
		Night	0-250m	17, 25
			0-750m	18, 27
			0-1250m	19, 39
	Slope	Day	0-750m	1, 3

*Set numbers are allocated sequentially with each survey patterns of diel vertical migration change, with most strong migrators within shallower depths (Angel and Baker 1982). A deeper stratum of 1250-1750m fishing depth was not feasible at the Gully Main Station due to the bottom depth of approximately 1300-2000m. However, one unreplicated opportunistic deep exploratory trawl to 1500m was completed in order to at least make an inference about the deeper fauna below the replicated stratified survey, and allow limited comparisons.

Two sets to 750m during the day were collected in 2009 outside the Gully at an adjacent Slope Station of similar bottom depth, approximately 2000m. This allowed for a comparison with the three replicate sets at the Gully Main Station of the same year, time of day and depth (Table 2.2).

Deeper trawls followed a "V" profile, continuously lowered to the maximum depth within the targeted nominal stratum then hauled back (Kenchington et al. 2009, 2011). During 2008 and 2009, the net was set and hauled to and from the target depth at a steady and predetermined speed in order to standardize the amount of time fishing at depths above target or nominal strata. In 2007, the trawl was set and hauled somewhat faster, but catches are considered comparable to 2008 and 2009 for the purposes of this investigation. In addition, trawls to 250m initially followed a stepped-oblique profile in 2007, lowered and hauled back fishing along series of 50m steps or trawl horizons within the strata. However, due to ship and winch operational practicalities, this approach was abandoned during the 2007 survey, and a continuous "W" profile adopted, the trawl lowered to 250m, hauled to 50m, and then repeated, for a total of 60 minutes within the stratum. Catches with both profiles are considered comparable for the purposes of this investigation. All trawls in 2008 and 2009 employed a solid aquarium cod-end (Figure

Figure 2.5. Photo of the modified aquarium cod end.

2.5) designed to reduce damage to specimens during collection while most trawls in 2007 did not. A comparison (albeit limited) of catch in 2007 from two trawl sets fishing with an aquarium indicated no systematic effect of an aquarium across all taxa at two different depths. However, catch of the northern krill *Meganyctiphanes norvegica* may decrease with the use of the aquarium cod-end, possibly by over 30% in shallow sets to 250m (Kenchington et al. 2009). The procedures employed for the two sets to 750m at the adjacent Slope Station were identical to the 750m sets collected at Gully Main, but were collected several days earlier.

2.2.5. Biological Data

At sea, all Crustacea were sorted, identified to the lowest taxonomic level possible and a total wet weight per species recorded. Counts of total number per species were also recorded if time allowed. All taxa were either fixed in a 4% solution of buffered formaldehyde or bagged and frozen. In those sets with a particularly abundant catch of the decapod *Sergestes arcticus*, the large krill *M. norvegica* and the hyperiid amphipod *Themisto gaudichaudii*, all other species were first removed for individual processing. The remaining catch was weighed and sub-samples collected to estimate total biomass and/or abundance of each of the three abundant species. In the laboratory ashore, taxa were identified to species, weighed, counted (totals per species per set), then preserved in 70% ethanol or re-frozen. Where necessary, laboratory wet weights were used to divide species-amalgamated wet weights recorded at sea. Additional details of sample processing are summarized in Chapter 3.

Biological data consisted of actual and estimated wet weight biomasses and counts of species by trawl. Accurate estimates of volumes of water filtered are not available, though density estimates based on an effective trawl fishing area of $60m^2$ could be calculated.

All replicated trawl sets had nominal strata target depths which were fished for 60 minutes. The net cycled through the shallow 0-250m nominal stratum twice over 60 minutes but just once through the deeper nominal strata. To better facilitate comparisons with deeper trawl sets with 500m nominal strata, the 0-250m catches data were divided by two, and these data are identified as “epipelagic adjusted” catch data (Appendix C).

Though well documented in the literature for many species, evidence for diel vertical migration has been incorporated, as its presence or absence and possible variations from published reports may be pertinent to the results. Previous studies using IYGPT trawls have employed a shallow “control haul” as a best attempt to correct catch and most accurately estimate the actual catch at depth (Holden 1981, Koeller et al. 1981). Others have estimated the numbers of specimens at a certain depth by subtracting an estimated catch at depths above from the total catch, resulting in what is believed good information on vertical distribution (Shih 1969 and references therein). For the present investigation, multiple shallow control trawl sets were created by averaging the catches from shallower sets for each year and time of day. Thereby an average catch calculated from the three 0-250m night trawl sets in 2007 was subtracted from each of the 0-750m night sets from 2007, to estimate the actual 250-750m nominal stratum catch in each of the night sets. Negative values were considered as zero catch, with the possibility that some species may occasionally have zero catch abundance but a positive catch biomass, or visa versa. This was repeated for all of the deeper sets, and these data are identified as “estimated nominal stratum” catch data (Appendix C). Such averages are considered robust due to the moderately large net and long distance towed homogenizing species patchiness (Hargreaves 1985b and references therein), combined with the fairly close temporal replication (hours to days) of this study. An estimated 1250-1500m stratum catch was also calculated from the one exploratory set to 1500m, by similarly subtracting the catch from an average 0-1250m set.

2.2.6. Data Summaries and Analyses

Unadjusted catch for all species collected at the Gully Main Station is presented in Chapter 3. Epipelagic adjusted data, ranked from the greatest total biomass, are presented here to give a more accurate allocation of the relative catch of species at the Gully Main Station. Data from estimated nominal depth strata are summarized as mean (per trawl set) biomass and abundance, with absolute and relative values of those species accounting for greater than 5% of the total catch in any one stratum tabulated for comparison of individual species. Although just one set sampled below 1250m at the Gully Main Station, these data are also presented as an estimated stratum.

Species that accounted for very small amounts of biomass and abundance were eliminated prior to all analyses. This was done to eliminate the distorting effect of rarities on assemblage patterns (Clarke & Warwick 2001) even though rare species should have little effect and there removal is arbitrary (T. Sutton personal communication). Species accounting for greater than 2% of biomass and 3% of abundance were included, providing a similar number of about 25 species for each analysis. Abundance and biomass values spanned orders of magnitude, so data were log(x + 1) transformed prior to analysis to down-weight particularly dominant species which could otherwise individually dictate assemblage patterns (Clarke &Warwick 2001, Sutton et al. 2008, DeForest & Drazen 2009).

Two multivariate techniques were employed to discriminate patterns in the sample data using the PRIMER v.6.1.6 software package (Clarke & Gorely 2006). Principal component analysis (PCA) of the covariance matrices of estimated stratum species log-transformed biomasses and abundances were used to examine the variability within the assemblage of crustacean species at the Gully Main Station. Three survey design factors were used to label trawl sets to visualize their influence on the observed patterns: Depth, Time of Day (diel variation), and Year (annual variation). SIMPROF (Similarity Profile) permutation tests on cluster analyses, imposed on MDS (Multidimensional Scaling) plots for both biomass and abundance, tested for significant clustering of trawl sets (Clarke &Warwick 2001).

Unadjusted (raw) trawl set totals for the two Slope Station sets to 750m during the day and the corresponding three trawl sets from the Gully Main Station are presented for comparison: trawl set biomass, abundance, numbers of species, and their respective means. Unadjusted species catch data are summarized as mean (per trawl) biomass and abundance, with absolute and relative values for all species at the two stations presented for comparison. Species accounting for greater than 1% of biomass or abundance were selected, and then analyses followed the same approach described above.

2.3. Results

2.3.1. The Gully Environment

Analysis and interpretation of the physical and chemical information collected is ongoing, but a general picture of the oceanographic conditions in the Gully is emerging.

The deeper water inside the Canyon itself appears to be filled with warm slope water or North Atlantic Central Water (McLellan et al. 1957, Gatien 1976). At more shallow depths conditions are more variable, with cold or Labrador Slope Water at the head or upper reaches in the canyon, the exact boundary between it and the warm slope water varying, at least annually (T. Kenchington personal communication). The waters above the canyon are those typical for the Scotian Shelf (Hachey 1942), with a warm upper layer in summer and a cold intermediate layer between it and the canyon. In 2007, a larger than normal cold intermediate layer existed at a depth of about 50-150m (Kenchington et al. 2009). Based on additional information, it is assumed a vertically and horizontally expanded cold layer sat over the Gully in 2007. This cold intermediate layer, originating in the Labrador Current and as outflow from the Gulf of St. Lawrence, was reduced in both 2008 and 2009, but is a reoccurring event with even larger volumes on record. In 2009, a shallow tongue of warm slope water extended to the mouth of the Gully, seaward of the Main Station. However, elements of the fish fauna at greater depths apparently contained an increase in the number of rare species, indicating what may be the remnant of a deep, warm water intrusion, possibly a warm core eddy from the Gulf Stream, no longer physically but biologically detectable (T. Kenchington, personal communication). Therefore, the present study spans what may be considered physical extremes, from colder in 2007 to warmer conditions in 2009, with one more or less intermediate year in 2008.

The oceanographic conditions at the adjacent Slope Station in 2009 were different from those of the Gully Main Station, with more cold slope water over the Gully but warm slope water over the adjacent slope to the west.

2.3.2. Trawling

A total of 41 IYGPT trawl sets were completed at the Gully Main Station over a three-year period, from 2007-2009 during the late summer: forty replicated sets at the Gully Main Station to depths of 250m, 750m and 1250m, both day and night, and one unreplicated opportunistic deep exploratory trawl to 1500m, in order to at least make an inference about the deeper fauna below the replicated stratified survey, and allow limited comparisons (Table 2.2). An exception to the standard target depth fishing time, the deep exploratory set only fished the nominal 1250-1500m stratum for approximately 30 minutes. Two sets to 750m during the day were collected in 2009 outside the Gully at an adjacent Slope Station of similar bottom depth, approximately 2000m (Figure 2.1, Table 2.2), allowing for a comparison with the three replicate sets at the Gully Main Station of the same year, time of day and depth. Though limited in scope, these data allow for both qualitative and quantitative contrasts between the two faunas.

2.3.3. A General Description of the Fauna

The pelagic Crustacea constitute a significant but variable component of the fauna sampled at the Gully Main Station in late summer, accounting for approximately 50%, 27%, and 43% of the total catch biomass (wet weight) in 2007, 2008, and 2009, respectively (Kenchington et al. 2011). At least 69 species (plus one variant) from eight orders of Crustacea, including four large (meroplanktonic) larval forms, were identified from the 41 Gully Main Station fishing sets (Table 2.3). A large proportion of the total catch of smaller species of euphausiids (not *Meganyctiphanes norvegica* or *Thysanopoda acutifrons*) could not be confidently assigned to species, and were grouped together as

Table 2.3 (in part) Pelagic Crustacea collected at the Gully Main Station 2007-2009, epipelagic adjusted data

Species or Lowest Taxon	Order	Family	Total Biomass (g)	Total Number
Meganyctiphanes norvegica	Euphausiacea	Euphausiidae	75,683*	306,952*
Sergestes arcticus	Decapoda	Sergestidae	54,302*	66,484*
Pasiphaea multidentata	Decapoda	Pasiphaeidae	9,891	3,368
Acanthephyra pelagica	Decapoda	Oplophoridae	6,264	1,987
Themisto gaudichaudii	Amphipoda	Hyperiidae	3,693*	28,602*
Gennadas elegans	Decapoda	Benthesicymidae	1,977	3,694
Parapasiphaea sulcatifrons	Decapoda	Pasiphaeidae	712	527
Sergia japonica	Decapoda	Sergestidae	598	1079
Unidentified Euphausiacea+	Euphausiacea	undetermined	587*	7,071*
Acanthephyra purpurea	Decapoda	Oplophoridae	403	247
Gnathophausia gigas	Lophogastrida	Lophogastridae	389	246
Gnathophausia zoea	Lophogastrida	Lophogastridae	326	200
Sergia robusta	Decapoda	Sergestidae	321	272
Thysanopoda acutifrons	Euphausiacea	Euphausiidae	260	352
Eucopia australis	Lophogastrida	Eucopiidae	227	776
Megalanceola stephenseni	Amphipoda	Lanceolidae	150	71
Pasiphaea tarda	Decapoda	Pasiphaeidae	111	7
Acanthephyra eximia	Decapoda	Oplophoridae	108	4
Notostomus robustus	Decapoda	Oplophoridae	104	23
Eucopia sculpticauda	Lophogastrida	Eucopiidae	81	112
Gennadas valens	Decapoda	Benthesicymidae	73	112
Notostomus elegans	Decapoda	Oplophoridae	73	5
Altelatipes falkenhaugae	Decapoda	Benthesicymidae	46	14
Meningodora vesca	Decapoda	Oplophoridae	34	32
Cystisoma spp.	Amphipoda	Cystisomatidae	20	8
Lanceola spp.+	Amphipoda	Lanceolidae	17	37
Eurythenes obesus	Amphipoda	Lysianassidae	16	33
Gennadas capensis	Decapoda	Benthesicymidae	16	30
Themisto libellula	Amphipoda	Hyperiidae	16	86
Parandania boecki	Amphipoda	Stegocephalidae	11	43
Meningodora mollis	Decapoda	Oplophoridae	11	7
Gigantocypris muelleri (ostracod)	Myodocopida	Cypridinidae	10	16
Hyperia galba	Amphipoda	Hyperiidae	9	38
Hymenodora gracilis	Decapoda	Oplophoridae	8	29
Phronima sedentaria	Amphipoda	Phronimidae	7	22
Galatheidae juveniles	Decapoda	Galatheidae	7	8
Bentheogennema intermedia	Decapoda	Benthesicymidae	7	12

Table 2.3 (continued) Pelagic Crustacea collected at the Gully Main Station 2007-2009, epipelagic adjusted data

Species or Lowest Taxon	Order	Family	Total Biomass (g)	Total Number
Hymenopenaeus laevis	Decapoda	Solenoceridae	6	5
Sergia grandis	Decapoda	Sergestidae	6	4
Eupasiphaea serrata	Decapoda	Pasiphaeidae	5	1
Acanthephyra pelagica var.	Decapoda	Oplophoridae	5	1
Gennadas tinayeri	Decapoda	Benthesicymidae	4	19
Sergia tenuiremis	Decapoda	Sergestidae	4	3
Idotea metallica	Isopoda	Idoteidae	4	6
Boreomysis arctica	Mysida	Mysidae	3	24
Gennadas bouvieri	Decapoda	Benthesicymidae	3	10
Phrosina semilunata	Amphipoda	Phrosinidae	3	6
Phyllosoma larvae+	Decapoda	Palinuridae/ Scyllaridae	2	12
Oplophorus spinosus	Decapoda	Oplophoridae	2	2
Paracallisoma sp.	Amphipoda	Lysianassidae	2	3
Meningodora miccyla	Decapoda	Oplophoridae	1	5
Platyscelus ovoides	Amphipoda	Platyscelidae	1	8
Systellaspis debilis	Decapoda	Oplophoridae	1	1
Boreomysis semicoeca	Mysida	Mysidae	1	22
Ephyrina bifida	Decapoda	Oplophoridae	1	2
Gennadas talismani	Decapoda	Benthesicymidae	1	2
Stomatopoda larvae	Stomatopoda	undetermined (multiple?)	1	5
Hyperia medusarum	Amphipoda	Hyperiidae	1	3
Gennadas scutatus	Decapoda	Benthesicymidae	<1	2
Brachyura megalopse	Decapoda	undetermined multiple	<1	1
Cyphocaris richardi	Amphipoda	Cyphocarididae	<1	1
Pegohyperia princeps	Amphipoda	Hyperiidae	<1	1
Scina spp.	Amphipoda	Scinidae	<1	1
Hyperia spinigera	Amphipoda	Hyperiidae	<1	1
Sergestes henseni	Decapoda	Sergestidae	<1	1
Bentheuphausia amblyops	Euphausiacea	Bentheuphausiidae	<1	1
Anuropus panteni	Isopoda	Anuropidae	<1	1

* total biomass and abundance estimated
+ more than one species present

Euphausiacea spp. Data on each species or taxon are summarized in Chapter 3, but only a few of the 69 taxa were frequently observed, with eight occurring in more than 80% of sets, 33 in less than 25% of sets, 12 of these species recorded in one set only. In terms of biomass, the northern krill *M. norvegica* and the decapod *Sergestes arcticus* were estimated to comprise over 80% of total catch biomass, the former also contributing over 70% of the total number individuals estimated to have been collected. Only four other species accounted for more than 1% of total catch biomass: the decapods *Pasiphaea multidentata*, *Acanthephyra pelagica*, and *Gennadas elegans*, and the hyperiid amphipod *Themisto gaudichaudii*.

Decapoda - The Decapoda was by far the most speciose group with at least 36 species from two major taxonomic groupings: the Dendrobranchiata (principally the Benthesicymidae and Sergestidae) and the Pleocyemata (principally the Oplophoridae and Pasiphaeidae). Nine species of Benthesicymidae were recorded in the Gully but both biomass and abundance was dominated by *G. elegans* (Table 2.3). Estimated stratum catch revealed *G. elegans* to be concentrated somewhere between 250-750m, day and night (Table 2.4a-c), with the single deep exploratory set indicating a relatively large presence deeper in the bathypelagic zone below 1250m (Table 2.5).

The other principal group of dendrobranchiate Decapoda, the Sergestidae, included six species, with overall biomass and abundance dominated by *S. arcticus* (Table 2.3). Estimated to be more broadly distributed than *G. elegans*, *S. arcticus* was similarly concentrated somewhere between 250-750m by day, but with a considerable part of the population also extending below 750m (Table 2.4a-c). At dusk, a large portion of the population migrated to above 250m, with a small number occasionally remaining

Below 750m. Deeper than 750m, the biomass and abundance of *Sergia japonica* increased (Table 2.4c), the single deep exploratory set indicating a relatively large presence of this species deeper in the bathypelagic zone below 1250m, where *S. japonica* replaced *S. arcticus* as the most abundant sergestid (Table 2.5).

The Oplophoridae was the most species rich family of large crustaceans in the water column at the Gully Main Station with 13 species (Table 2.3). Biomass and abundance were dominated by *Acanthephyra pelagica*, largely restricted below 250m, concentrated somewhere between 250-750m, but with a considerable part of the population also extending below 750m (Table 2.4a-c). The single deep exploratory set indicated a relatively large presence deeper in the bathypelagic zone below 1250m (Table 2.5).

The other principle family of Pleocyemata, the Pasiphaeidae, included four species, with overall biomass and abundance dominated by *Pasiphaea multidentata* (Table 2.3). Estimated stratum catch indicated a population concentrated during the day somewhere between 250-750m, with a small number occasionally below 750m (Table 2.4a-c). At dusk, most of the population migrated to above 250m, but with small numbers extending to below 750m. Catch of *Parapasiphaea sulcatifrons* increased with depth, with estimated biomass and abundance below 750m greater than for *P. multidentata* (Table 2.4c). The single deep exploratory set indicated a relatively large presence for both species deeper in the bathypelagic zone below 1250m (Table 2.5).

Euphausiacea - The larger Euphausiacea included just three species, with biomass and abundance dominated by the northern krill, *Meganyctiphanes norvegica* (Table 2.3). Estimated stratum catch indicated a population concentrated shallower than

Table 2.4a Mean biomass (g) and abundance per trawl set with percentage of total crustacean catch for the more common species in the 0-250m depth stratum (epipelagic adjusted data), arranged in decreasing order of rank. More common species defined as those with ≥ 5% of the estimated total biomass or abundance in any estimated nominal stratum. Presence is only inferred by estimated nominal stratum catch data

Species	Biomass (%)	Species	Abundance (%)
Day			
Meganyctiphanes norvegica	548 (86.3)	*Meganyctiphanes norvegica*	2,096 (74.6)
Themisto gaudichaudii	64 (10.0)	*Themisto gaudichaudii*	514 (18.3)
Euphausiacea	15 (2.3)	*Euphausiacea*	183 (6.5)
Sergestes arcticus	3 (0.5)	*Sergestes arcticus*	6 (0.2)
Pasiphaea multidentata	3 (0.5)	*Pasiphaea multidentata*	1 (<0.1)
*Eucopia australis**	<1 (<0.1)	*Eucopia australis**	1 (<0.1)
*Acanthephyra pelagica**	<1 (<0.1)	*Acanthephyra pelagica**	<1 (<0.1)
*Gennadas elegans**	<1 (<0.1)	*Gennadas elegans**	<1 (<0.1)
Gnathophausia zoea	0	*Gnathophausia zoea*	0
Gnathophausia gigas	0	*Gnathophausia gigas*	0
Parapasiphaea sulcatifrons	0	*Parapasiphaea sulcatifrons*	0
Sergia japonica	0	*Sergia japonica*	0
Night			
Meganyctiphanes norvegica	4,240 (74.5)	*Meganyctiphanes norvegica*	17053 (84.2)
Sergestes arcticus	905 (15.9)	*Sergestes arcticus*	1437 (7.1)
Pasiphaea multidentata	350 (6.1)	*Themisto gaudichaudii*	1379 (6.8)
Themisto gaudichaudii	156 (2.7)	*Euphausiacea*	234 (1.2)
Euphausiacea	21 (0.4)	*Pasiphaea multidentata*	129 (0.6)
Acanthephyra pelagica	5 (0.1)	*Acanthephyra pelagica*	3 (<0.1)
Parapasiphaea sulcatifrons	1 (<0.1)	*Sergia japonica*	1 (<0.1)
Gennadas elegans	<1 (<0.1)	*Gennadas elegans*	1 (<0.1)
Sergia japonica	<1 (<0.1)	*Parapasiphaea sulcatifrons*	<1 (<0.1)
Gnathophausia zoea	<1 (<0.1)	*Eucopia australis*	<1 (<0.1)
Eucopia australis	<1 (<0.1)	*Gnathophausia zoea*	<1 (<0.1)
Gnathophausia gigas	0	*Gnathophausia gigas*	0

* Possibly net contamination from an immediately preceding set to 750m or 1250m

Table 2.4b Estimates of mean biomass (g) and abundance per trawl set with percentage of total catch (%) for the more common species in the 250-750m nominal depth stratum, arranged in decreasing order of rank. More common species defined as those with ≥ 5% of the estimated total biomass or abundance in any estimated nominal stratum. Presence is only inferred by estimated nominal stratum catch data

Species	Biomass (%)	Species	Abundance (%)
Day			
Sergestes arcticus	1,823 (72.6)	*Sergestes arcticus*	2,008 (66.3)
Pasiphaea multidentata	282 (11.2)	*Themisto gaudichaudii*	559 (18.5)
Acanthephyra pelagica	163 (6.5)	*Gennadas elegans*	155 (5.1)
Gennadas elegans	84 (3.4)	*Pasiphaea multidentata*	92 (3.1)
Themisto gaudichaudii	69 (2.7)	*Acanthephyra pelagica*	56 (1.8)
Meganyctiphanes norvegica	13 (0.5)	*Meganyctiphanes norvegica*	46 (1.5)
Sergia japonica	5 (0.2)	Euphausiacea	43 (1.4)
Euphausiacea	4 (0.2)	*Sergia japonica*	10 (0.3)
Gnathophausia zoea	2 (0.1)	*Eucopia australis*	5 (0.2)
Parapasiphaea sulcatifrons	2 (0.1)	*Parapasiphaea sulcatifrons*	2 (0.1)
Eucopia australis	1 (0.1)	*Gnathophausia zoea*	2 (0.1)
Gnathophausia gigas	1 (<0.1)	*Gnathophausia gigas*	1 (<0.1)
Night			
Meganyctiphanes norvegica	1,452 (57.9)	*Meganyctiphanes norvegica*	7,157 (88.6)
Sergestes arcticus	635 (25.3)	*Sergestes arcticus*	398 (4.9)
Acanthephyra pelagica	206 (8.2)	*Gennadas elegans*	132 (1.6)
Gennadas elegans	74 (2.9)	Euphausiacea	132 (1.6)
Themisto gaudichaudii	45 (1.8)	*Themisto gaudichaudii*	119 (1.5)
Pasiphaea multidentata	23 (0.9)	*Acanthephyra pelagica*	68 (0.8)
Gnathophausia zoea	12 (0.1)	*Sergia japonica*	10 (0.4)
Euphausiacea	9 (0.4)	*Pasiphaea multidentata*	8 (0.1)
Sergia japonica	4 (0.2)	*Eucopia australis*	6 (0.1)
Eucopia australis	2 (0.1)	*Gnathophausia zoea*	6 (0.1)
Parapasiphaea sulcatifrons	1 (<0.1)	*Parapasiphaea sulcatifrons*	2 (<0.1)
Gnathophausia gigas	1 (<0.1)	*Gnathophausia gigas*	1 (<0.1)

Table 2.4c Estimates of mean biomass (g) and abundance per trawl set with percentage of total catch (%) for the more common species in the 750-1250m nominal depth stratum, arranged in decreasing order of rank. More common species defined as those with ≥ 5% of the estimated total biomass or abundance in any stratum estimate. Presence is only inferred by estimated nominal stratum catch data

Species	Biomass (%)	Species	Abundance (%)
Day			
Sergestes arcticus	518 (54.4)	*Meganyctiphanes norvegica*	415 (37.3)
Meganyctiphanes norvegica	105 (11.0)	*Sergestes arcticus*	398 (35.7)
Acanthephyra pelagica	78 (8.2)	*Sergia japonica*	78 (7.0)
Parapasiphaea sulcatifrons	49 (5.2)	*Parapasiphaea sulcatifrons*	44 (4.0)
Sergia japonica	49 (5.1)	*Eucopia australis*	40 (3.6)
Gnathophausia gigas	38 (4.0)	Euphausiacea	33 (2.9)
Pasiphaea multidentata[09]	35 (3.6)	*Acanthephyra pelagica*	20 (1.8)
Eucopia australis	13 (1.4)	*Gnathophausia gigas*	18 (1.6)
Gnathophausia zoea	11 (1.2)	*Pasiphaea multidentata*[09]	10 (0.9)
Gennadas elegans	4 (0.5)	*Gnathophausia zoea*	9 (0.8)
Euphausiacea	4 (0.4)	*Gennadas elegans*	5 (0.5)
Themisto gaudichaudii	0	*Themisto gaudichaudii*	0
Night			
Acanthephyra pelagica	68 (20.5)	*Meganyctiphanes norvegica*[08]	95 (27.8)
Parapasiphaea sulcatifrons	52 (15.5)	*Eucopia australis*	51 (14.9)
Sergestes arcticus[08]	45 (13.5)	*Sergia japonica*	40 (11.8)
Pasiphaea multidentata	34 (10.2)	*Parapasiphaea sulcatifrons*	26 (7.8)
Sergia japonica	22 (6.8)	*Sergestes arcticus*[08]	24 (7.0)
Gnathophausia gigas	21 (6.3)	*Gnathophausia gigas*	16 (4.6)
Meganyctiphanes norvegica[08]	19 (5.7)	*Themisto gaudichaudii*[09]	14 (4.0)
Eucopia australis	14 (4.3)	*Pasiphaea multidentata*	11 (3.4)
Gnathophausia zoea	10 (3.0)	*Acanthephyra pelagica*	9 (2.7)
Gennadas elegans	8 (2.3)	*Gennadas elegans*	8 (2.3)
Themisto gaudichaudii[09]	<1 (0.1)	*Gnathophausia zoea*	6 (1.8)
Euphausiacea	0	Euphausiacea	0

[08] Only occurred in 1 set (from 2008) over the 3 year sampling period
[09] Only occurred in 1 set (from 2009) over the 3 year sampling period

Table 2.5 Estimates of biomass (g) and abundance with percentage of total catch (%) for the more common species in the 1250-1500m nominal depth stratum based on the one deep exploratory set to 1500m, arranged in decreasing order of rank. More common species defined as those with ≥ 5% of the estimated total in any stratum estimate. Presence only inferred by estimated nominal stratum catch data

Species	Biomass (%)	Species	Abundance (%)
Day			
Acanthephyra pelagica	174 (22.4)	*Gennadas elegans*	52 (25.2)
Parapasiphaea sulcatifrons	170 (22.0)	*Sergia japonica*	40 (19.4)
Pasiphaea multidentata	149 (19.2)	*Pasiphaea multidentata*	28 (13.5)
Sergia japonica	87 (11.2)	*Eucopia australis*	26 (12.3)
Gnathophausia gigas	64 (7.6)	*Acanthephyra pelagica*	23 (11.2)
Gnathophausia zoea	51 (6.1)	*Parapasiphaea sulcatifrons*	16 (7.6)
Gennadas elegans	45 (5.3)	*Gnathophausia zoea*	1 (0.3)
Eucopia australis	17 (2.0)	*Gnathophausia gigas*	<1 (<0.1)
Meganyctiphanes norvegica	0	*Meganyctiphanes norvegica*	0
Sergestes arcticus	0	*Sergestes arcticus*	0
Themisto gaudichaudii	0	*Themisto gaudichaudii*	0
Euphausiacea	0	Euphausiacea	0

250m at night, but with a significant part of the population extending below 250m, and a small number occasionally below 750m (Table 2.4a-c). Daytime distribution was similar, but with dramatically fewer animals collected. The occurrence of smaller unidentified species of euphausiids was primarily above 750m, but a small number were estimated to occur deeper during the day.

Lophogastrida – *Eucopia australis* was the most abundant lophogastrid, but the biomasses of the much larger species, *Gnathophausia gigas* and *Gnathophausia zoea*, were greater (Table 2.3). The biomass and abundance the Lophogastrida increased with depth, their relative contribution to the Gully pelagic fauna noticeable below 750m (Table 2.4c). The single deep exploratory set indicated a relatively large presence of both *G. zoea* and *E. australis* deeper in the bathypelagic zone below 1250m (Table 2.5).

Amphipoda - The Amphipoda was the second most speciose group overall with 23 species (Table 2.3). However, except for the dominant species *Themisto gaudichaudii*, catches were relatively low. Estimated stratum catch indicated the population of *T. gaudichaudii* concentrated shallower than 250m at night, but with a significant part of the population extending below 250m, and a small number occasionally below 750m (Table 2.4a-c). With a similar daytime distribution, but with overall fewer animals collected.

2.3.4. Species Assemblages

Principal component analysis of the covariance matrix of estimated species biomasses in nominal strata yielded similar, yet not identical, information to that from the PCA of estimated stratum species abundances. The total amount of variability explained by the first three components of biomass data was nearly 60% (Table 2.6), with individual species coefficients showing that assemblage variability was not driven by one or few dominant species, with the possible exception of *M. norvegica* on the third component (Table 2.7). The first principle component (PC) of the matrix of biomasses explained 33.1% of the variation and was related to estimated depth, with sets from the 0-250m stratum scoring negative and those in the estimated 250-750m and 750-1250m strata positive (Figure 2.6). Separation of the sets from the 250-750m stratum and sets from the 750m-1250m stratum was not clear, with a considerable overlap in scores of individual sets. All species largely abundant in the upper 250m (Table 2.4a-c), day or night, had negative eigenvalues for the first PC (Table 2.7). The second PC of the matrix of biomasses explained 16.4% of variation and was related to diel change in catch within nominal strata, depth, and to a lesser extent year. All sets from the 250-750m stratum scored negative while those in the 750-1250m stratum were largely positive. Daylight and night sets from the upper 250m separated along the second PC, with daylight sets having positive scores (Figure 2.6). This diel separation was also apparent though incomplete for the 250-750m stratum, with night sets scoring less negative than those made during the day; values for night sets were intermediate between 250-750m daytime sets and sets from 750-1250m. No clear diel separation existed deeper, among sets fishing below 750m. In addition, 2007 sets generally had more positive PC2 scores than those for 2008/2009 within respective strata and diel groupings. The third PC of the matrix of biomasses explained just 8.9% of assemblage variability and appeared weakly related to diel variation (Figure 2.7). Unlike the first two principal components, the third PC was influenced by a larger negative value, that of the euphausiid *M. norvegica* (Table 2.7).

The total amount of variability explained by the first three principal components

Table 2.6 Results for principal component analysis of the matrix of estimated nominal stratum species biomasses and abundances, Gully Main Station, total amount of variation explained by the first three components. Only species accounting for >3% of total biomass and >2% of total abundance in any one set included

	Biomass		**Abundance**	
	% Variation	**Cumulative %**	**% Variation**	**Cumulative %**
PC1	33.1	33.1	27.5	37.5
PC2	16.4	49.5	21.1	58.6
PC3	8.9	58.4	12.0	70.6

Table 2.7 Species coefficients (eigenvalues) from principal component analysis of the matrix of estimated nominal stratum species biomasses at the Gully Main Station. Only species accounting for >3% of total biomass in any one set included

Species	**PC1**	**PC2**	**PC3**
Gennadas elegans	0.127	-0.468	0.126
Altelatipes falkenhaugae	0.095	-0.070	-0.294
Sergestes arcticus	-0.068	-0.476	-0.332
Sergia japonica	0.277	-0.029	-0.053
Sergia robusta	0.180	-0.271	0.095
Acanthephyra pelagica	0.226	-0.252	-0.127
Acanthephyra purpurea	0.113	-0.300	-0.007
Notostomus robustus	0.165	0.025	0.058
Parapasiphaea sulcatifrons	0.290	0.147	0.008
Pasiphaea multidentata	-0.119	-0.432	0.304
Pasiphaea tarda	0.062	0.057	0.127
Meganyctiphanes norvegica	-0.346	-0.012	-0.687
Thysanopoda acutifrons	0.256	-0.165	-0.294
Euphausiacea	-0.161	0.050	-0.126
Eucopia australis	0.256	0.040	-0.023
Eucopia sculpticauda	0.246	0.111	-0.082
Gnathophausia zoea	0.253	0.031	-0.049
Gnathophausia gigas	0.281	0.203	-0.062
Themisto gaudichaudii	-0.346	-0.113	0.211
Themisto libellula	-0.138	0.105	-0.068
Megalanceola stephenseni	0.220	-0.010	-0.132

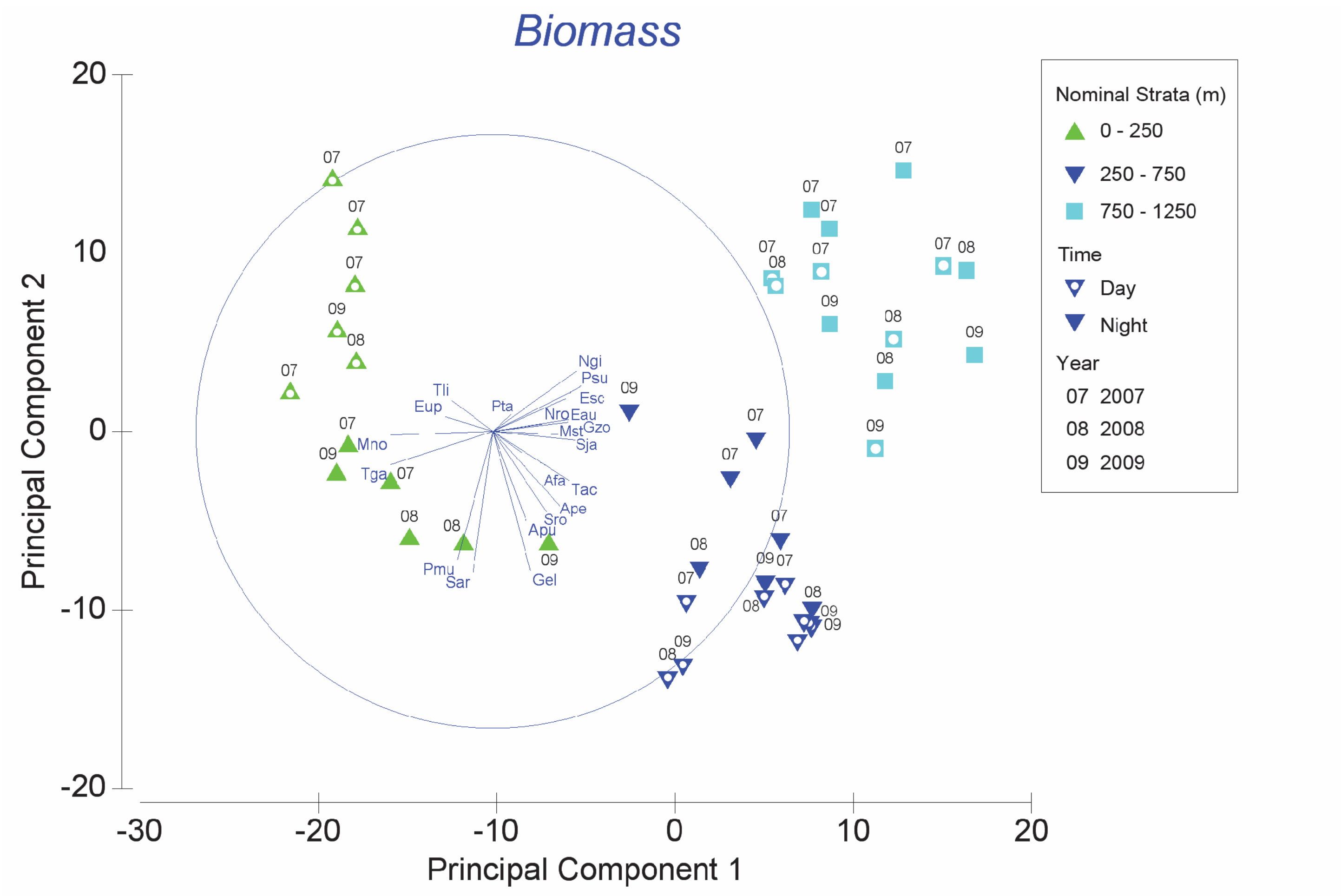

Figure 2.6. Principal component analysis of the correlation matrix of estimated nominal stratum species biomasses, Gully Main Station, results plotted in the plane of 1st and 2nd principal component, including species eigenvectors. Trawl set depth, time of day and year indicated. Only species accounting for >3% of total biomass in any one set included

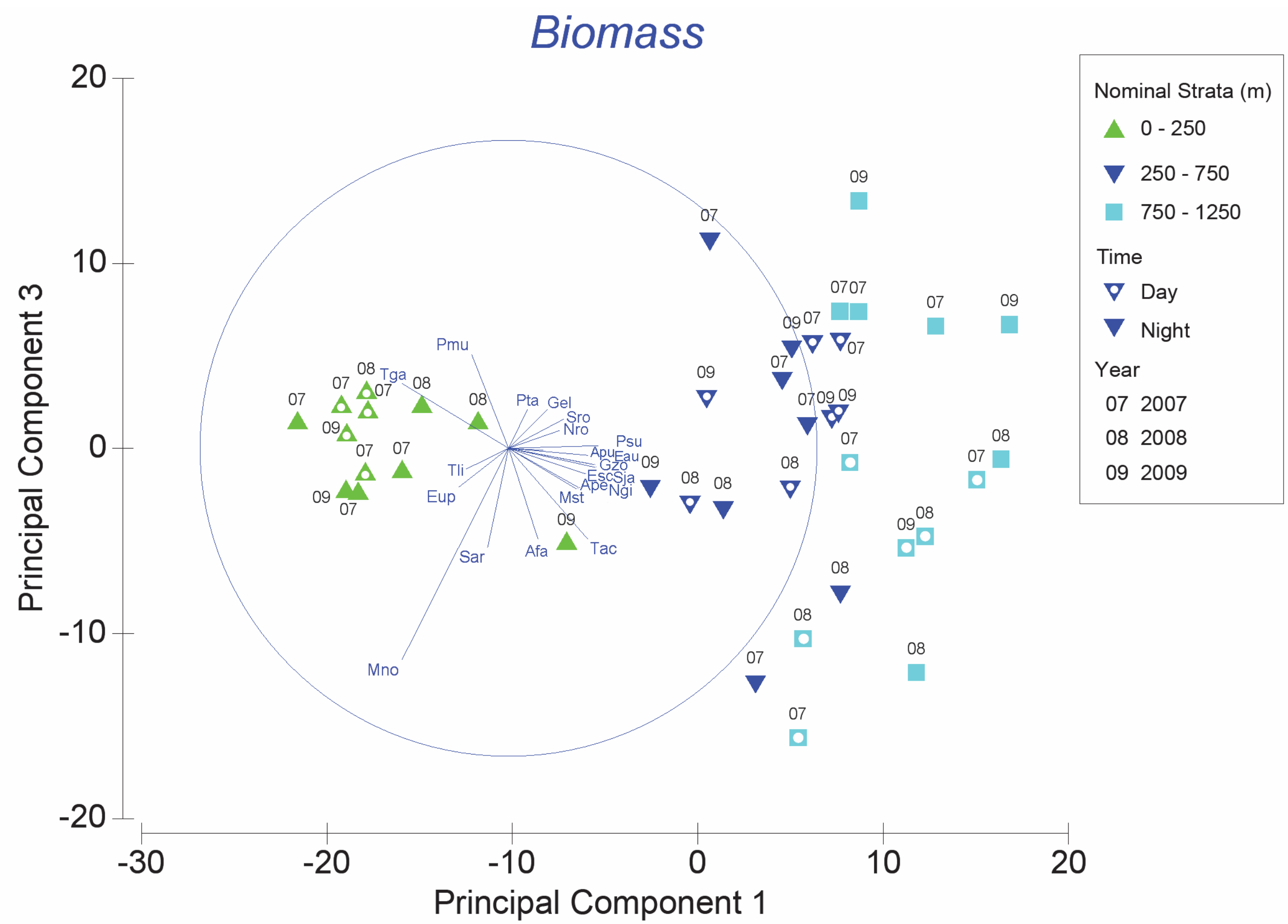

Figure 2.7. Principal component analysis of the matrix of estimated nominal stratum species biomasses, Gully Main Station, results plotted in the plane of 1st and 3rd principal component, including species eigenvectors. Trawl set depth, time of day and year indicated. Only species accounting for >3% of total biomass in any one set included

for abundance data was over 70% (Table 2.6). Individual species correlation coefficients for the first three principal components showed that assemblage variability was influenced by the numerically dominant species *M. norvegica*, *S. arcticus*, and *T. gaudichaudii* (Table 2.8). The first PC of the matrix of abundance explained 37.5% of assemblage variability and was related to estimated depth, with sets from the 0-250m stratum scoring negative and those in the estimated 250-750m and 750-1250m strata mostly positive with some overlap (Figure 2.6). As with biomass, those species with a majority of the population occurring in the nominal 0-250m stratum (Table 2.4a-c), day or night, scored negative on PC1 (Table 2.8). The second PC explained 21.1% of variation and was related to diel change, and to a lesser degree, estimated nominal depth (Figure 2.8). Sets from the 250-750m stratum scored more negative, while those in the 750-1250m were largely positive, with some overlap. Day and night sets from the upper 250m separated along the second PC, with day sets having positive scores (Figure 2.8). This diel separation was also apparent though incomplete in the 250-750m stratum, with night sets scoring more negative than those made during the day; values for night sets were intermediate between 250-750m daytime sets and sets from 750-1250m. No clear diel separation existed deeper, among sets fishing below 750m. Unlike the second PC of the matrix of biomass, an annual effect was less clear, scores for sets from 2007 more negative, but with considerable overlap. The third PC accounted for 12.0% of assemblage variability but did not appear related to any of our design factors (Figure 2.9).

Results of SIMPROF permutation tests on cluster analysis, imposed on MDS plots for both biomass and abundance, revealed significant clustering corresponding primarily to the three estimated nominal depth strata, 0-250m, 250-750m, and 750-1250m (Figure

Table 2.8 Species correlation coefficients (eigenvalues) from principal component analysis of the matrix of estimated nominal stratum species abundances at the Gully Main Station. Only species accounting for >2% of total abundance in any one set were included

Species	**PC1**	**PC2**	**PC3**
Gennadas elegans	0.094	0.430	-0.015
Sergestes arcticus	-0.219	0.668	0.390
Sergia japonica	0.236	-0.068	0.180
Sergia tenuiremis	0.012	-0.009	0.000
Sergia robusta	0.013	0.165	0.044
Acanthephyra pelagica	0.115	0.226	0.097
Acanthephyra purpurea	0.018	0.199	0.092
Hymenodora gracilis	0.050	-0.050	0.019
Parapasiphaea sulcatifrons	0.213	-0.109	0.087
Pasiphaea multidentata	-0.129	0.252	-0.164
Pasiphaea tarda	0.008	0.009	-0.025
Meganyctiphanes norvegica	-0.346	-0.012	0.687
Thysanopoda acutifrons	0.149	0.058	0.185
Euphausiacea	-0.244	-0.040	0.088
Eucopia australis	0.218	-0.063	0.104
Eucopia sculpticauda	0.119	-0.076	0.062
Gnathophausia zoea	0.110	-0.004	0.083
Gnathophausia gigas	0.165	-0.124	0.062
Boreomysis semicoeca	0.047	-0.042	0.016
Eurythenes gryllus	0.030	0.004	-0.001
Themisto gaudichaudii	-0.437	0.091	-0.626
Themisto libellula	-0.084	-0.065	-0.054
Lanceola spp.	0.036	-0.005	0.041
Megalanceola stephenseni	-0.067	-0.024	0.061

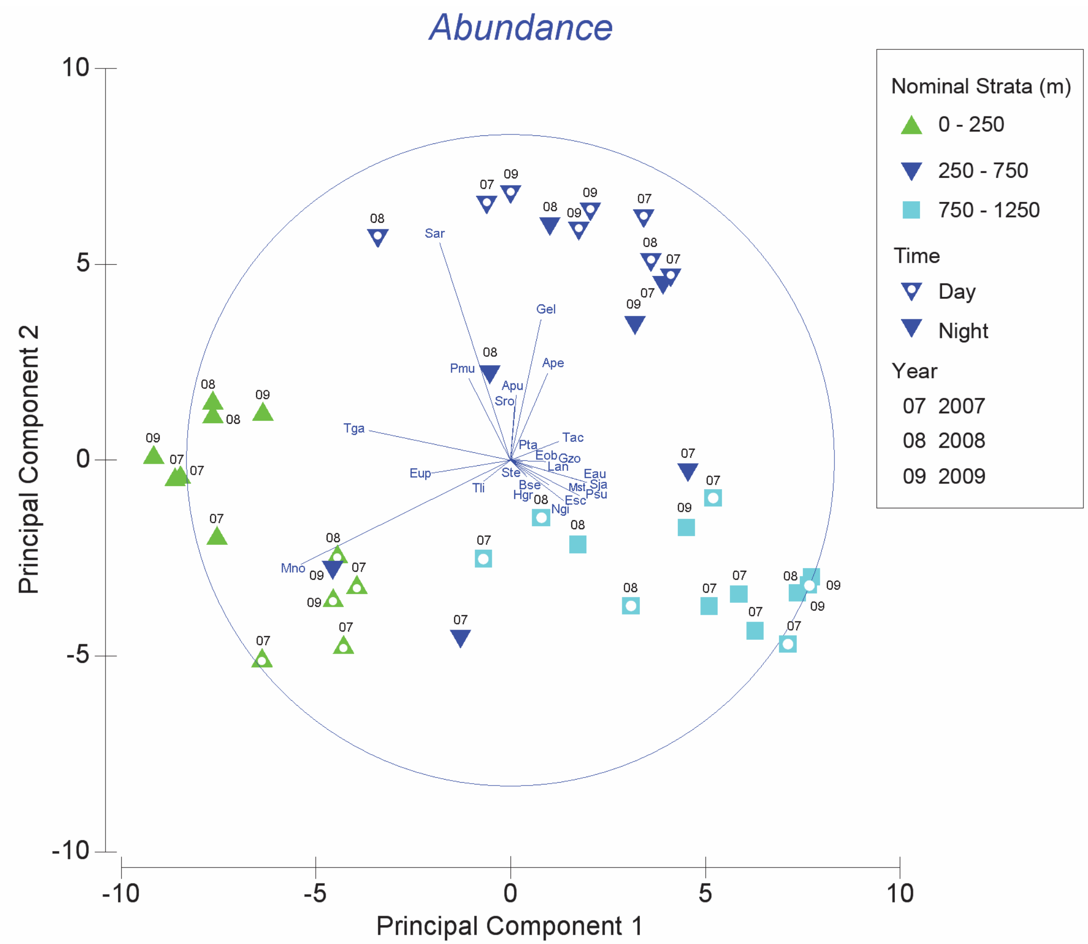

Figure 2.8. Principal component analysis of the matrix of estimated nominal stratum species abundances, Gully Main Station, results plotted in the plane of 1st and 2nd principal component, including species eigenvectors. Trawl set depth, time of day and year indicated. Only species accounting for >3% of total biomass in any one set included

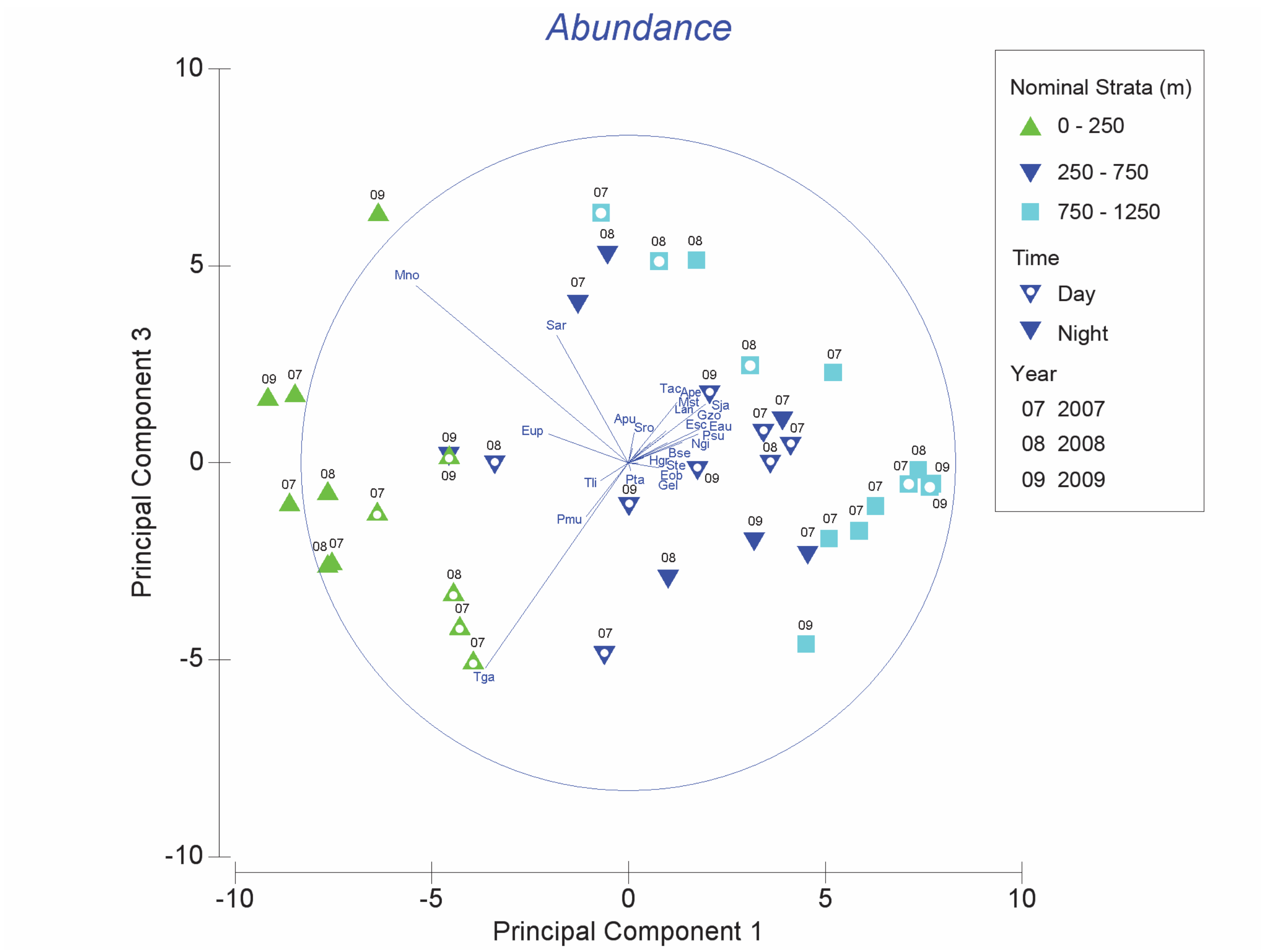

Figure 2.9. Principal component analysis of the matrix of estimated nominal stratum species abundances, Gully Main Station, results plotted in the plane of 1st and 3rd principal component, including species eigenvectors. Trawl set depth, time of day and year indicated. Only species accounting for >3% of total biomass in any one set included

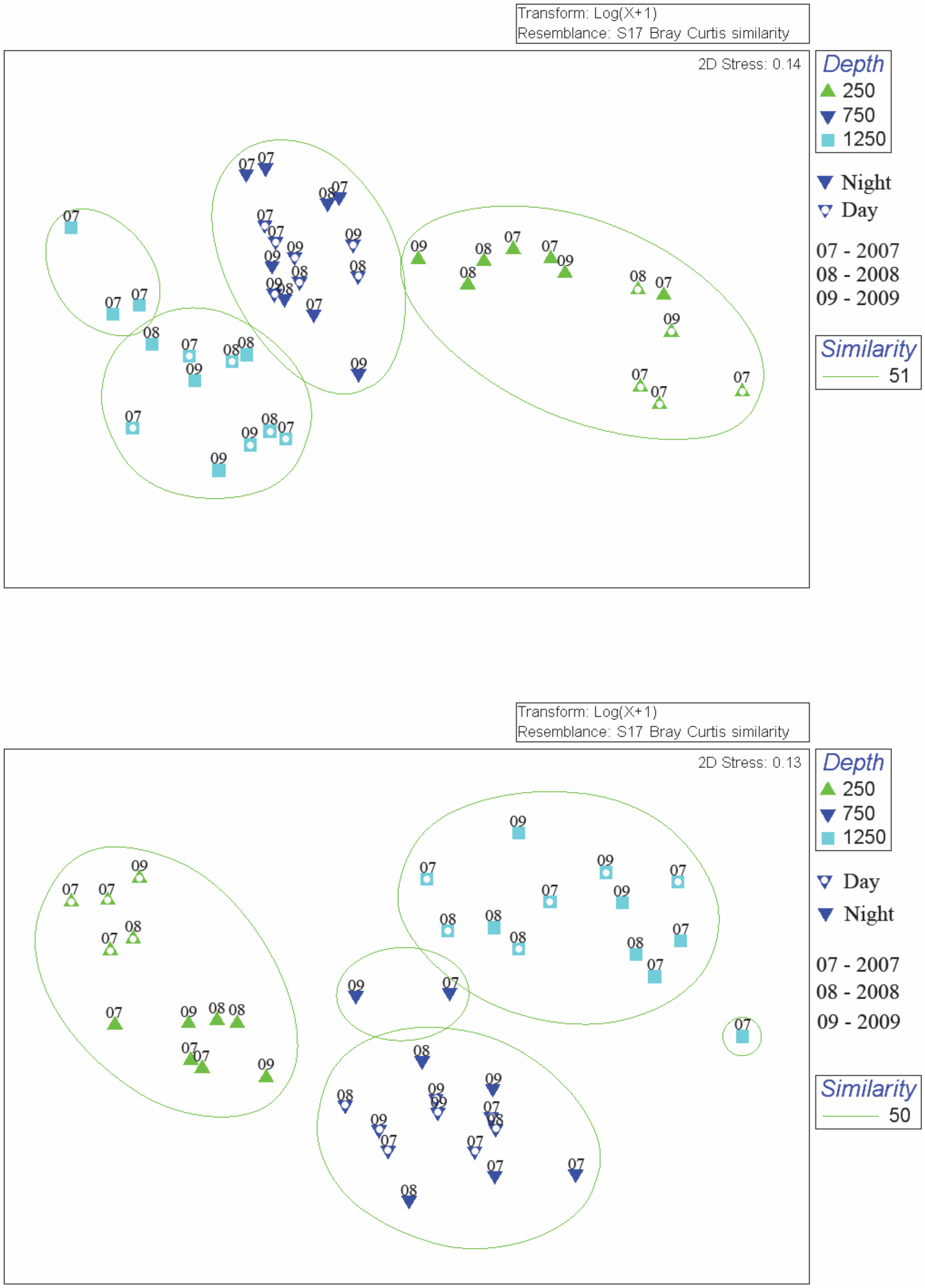

Figure 2.10. Results of SIMPROF permutation tests on cluster analysis for Gully Main Station, imposed on MDS plots for biomass and abundance, significant clustering indicated by circles ($p<0.05$). Maximum trawl set depth, time of day and year indicated

2.10, $p<0.05$). However, the three night time trawl sets fishing below 750m in 2007 formed an additional significant cluster based on species biomass. These sets included the lowest biomass, abundance, and species richness observed in the deep 750-1250m stratum at night, and three of only four trawl sets with biomass dominated by *A. pelagica*; the only other being the closely related set from 2008, but this set also contained approximately 50% additional or differing species. This indicated some annual effect, at least between 2007 and the other two years. There was some indication of separation by time of day, at least for sets fishing 0-250m, but it was not significant.

2.3.5. Comparison of Gully Main Station and Adjacent Slope Station

Overall catch biomass, abundance, and the numbers of species collected were greater in the Gully Main Station sets to 750m during the day, compared to sets from the same depth and diel cycle at the adjacent Slope Station (Table 2.9). Species dominance structure was also different at the two sites, with *S. arcticus*, accounting for over 70% of catch biomass and abundance at the Gully Main Station, compared to approximately 30% at the Slope Station (Table 2.10). *Meganyctiphanes norvegica*, on the other hand, was much more abundant at the Slope Station, representing nearly half of the animals collected and over 30% of biomass, compared to just 6% of biomass at the Gully Main Station (Table 2.10).

Though not overly abundant, other notable species also differed dramatically, in absolute and relative terms. An average of 221 *T. gaudichaudii* per set was collected at the Slope Station, but just 32 at the Gully Main Station, and *P. multidentata* averaged 41 animals per set at the Gully Main Station, but was all but absent at the Slope Station with an average of just two (Table 2.10). In absolute terms, the average catch of *A. pelagica* was double at the Slope Station, and although I do not know what species increased or decreased, the catch of smaller species of euphausiids was three times higher at the Gully Main Station (Table 2.10).

Catch of *G. elegans* at the Gully Main Station was not remarkably greater than the Slope Station, but half of the eight benthesicymid species, *Altelatipes falkenhaugae*, *Gennadas bouvieri*, *Gennada talismani*, and *Gennadas tinayeri*, only occurred at the Gully Main Station, while none were unique to the Slope Station. And though three of the 11 hyperiid species, *Lycaea* sp., *Platyscelus ovoides*, and *Scina* sp., only occurred at the Slope Station, with no species unique to the Gully Main Station, the extremely rare and unusually large hyperiid, *Megalanceola stephenseni*, occurred in all three sets at the Gully Main Station, with considerably more biomass and a total of 6 individuals compared to two at the Slope Station. The giant, deep-dwelling ostracod, *Gigantocypris muelleri*, was only observed at the Gully Main Station, and though sample effort was not sufficient to typify a slope fauna, two oceanic species at the Slope Station were not observed over the entire three years of sampling at the Gully Main Station at any depths: the rare larval decapod genus *Cerataspis* and the hyperiid amphipod *Lycaea*.

When catch biomasses and abundances are compared (Table 2.9), not only is catch greater at the Gully Main Station, but the overall average individual biomass of animals (all species grouped) is considerably greater, over 125mg per average individual. However, when the large catches of *S. arcticus* are removed from calculations, values from the two sites are essentially identical, just 3mg heavier at the Gully. A possible Gully size effect on animals is therefore largely, though not exclusively, restricted to one

Table 2.9 Comparison of biomass (B), abundance (A) and species richness (S) at the Gully Main and Slope Stations, individual set totals with means based on raw (unadjusted) catch data (all sets 0-750m during the day)

	Gully Main				**Slope**		
	B (g)	**A**	**S**		**B (g)**	**A**	**S**
Set 31	1813	3144	33	Set 1	1832	3647	30
Set 35	3329	4864	25	Set 3	748	1122	23
Set 40	3099	4409	23		-	-	-
Mean	2747	4139	30		1290	2384	26

Table 2.10 Comparison of the raw (unadjusted) catch 2009 Gully Main Station day 0-750m tows to adjacent Slope day 0-750m tows: mean biomass (g) and abundance per trawl with percentage of total crustacean catch (%) for the more common species, arranged in decreasing order of rank. More common species defined as those with ≥ 5% of the total biomass or abundance in any one set

Species	Biomass (%)	Species	Abundance (%)
Gully Main			
Sergestes arcticus	2,154 (79.5)	*Sergestes arcticus*	2,936 (70.9)
Meganyctiphanes norvegica	172 (6.4)	*Meganyctiphanes norvegica*	688 (16.6)
Acanthephyra pelagica	132 (4.9)	Euphausiacea	180 (4.4)
Pasiphaea multidentata	110 (4.1)	*Gennadas elegans*	134 (3.2)
Gennadas elegans	67 (2.5)	*Acanthephyra pelagica*	47 (1.1)
Euphausiacea	16 (0.6)	*Pasiphaea multidentata*	41 (<1.0)
Themisto gaudichaudii	4 (0.1)	*Themisto gaudichaudii*	32 (<1.0)
Slope			
Sergestes arcticus	445 (35.6)	*Meganyctiphanes norvegica*	1,127 (47.3)
Meganyctiphanes norvegica	408 (32.7)	*Sergestes arcticus*	663 (27.8)
Acanthephyra pelagica	235 (18.8)	*Themisto gaudichaudii*	221 (9.3)
Gennadas elegans	61 (4.9)	*Gennadas elegans*	118 (4.9)
Themisto gaudichaudii	25 (2.1)	*Acanthephyra pelagica*	86 (3.6)
Pasiphaea multidentata	8 (<0.1)	Euphausiacea spp.	46 (1.9)
Euphausiacea	4 (<0.1)	*Pasiphaea multidentata*	2 (<0.1)

species: *S. arcticus*. A limited comparison of carapace length frequencies for *S. arcticus* at both sites shows near identical bimodal distributions (Figure 2.11). The largest individuals measured occurred at the Gully Main Station, the smallest at the Slope Station, but no conclusive size difference was apparent based on length alone.

Principal component analysis of the matrix of species biomasses yielded similar information as for abundances (Figures 2.12 and 2.13). The total amount of variability explained by the first component of biomass and abundance was 49.6% and 72.7%, respectively (Table 2.11), and the pattern was clearly related to location, with all Slope Station sets scoring more negative. For the biomass data, *P. sulcatifrons*, *Gennadas valens*, *Phrosina semilunata* and *T. gaudichaudii* had strong negative correlations with PC1 and so had greater biomass at the Slope Station than the Gully Main Station, while *M. stephenseni*, *P. multidentata* and *S. arcticus* showed the reverse (Table 2.12). The same pattern was seen in the abundance of the taxa except that *M. stephenseni* was not included and the smaller species of Euphausiacea were more abundant at the Gully Main Station than the Slope Station.

Results of SIMPROF permutation tests on cluster analysis imposed on MDS plots for both biomass and abundance revealed significant clusters ($p<0.05$) corresponding to the two sites: Gully Main Station vs. Slope Station (Figure 2.14).

2.4. Discussion and Conclusions

2.4.1. Gully Main Station Species

The Crustacea are a prominent component of the pelagic nekton at the Gully Main Station, representing up to 50% of the total biomass caught by the IYGPT. At depths above 1250m, the dominant members of the Gully Main fauna are more northern, cold

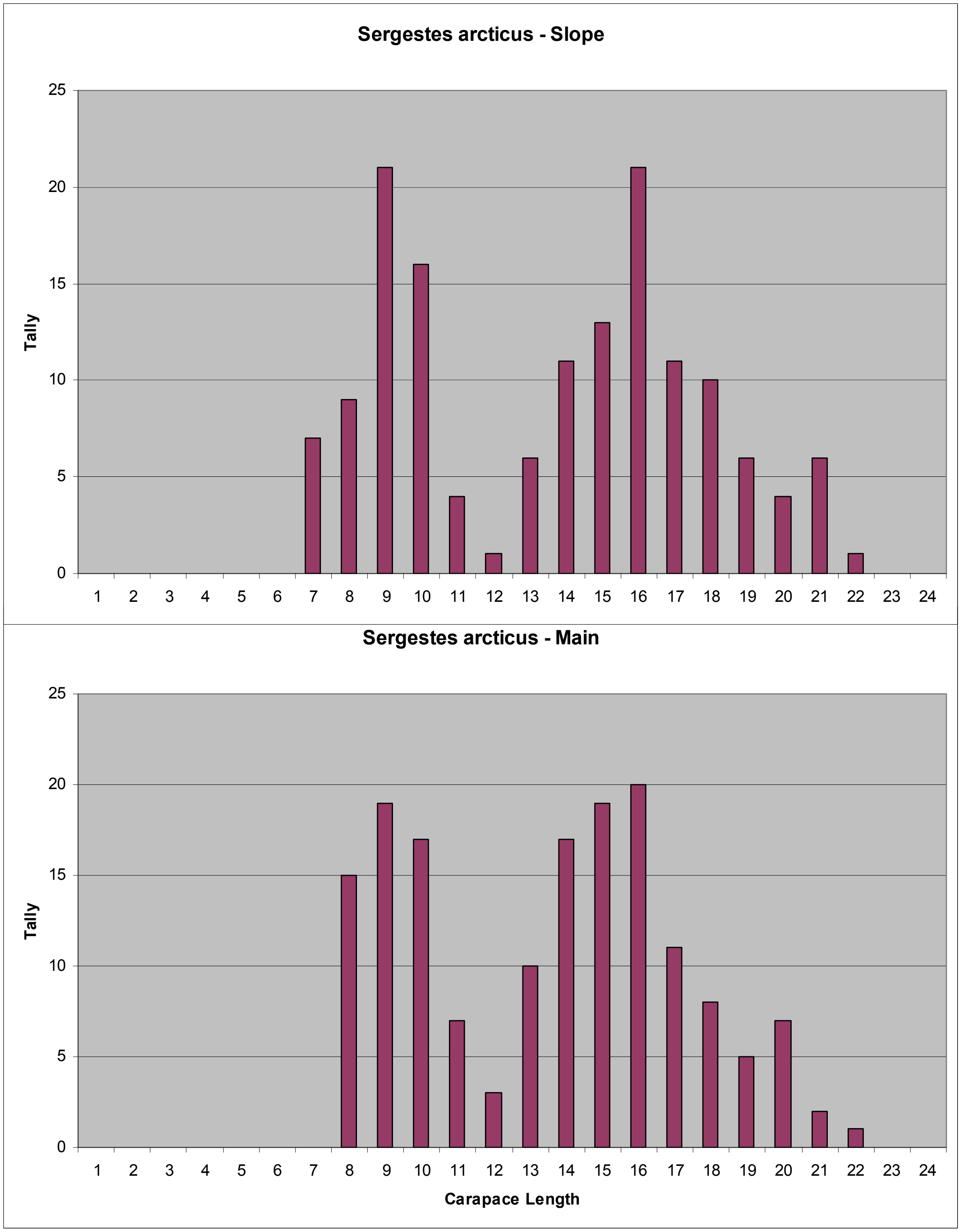

Figure 2.11. Frequency distribution of carapace lengths (mm) for *S. arcticus* at the Slope Station (top) and the Gully Main Station (bottom), based on an arbitrary subsample of 437 individuals from across the two Slope and three Main Station sets.

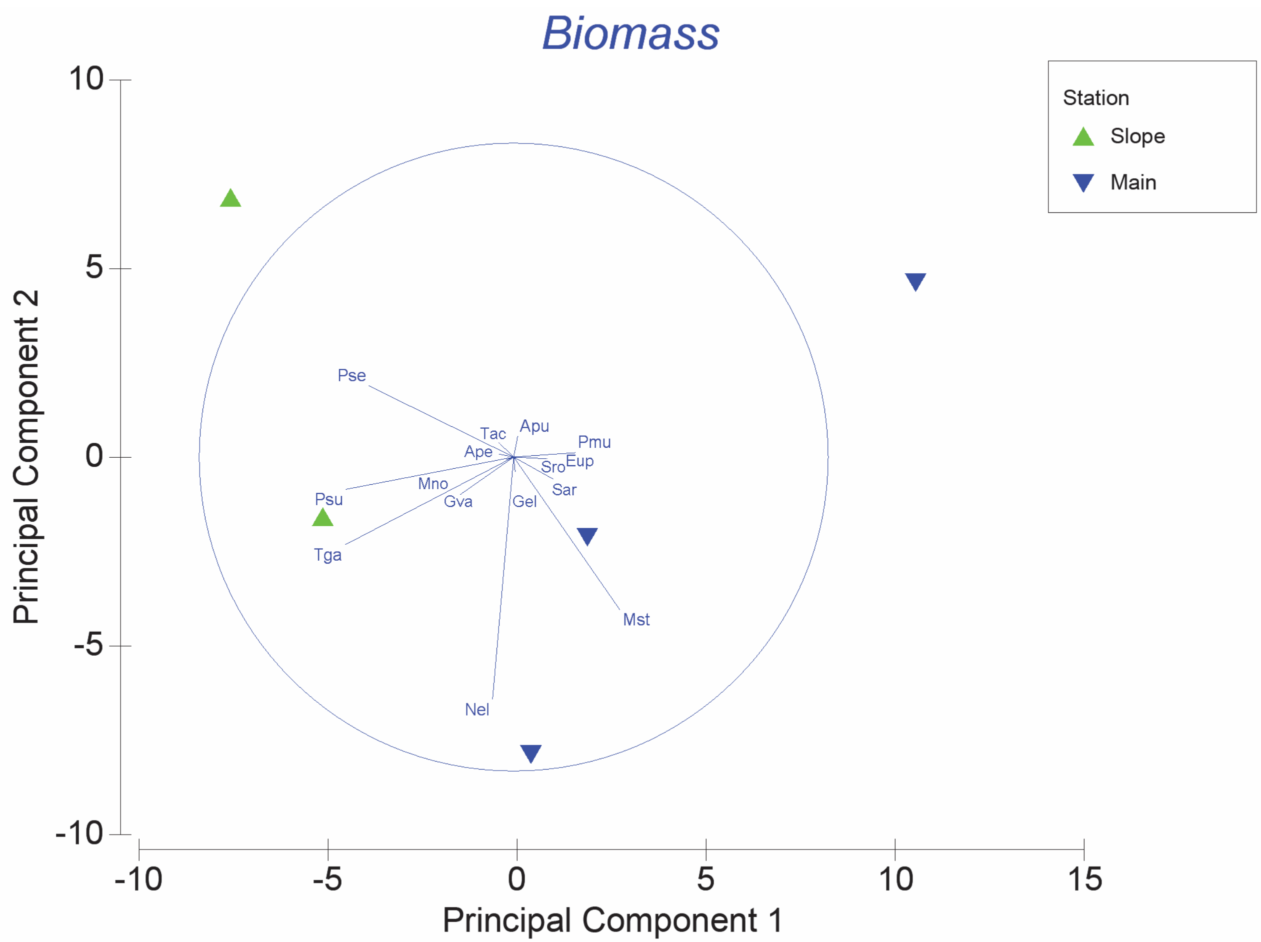

Figure 2.12. Comparison of Gully Main Station to adjacent Slope: principal component analysis of the matrix of estimated nominal stratum species biomasses, results plotted in the plane of 1st and 2nd principal component, including species eigenvectors. Trawl set depth, time of day and year indicated. Only species accounting for >1% of total biomass in any one set included

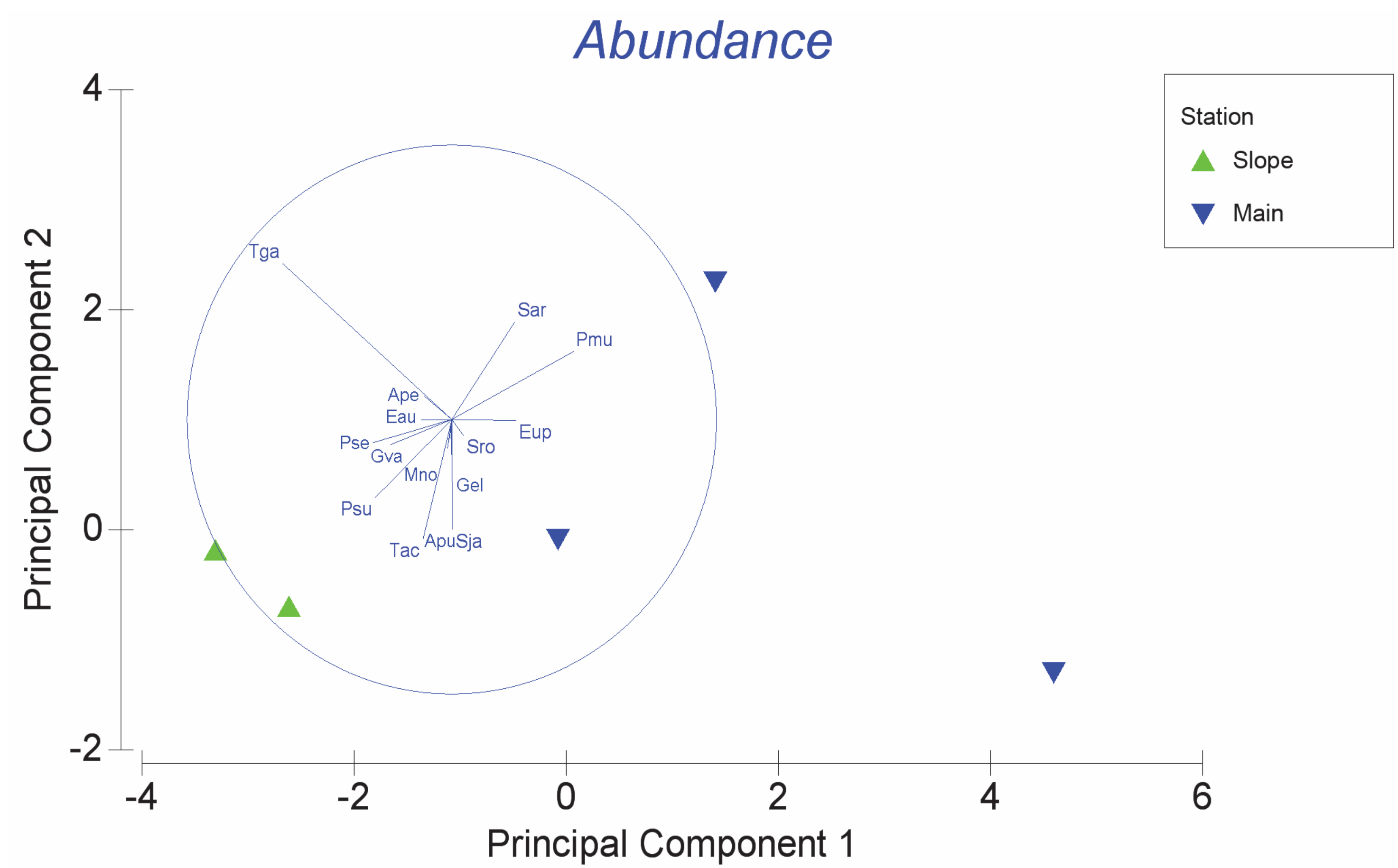

Figure 2.13. Comparison of Gully Main Station to adjacent Slope: principal component analysis of the matrix of estimated nominal stratum species abundances, results plotted in the plane of 1st and 2nd principal component, including species eigenvectors. Trawl set depth, time of day and year indicated. Only species accounting for >1% of total biomass in any one set included

Table 2.11 Comparison of Gully Main to adjacent Slope: results for principal component analysis of the matrix of estimated nominal stratum species biomasses and abundances. Total amount of variation explained by the first three components. Only species accounting for >1% of total biomass and abundance in any one set included

	Biomass		**Abundance**	
	% Variation	**Cumulative %**	**% Variation**	**Cumulative %**
PC1	49.6	49.6	72.7	72.7
PC2	34.0	83.6	13.2	85.8
PC3	14.1	97.6	7.7	93.6

Table 2.12 Comparison of Gully Main to adjacent Slope: species coefficients (eigenvaluess) from the principal component analysis of the matrix of species biomasses and Abundances. Only species accounting for >1% of total biomass and abundance in any one set included

Biomass		**Abundance**	
Species	**PC1**	**Species**	**PC1**
Gennadas elegans	0.005	*Gennadas elegans*	-0.107
Gennadas valens	-0.170	*Gennadas valens*	-0.231
Sergestes arcticus	0.126	*Sergestes arcticus*	0.238
Sergia robusta	0.005	*Sergia japonica*	0.004
Acanthephyra pelagica	-0.047	*Sergia robusta*	0.045
Acanthephyra purpurea	0.013	*Acanthephyra pelagica*	-0.107
Notostomus elegans	-0.067	*Acanthephyra purpurea*	-0.003
Parapasiphaea sulcatifrons	-0.533	*Parapasiphaea sulcatifrons*	-0.289
Pasiphaea multidentata	0.196	*Pasiphaea multidentata*	0.461
Meganyctiphanes norvegica	-0.023	*Eucopia australis*	-0.114
Thysanopoda acutifrons	-0.043	*Meganyctiphanes norvegica*	-0.016
Euphausiacea spp.	0.103	*Thysanopoda acutifrons*	-0.108
Megalanceola	0.337	Euphausiacea spp.	0.244
Phrosina	-0.460	*Phrosina*	-0.298
Themisto gaudichaudii	-0.536	*Themisto gaudichaudii*	-0.639

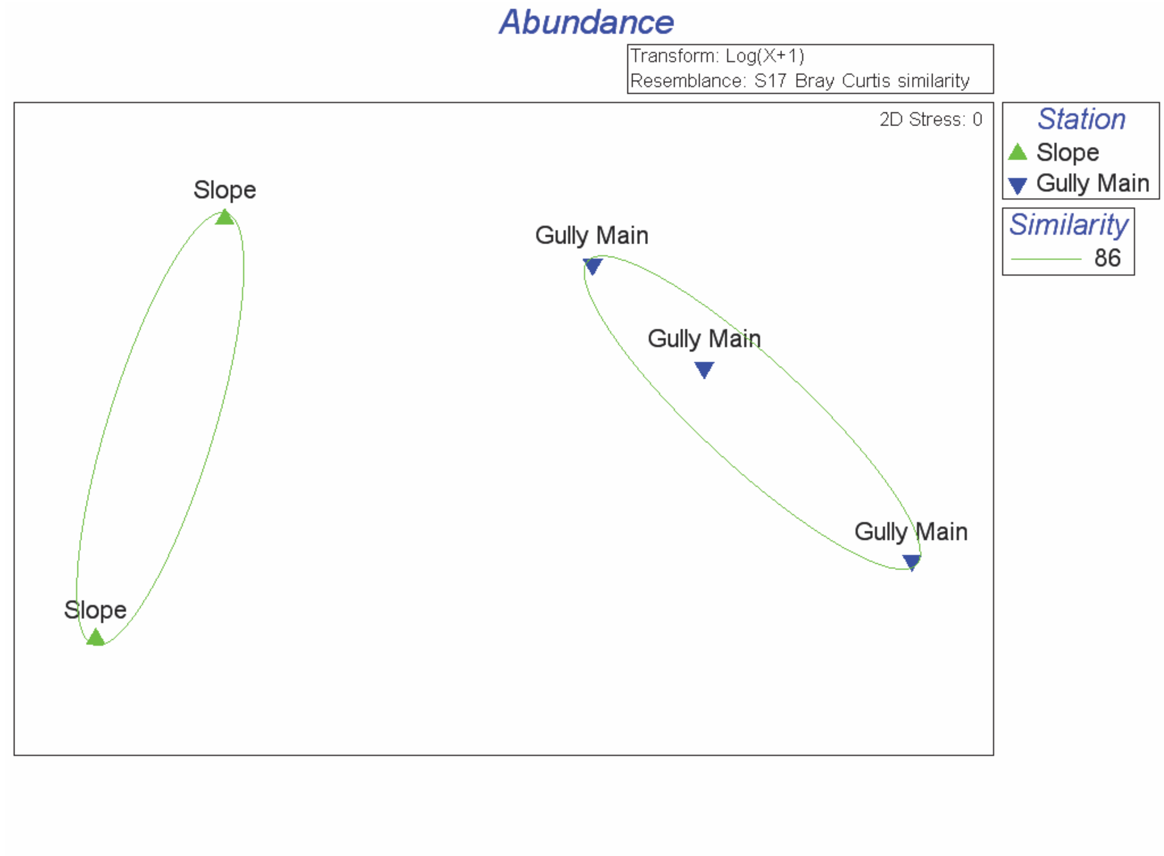

Figure 2.14. Comparison of Gully Main Station to the adjacent Slope: results of SIMPROF permutation tests on cluster analysis, imposed on MDS plots for biomass, significant clustering indicated by circles ($p<0.05$) (plot for abundance essentially identical)

temperate, pelagic and benthopelagic species, generally widespread in the North Atlantic, but more abundant at mid to higher latitudes: the decapods *S. arcticus* (Sund 1920, Fasham & Foxton 1979, Squires 1990), *P. multidentata* (Sivertsen & Holthuis 1956, Fasham & Foxton 1979, Squires 1990), *A. pelagica* (Chace 1940, Foxton 1972, Fasham & Foxton 1979), and *G. elegans* (Murray & Hjort 1912, Sund 1920, Fasham & Foxton 1979), the hyperiid amphipod *T. gaudichaudii* (Bowman 1960, Dunbar 1963, Vinogradov 1996), and the northern krill, *M. norvegica* (Eianarsson 1945, Mauchline 1971, Tarling et al. 2010).

Under the influence of the Labrador Current, at least one Arctic species occurred at Gully Main Station at the depths surveyed (Chapter 3). In close proximity to the Gulf Stream, this region is also one of transition from the central North Atlantic/Sargasso Sea, and there is a considerable complement of warmer temperate species (Chapter 3). Straddling another, more arbitrary boundary, the deepest trawl sets entered the bathypelagic zone below 1000m, and the distributions of many species present were estimated to occur deeper into the bathypelagic. The fauna from depths greater than 1250m remains essentially unknown, though replicated trawl samples have been collected to depths of 1750m at a deep station near the mouth of the canyon, and additional deep opportunistic sets were collected, but analyses are not yet complete. Sampling with the IYGPT was necessarily limited by proximity to the bottom and the need to avoid contact, therefore important aspects of near-bottom species and their spatial and temporal distribution are lacking.

Based on the relative catches of the more common species, the assemblage at the Gully Main Station most resembles the fauna of the north-eastern North Atlantic open ocean and continental slope (Hargreaves 1985a, b, 1999, and references with each species above). The distribution of most of the dominant species are known to extend into the North Sea and parts of the Norwegian Sea (Rice 1967, Mauchline 1971, Lagardere 1978), with what may be considered glacial relict populations for all in the deeper Mediterranean (Cartes et al. 1994, Abello and Valladares 1988). One of the main distinctions of the Gully assemblage is the overwhelming dominance of *M. norvegica* and *S. arcticus*. The northern krill, *M. norvegica*, was particularly abundant, as previously observed (Sameoto et al. 2002) and to be expected, as the Gully cuts deeply across a continental margin, preferred habitat for *M. norvegica* (Einarsson 1945, Tarling et al. 2010), in a region known to have large populations of the species (Einarsson 1945, Sameoto 1996, Simard & Lavoie 1999). To the south, including the central North Atlantic, Caribbean and into the Gulf of Mexico, species richness generally increases (Donaldson 1975, Gasca 2007) and species dominant in the Gully are replaced by others (Foxton 1970a, b).

Though species differ, the Gully fauna appears functionally similar to the fauna of the north-eastern Pacific, along the continental margin of Oregon. This region is known to contain great numbers of the large krill, *Euphausia pacifica* (Brodeur and Yamamura 2005), as well as a mesopelagic decapod fauna dominated by *Sergestes similis* (Krygier & Pearcy 1981, Nishida et al. 1988). Similar to *S. arcticus*, *S. similis* is a widespread subarctic transitional species, reportedly the most abundant oceanic pelagic shrimp in the North Pacific (Omori & Gluck 1979).

This is the first comprehensive survey of the larger pelagic Crustacea from a submarine canyon with a moderately large pelagic trawl fishing to bathypelagic depths.

Previous pelagic surveys in the Gully have concentrated on smaller zooplankton with smaller nets, shallower depths, or on a few species (Head and Harrison 1998, Gordon and Fenton 2002, Sameoto et al. 2002). Results based on those surveys revealed nothing unusually remarkable about the Gully fauna, at least in part prompting the present investigation. Studies elsewhere have similarly surveyed shallower depths (Bosely et al. 2004) or used smaller nets, traps or gear that better target zooplankton, with micronekton probably avoiding capture (Macquart-Moulin & Patriti 1996, Bouillon et al. 2000 and references therein). Genin (2004) summarized what is known about zooplankton and fish aggregations in submarine canyons: fish, shrimps and other micronekton, euphausiids and other zooplankton, including *M. norvegica*, have been reported abundant or aggregated in and along the walls or at the heads of canyons. The shallow oceanic migratory fauna in the Cap-Ferret Canyon along the Mediterranean coast of France was reportedly dominated by *T. gaudichaudii* (Macquart-Moulin & Patriti 1996), and surveys to depths of 264m in Astoria Canyon off Oregon and Washington state found squid, euphausiids, larger shrimps and mesopelagic fish particularly abundant along the canyon walls (Bosely et al. 2004). Large concentrations of *M. norvegica* were observed within canyons along the edge of Georges Bank at depths of several hundred meters (Greene et al. 1988, Youngbluth et al. 1989), and mesopelagic fish and euphausiids (*M. norvegica*) have been observed abundant in the Gully, with euphausiids concentrated at the head of the canyon (Gordon and Fenton 2002, Sameoto et al. 2002). Information on the pelagic fauna of submarine canyons also comes from surveys with bottom trawls (Cartes et al. 1994, Sabatini et al. 2007), indicating benthopelagic and in some cases nektobenthic habits (Cartes and Sabatini 1993).

Patterns of absolute and relative catch within estimated nominal depth strata for species changed notably with depth and between day and night. However, catch across years for abundant species was essentially non-variable, with very little change in observed biomass or abundance (Chapter 3, Appendix B). Only the catch of *M. norvegica* could be said to have changed significantly, with a dramatic decrease in catch from 2007 to 2008.

Principal Component Analysis of the covariance matrix of estimated nominal stratum species biomass and abundance revealed most variation in assemblage patterns could be explained by estimated nominal depth of species and observed diel changes (or lack thereof) within strata altering (or maintaining) species associations. This is not entirely unexpected, as similar results have been reported for both meso- and bathypelagic assemblages in the eastern North Atlantic and over the Mid Atlantic Ridge (Domanski. 1984, Sutton et al. 2008). Depth is more or less correlated with many factors in the water column, including pressure, temperature, food, light intensity, and others. At least some if not most of the diel changes in catch was due to the phenomenon of diel vertical migration (DVM). Though variably flexible in timing, proportion of the population involved, and vertical amplitude, DVM can be broadly described as a mechanism to avoid visual predation: individuals inhabit deeper, darker depths during the day, swimming up into more productive and food rich shallower depths at dusk to feed under cover of darkness at night. Diel vertical migration is cued by light, subject to strong influence by food availability and temperature, and modified by a number of other factors (Cushing 1951, Lampert 1989, Kaartvedt 2010). However, though DVM could account for most species observed diel changes in catch, other factors necessarily played a role, mainly active net avoidance at shallow depths during the day and change in behaviour or shoaling and swarming at night (Hovecamp 1989, Kaartvedt 2010). In addition, species may have different responses to the net, some possibly better "herded" by the net, swimming away from the mesh towards the centre of the net, while others readily pass through the mesh. The relative catchability of species can be expected to be different with the IYGPT trawl used, but no attempt was made to account for or accommodate these possible variations (Heino et al 2011).

Trawl sets fishing shallower than 250m, a nominal "epipelagic" stratum, were consistently separate from all deeper trawl sets, with scores more negative along PC1. Within the 0-250m stratum, daytime trawl sets always separated from those taken at night along PC2. Based on the established literature and the similar overall catch during day and night (Chapter 3), the diel change in catch for *S. arcticus* and *P. multidentata* was due to a pronounced DVM from below 250m at dusk. However, the total nighttime catches of *T. gaudichaudii*, *M. norvegica* and other small species of Euphausiacea were greater than catches during the day, dramatically so for *M. norvegica*, indicating some role for active net avoidance at depths shallower than 250m during the day. Shoaling or swarming could concentrate animals in the path of the trawl at night, but may also have the effect of just increasing the catch variance and not the mean in the long trawl sets used. The small increases in biomass or abundance of *A. pelagica*, *G. elegans* and other species at night in the 0-250m stratum could have resulted from either DMV or net contamination, with the few individuals recorded originating from previous sets fishing deeper. Such sporadic occurrences above 250m were also recorded during the day (Chapter 3). Most, but not all species, with negative eigenvalues for PC 2 showed evidence for diel change in catch, possibly DVM, while most species with positive values lacked such evidence and may be considered weak or non-migrators.

The nominal 250-750m stratum or upper mesopelagic also consistently separated from the deeper 750-1250m stratum or lower mesopelagic to bathypelagic sets along PC2. Within the 250-750m stratum, day sets separated from night along PC2, more apparent within biomass data, however there was no similar diel separation in sets from the deeper 750-1250m stratum. The relative increase in non- or weakly migrating species in the deep 750-1250m stratum, like *S. japonica* and *P. sulcatifrons*, explains the lack of diel differences in sets from the deepest stratum. In addition, night sets from the 250-750m strata were intermediate in position along PC2 between day sets in the same stratum and sets from the deeper 750-1250m stratum; at night diel migration removed migrating species like *S. arcticus* and *P. multidentata* from the 250-750m stratum, deserting the non- or weakly migrating species present, which have more affinity to the deepest stratum. When compared, the polarities of day and night set scores on PC2 in the 0-250m and 250-750m nominal strata were opposite; night sets at 0-250m were more similar to day sets at 250-750m, because they shared a bulk of the migrating fauna at opposite times of the day.

With the exception of *M. norvegica*, catch of the more common Crustacea at the Gully Main Station were quite consistent over the three year period (Chapter 3, Appendix B). However, there were minor effects of Year on variation within the assemblage, most notably the tendency for 2007 sets to separate from other years, within respective nominal strata and diel groupings. Two events in 2007 may have played a role: the larger than normal cold intermediate layer in 2007 and the use of a cod end aquarium in 2008 and 2009. *Meganyctiphanes norvegica* was identified as a species that may be systematically underestimated by employing the aquarium cod end (Kenchington 2009), and catches were greatest in 2007 without the aquarium and lowest in 2008 with the aquarium (Chapter 3). However, catch rebounded notably in 2009, albeit not to the levels observed in 2007, but still a variable result not consistent with a systematic gear bias. The other most dominant species, *S. arcticus*, also had catch minima in 2008, but both scored negative on the second PC of the matrix of biomasses, not in the direction of separation for the 2007 sets. In addition, *G. elegans*, *A. pelagica*, *P. multidentata* and *T. gaudichaudii* had catch maxima in 2008 (Chapter 3), suggesting something other than, or in addition to, an aquarium effect.

The large volume cold intermediate layer in 2007 may represent the most extreme event in the area in the past two decades (Kenchington personal communication). Several rare species were absent or less common in 2007 (Chapter 3), and the increase of at least one cold-water crustacean, the amphipod *Themisto libellula*, was most likely a result of advection via the large volume of cold water originating in the Labrador Current/Gulf of St. Lawrence outflow (Chapter 3). The extremely large catches of *M. norvegica* in 2007, another cold water species, may also have been the result of such a large, cold water advection event.

The large volume cold intermediate layer in 2007 did not appear to overly influence the more common species at the Gully Main Station, other than possibly *M. norvegica*. The cold intermediate layer in the nearby Gulf of St. Larence has been observed to affect the vertical distribution of macrozooplankton species (Harvey et al. 2009). Temperature has been demonstrated to partially explain broad geographic distributions of pelagic Crustacea (Foxton 1972), influence species distributions at smaller scales across ocean fronts (Fasham & Foxton 1979) and affect or structure vertical migrations (Foxton 1972, Flock & Hopkins 1992, Kaartvedt 2010). But in some surveys, even dramatic seasonal or regional variations in the presence or depth of temperature clines did not affect species' distributions (Donaldson 1975, Hopkins et al. 1989). The diel range in temperature experienced by species as they migrate may be similar to or in excess of other variations in temperature. Despite the extremity of the event, lack of a big effect by the large volume cold intermediate layer in 2007 was probably mostly due to its relatively shallow depth, a maximum of only 150m, where a minimum of species occur (Chapter 3). And though many more species and individuals undoubtedly migrated into depths shallower than 250m at night, possibly bringing them into the cold intermediate layer, the distributions of vertically migrating species were relatively unaffected. It has been observed that the distribution of pelagic Decapoda can be related to the water mass occupied during the day, not shallow depths at night, even if water masses differ (Fasham & Foxton 1979). Additional data on the physical oceanography and the broader horizontal and vertical distribution of species throughout the Gully submarine canyon from additional sampling stations may allow better interpretation in the near future.

Though not explaining much variation, species eigenvalues for PC3 generally reflected an effect of Year. Species with catch minima in 2008 (Chapter 3), *M. norvegica* and *S. arcticus*, had the same polarities, while species with catch maxima in 2008, *G. elegans*, *A. pelagica*, *P. multidentata* and *T. gaudichaudii* had the opposite. Catch minima for the two dominant species, *M. norvegica* and *S. arcticus*, not surprisingly correspond to the lowest annual contribution of Crustacea to the total catch biomass at Gully Main: just 27% in 2008, compared to over 40% in other years. Though a relative and not absolute measure, it is indicative of a considerable change in the fauna at the Gully Main Station, due mainly to a reduced catch of the most abundant species, *M. norvegica* and to a lesser extent *S. arcticus*. The emerging portrait of the Gully ecosystem will expand with the inclusion of several additional sampling stations from other locations within the Gully submarine canyon (Kenchington et al. 2009), including the contribution of other taxonomic groups, chiefly the fish and cephalopods.

2.4.2. Comparison of Gully Main Station and Slope Station

Although elements of faunal overlap were significant, with essentially the same species at each station, and sampling effort was small, restricted to five sets from one trawl depth at one time of day, the larger pelagic crustacean fauna at the Gully Main Station was qualitatively and quantitatively different from the Slope Station over an adjacent area of continental slope. Catch biomass, abundance and species richness were all greater inside the canyon. Species dominance structure differed dramatically, particularly the relative importance of *S. arcticus* and *P. multidentata* at the Gully Main Station compared to *M. norvegica* and *T. gaudichaudii* at the Slope Station. Apart from total biomass and abundance of animals, the weight of an average individual *S. arcticus*, but not length, was greater at the Gully Main Station based on gross calculations.

Meganyctiphanes norvegica has been observed to be larger in some fjords compared to populations outside the fjord, possibly due to increased food resources (Cuzin-Roudy et al. 2004). Diets of *S. arcticus* and *M. norvegica* are similar, the two being largely zooplanktivores that also consume various kinds of detritus, and it has been pointed out that many aspects of the life history of euphausiids and sergestids are similar (Omori 1974). However, unlike *M. norvegica*, *S. arcticus* does not feed on phytoplankton and *S. arcticus* is able to consume zooplankton larger than copepods. If the larger average individual weight of *S. arcticus* was due to increased food resources, it was most likely due to the availability of zooplankters larger than copepods, whether that be in terms of total biomass, increased flux of zooplankton, increased concentration, or some other mechanism.

Distribution patterns for both *M. norvegica* and *Themisto* have been reported to be current driven in the Gulf of St. Lawrence (Cotte & Simard 2005, Descroix et al. 2005), but currents that could concentrate *S. arcticus* and *P. multidentata* in the Gully could surely act similarly on the smaller *M. norvegica* and *T. gaudichaudii*. However, adult *S. arcticus* and *P. multidentata* are larger than *M. norvegica* and *T. gaudichaudii*, and would be less susceptible to the westward flowing Labrador Current over the slope in this area, and may be able to better maintain position within the Gully. Although the top swimming speed for *M. norvegica* is in the range of 7-8 cm/s (Tarling et al. 1998, 1999, Kaartvedt 2010), it has been only been observed capable of maintaining local populations by swimming against currents of 3-4 cm/s (without increasing standard metabolism).

In bottom trawls on the slope to the east and west of the Gully, catches of *P. multidentata* were unspectacular compared to present observations, and the species was restricted to bottom depths shallower than just 840m (Markle et al. 1988), but comparable data are not available.

I do not necessarily suggest that *S. arcticus* and *P. multidentata* are the reasons the Gully may be more productive at greater depths than surrounding waters, but it is at least indicative of processes that may be occurring, in particular the trophic level at which additional energy may be entering the Gully ecosystem, that is at a size greater than copepods.

The Gully also had a slightly more diverse fauna, derived mainly from deeper meso- and bathypelagic species, as highlighted by the eight benthesicymid species compared to four at the Slope Station. Though ecologically insignificant themselves, the rare benthesicymids represent the existence of an atypical influence of deep water within the canyon, namely the warm slope or North Atlantic Central water filling the canyon. While most studies are preoccupied with flow of energy down canyon from more productive shallow (continental shelf) depths to the deep sea (Harding 1998, Company et al. 2008, De Leo et al. 2010), there are clear indications that deep-sea species may also play a role. The pelagic ecosystem is highly integrated from surface waters into at least the bathypelagic, with large amounts of biomass moving quickly across large depth ranges, including interactions with the sea floor. As in canyons, the pelagic paradigm is for energy to flow from the shallow (epipelagic) to the deep. But, if there was significant upward movement of energy from the deep sea into the canyon, production that once flowed down could return from where it was captured at greater depth, possibly by the movement of animals up into the canyon (Aguzzi et al. 2007, Company et al. 2008). It has also been suggested that significant energy may move from the sea floor up into the pelagic ecosystem (Gartner et al. 2008). Additional sampling stations from other locations within the Gully, including deeper trawls, may allow some insight into this, but notably absent from the Gully/Slope comparison are depths greater than 750m and the species more characteristic of deeper water. Non-migrating Decapoda and lophogastrids were not abundant in the comparison, but are common at greater depths at the Gully Main Station. Information is also lacking on suprabenthic species such as Mysida, and possibly significant near bottom (within 100m) concentrations of any number of organisms.

Principal component analysis of the matrix of species biomasses and abundances indicated 40-70% of variability within the species assemblage could be attributable to one factor: inside the canyon vs. outside the canyon. Biomass and abundance of species with positive eigenvalues scores were more indicative of inside the canyon (including *S. arcticus* and *P. multidentata*), those with negative values more indicative of the slope (including *M. norvegica* and *T. gaudichaudii*). Though not reportedly associated with a canyon, *T. gaudichaudii* was observed to dominate the shallow oceanic migratory fauna over a canyon in the Mediterranean (Macquart-Moulin and Patriti 1996). The same is surely the case over the Gully. Smaller species of Euphausiacea, the size range of zooplankton available as food for *S. arcticus* but not *M. norvegica*, had greater biomass and abundance inside the canyon, possibly contributing to the larger average individual weight of *S. arcticus* at the Gully Main Station. The very large hyperiid amphipod, *M. stephenseni*, is not only extremely rare in the world's oceans (Chapter 3, Zeidler 2009), but was identified as a canyon species. Parasitic on jellyfish, it is possibly indicative of another functional difference in the Gully ecosystem: an unusually large biomass or abundance of jellyfish and an increased availability of "pelagic substrate". Though jellyfish are typically thought of as predators on small animals, juveniles of some fish species have been observed actively seeking refuge from predation among tentacles beneath jellyfish umbrellas, a behaviour which has been shown to enhance survival (Lynam & Brierly 2007). Such commensal relationships have been reported for pelagic and abyssal fish species, but they are rarely studied. In addition to refugia, the jellyfish also function as a food source with juvenile fish stealing prey from the tentacles and feeding on crustaceans parasitic on the jellyfish (Lynam & Brierly 2007). Thus, the abundance, size, specific compliment, or some other jellyfish factor may influence the mortality of some deep-sea species, making the Gully a preferred area to rear young.

Although faunas differed, so did oceanographic conditions at the Gully Main Station compared to the Slope Station, with more cold slope water observed over the Gully but warm slope water at the Slope Station. However, this difference in water masses may have only been responsible for some slight differences. The presence of the warm-water, circumtropical *Platyscelus ovoides* at the Slope Station may have been due to the overlying warm slope water, but the four additional benthesicymids at the Gully Main Station also indicated that although colder slope water lay over the Gully Main Station, the fauna still had a broad representation of warm temperate species. All of the abundant species present at both sites were the same cold temperate species observed with little variation at the Gully Main Station over the three year survey, in spite of environmental variation, including both cold (2007) and warm water (2009) events. The one species that did vary notably at the Gully Main Station, *M. norvegica*, had its greatest catches associated with colder water in 2007, and yet it was the dominant species in the warmer water at the Slope Station. Available information indicate that differences in the occurrence of less common species and the absolute and relative biomass and abundance of more common species at the Gully Main Station and the Slope Station did not vary in a manner consistent with an effect of colder water over the Gully vs. warmer water at the Slope Station.

2.4.3. Summary

1. The pelagic Crustacea constitute a significant but variable component of the fauna sampled at the Gully Main Station.

2. At depths above 1250m, the Gully Main assemblage of larger pelagic Crustacea is dominated by northern species, widespread in the North Atlantic but more common or abundant at mid to higher latitudes in cooler temperate waters.

3. Though not yet fully analyzed and detailed, the physical environment at shallower depths varies annually, due mainly to the volume of cold intermediate water sitting over the canyon and the position of the cold slope water / warm slope water boundary at the head of the Gully, but most of the canyon, including all greater depths, is unchanging, filled with warm slope water and North Atlantic Central Water.

4. Species composition and the biomass and abundance of species vary considerably with depth sampled and between night and day.

5. The species assemblage at the Gully Main Station is structured primarily by depth occupied by species and considerable diel changes in this structure, with only minor effects at the larger temporal scale of interannual variation.

6. The pelagic fauna at the Gully Main Station appeared to differ from the adjacent continental slope, with a different assemblage of species and generally greater biomass and abundance of animals in the canyon, particularly the decapod *Sergestes arcticus*. These differences appeared canyon related

Chapter 3. The Larger Pelagic Crustacea of the Gully Submarine Canyon: Annotated Species List with Discussion.

3.1. Introduction

The oceanic pelagial is the largest global habitat, accounting for approximately 99% of the space inhabited by life (Herring 2002). It may be home to the largest assemblages of animals on the planet, with the greatest numbers of individuals and largest total biomass (Robison 2004). Knowledge of the species that inhabit the deep pelagial has been largely based on towed nets, which have not adequately sampled or quantified significant components of the fauna: gelatinous animals are not entirely retained, megafauna are suspected to evade, the benthopelagic fauna are varyingly inaccessible, and sampling effort generally decreases with increasing depth (Robson 2004, Burghart et al. 2007). Yet a great deal has been discovered about a large and central fraction of the fauna with largely net-based research: the micronekton and zooplankton of the epipelagic, mesopelagic and at least upper bathypelagic (Hopkins et al. 1994, Sutton et al. 2008, Deforest & Drazen 2009).

Squires' (1990) treatise of the Decapoda was at the time a comprehensive review of our knowledge on the taxonomy and distributions of one group of larger Crustacea in Atlantic Canada, including some pelagic and benthopelagic species, but essentially only those opportunistically collected with bottom trawls (also with unavoidably more trawls from relatively shallow depths). Reports of deep-sea species are typically sparse from this opportunistic compilation with varying gears and sampling strategies (Wenner & Boesch 1979, Haedrich et al. 1980, Pohle 1992), with species sometimes reported or appearing uncommon (Markle et al. 1988). Attempts have been made to fill the void (Pohle 1988) but efforts are similarly based on a limited amount of material available. The situation is comparable with other groups of large pelagic Crustacea off eastern Canada, with information lacking on deep-sea mysids and lophogastrids, hyperiid and gammarid amphipods and larger, deeper-dwelling euphausiids.

The taxonomy and biogeography of larger pelagic Crustacea in the North Atlantic is generally well known, but most of this knowledge comes from studies to the east and south (Crosnier & Forest 1973, Hargreaves 1985a, b, Gasca 2007), from broad or distant taxonomic reviews (Mauchline & Murano 1977, Chace 1986, Zeidler 2009), or still valuable but antiquated surveys (Sund 1920, Tattersall & Tattersall 1951, Sivertsen & Holthuis 1956). Recent work off the north-eastern United States (Moore et al. 2003, 2004) resulted in part from recognition of this lack of knowledge. The mesopelagic fish fauna bordering Atlantic Canada has been well studied (Themelis 1996), and the cephalopod fauna documented (Vecchione & Pohle 2002). Based on these results and knowledge of the faunas to the east and south, a potentially broad taxonomic range of crustacean species remains unreported from Canadian waters. In addition, regional ecological conditions and species have changed in recent decades at shallower depths over the continental shelves in Atlantic Canada, including aspects of trophic structure and energy flow and the abundance and biomass of species (Zwanenburg 2002, Bundy 2005). In the nearby Gulf of St. Lawrence, researchers have reported the establishment of one new species of large pelagic crustacean, the hyperiid amphipod *Themisto libellula* (Marion et al. 2008).

Submarine canyons are typically common along continental margins (Hickey 1995, Levin and Gooday 2003), by nature often the closest areas of deep sea to land based institutes of research. Submarine canyons reportedly support enhanced concentrations of some pelagic species, including mesopelagic crustaceans (Bosely et al. 2004, Genin 2004). Canyons can be areas of greatly elevated mixing and act as upwelling and downwelling conduits between the shelf and deep sea (Allen & de Madron 2009) which may have significant effects on deep-sea populations (Company et al. 2008). One of the largest submarine canyons along the continental margin of North America is the Gully (Figure 1), 110km long with areas reaching over 2000m depth (Fenton 1998, Rutherford & Breeze 2002).

As part of a larger program with the overall goal of better understanding the Gully ecosystem, both as an aid to management and a study of deep-sea and submarine canyon ecosystems in general (Kenchington et al. 2009, 2011), the epi-, meso-, and bathypelagic crustacean micronekton and larger macrozooplankton of the Gully are described for the first time. The objectives were to identify the full range of larger crustacean species present, document gross patterns of species vertical distribution in the water column, at least in terms of diel variation and functionally distinct depth strata, and examine interannual variations in species biomass and abundance against a backdrop of environmental variation.

3.2 Methods

3.2.1. Overall Program

The first deep pelagic trawl surveys of the Gully submarine canyon were run out of the Bedford Institute of Oceanography by the Canadian Department of Fisheries and Oceans. Biological data and other information for the present investigation are a subset of those collected during three comprehensive faunal surveys carried out during the late summer over a three-year period from 2007-2009 (Table 3.1 and 3.2). Most methodologies and other procedures were summarized in Chapter 2, and extensive details of the methodology and preliminary results are reported elsewhere (Kenchington et al. 2009, 2011). The present investigation deals with the fauna at one sampling station, the Gully Main Station.

3.2.2 Sample Processing at Sea

Trawl samples were processed as completely as possible at sea. Following a trawl, all net contents, including fouled organisms picked from the net, were transported to the wet laboratory below and sorted initially into five groups: fish, cephalopods, crustaceans, gelatinous organisms, and “other”. All Crustacea were then sorted and identified to the lowest taxonomic level possible with the aid of a dissection microscope (magnification 6-50X). Wet weights were recoreded for all species using motion compensating scales (total weight per species), and all data entered into an electronic database. Counts were recorded (total number per species) if time allowed. Newly encountered taxa and specimens in particularly good condition were photographed if time allowed. Taxa of particular taxonomic interest, not identified to species, rare, in pristine condition, particularly soft or fragile were fixed in a 4% solution of buffered formaldehyde. Tissue samples for genetic analysis were collected from a selection of species, if time allowed, and preserved in ethanol. The remainder of species were bagged and frozen, all for further processing in laboratory ashore.

In those sets with a particularly abundant catch of the decapod *Sergestes arcticus*, the large krill *Meganyctiphanes norvegica* and the hyperiid amphipod *Themisto gaudichaudii*, all other species were first removed and sub-samples of the abundant species were collected. In 2007, the three species were first separated, a total weight for

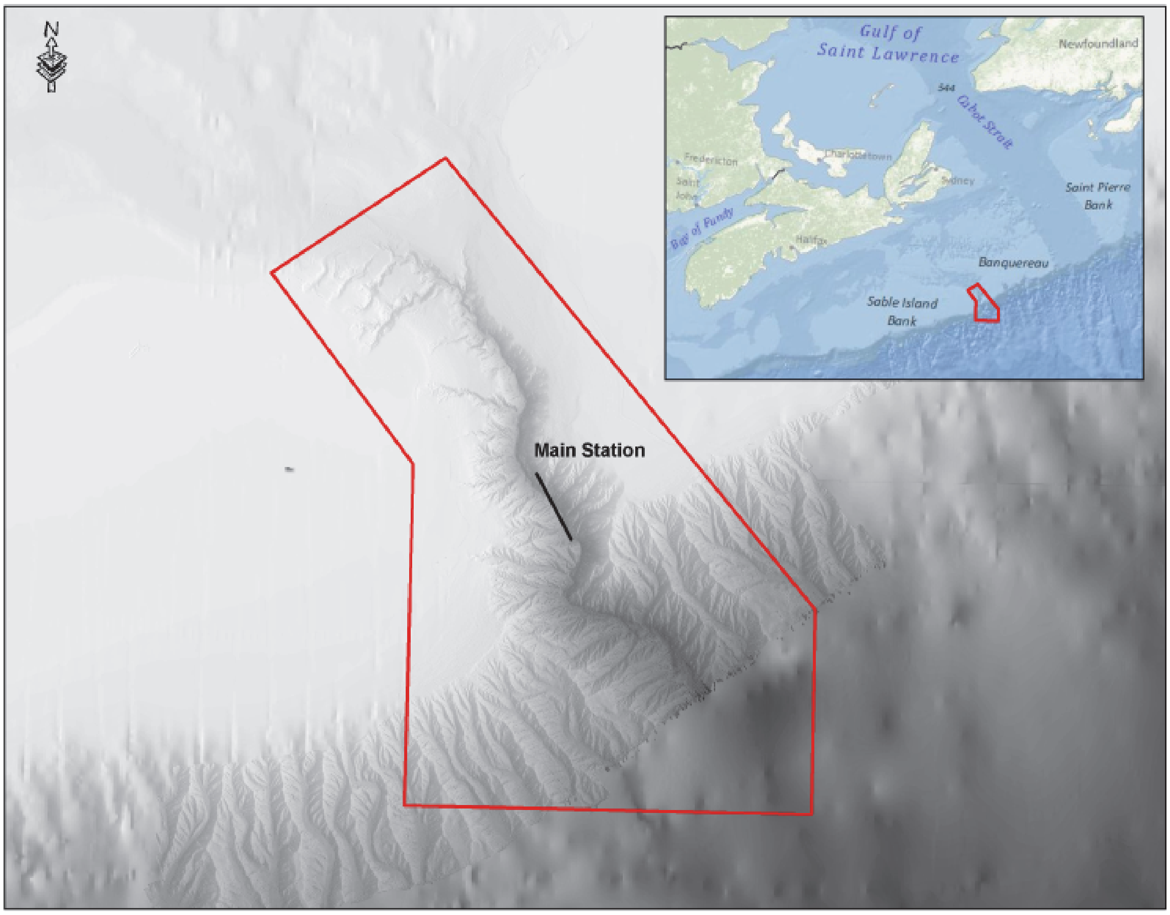

Figure 3.1. A map showing the location of the Gully submarine canyon and the location of fixed trawl stations.

Table 3.1 Survey dates based on Kenchington et al. (2009, 2011)

Year	Mission Dates
2007	September 07 – September 19
2008	August 30 – September 06
2009	August 13 – August 21

Table 3.2 IYGPT trawl sets at the Gully Main Stations used in present investigation based on Kenchington et al. 2009 (2011)

Year	Trawl Station	Time of Day	Depth	Set Numbers*
2007	Main	Day	0-250m	24, 31, 36
			0-750m	21, 23, 30
			0-1250m	22, 29, 35
			0-1500m	80
		Night	0-250m	19, 41, 43
			0-750m	27, 33, 42
			0-1250m	26, 28, 34
2008	Main	Day	0-250m	22
			0-750m	15, 39
			0-1250m	14, 53
		Night	0-250m	21, 38
			0-750m	19, 36
			0-1250m	20, 37
2009	Main	Day	0-250m	34
			0-750m	31, 35, 40
			0-1250m	46
		Night	0-250m	17, 25
			0-750m	18, 27
			0-1250m	19, 39

*Set numbers are allocated sequentially with each survey each was recorded, then subsamples were collected: an approximately 750ml subsample for *S. arcticus*, 375ml *M. norvegica* and 200ml for *Themisto*. Subsamples were fixed in a 4% solution of buffered formaldehyde for later sorting, weighing, and counting in laboratory ashore. Laboratory weights were corrected to better reflect weights collected at sea (see next section). The subsampling procedure was shortened in 2008 and 2009, the total weight of a menagerie of the three species was recorded, and an approximate 750ml subsample collected and fixed.

3.2.3. Sample Processing in Laboratory Ashore

In laboratory ashore, taxa were variously identified to species with the aid of a dissection microscope (magnification 6-50X), weighed, counted (total per species per set), then preserved in 70% ethanol or re-frozen. Where necessary, laboratory wet weights were used to divide species-amalgamated wet weights recorded at sea: the proportion of at sea species-amalgamated wet weight assigned to each species was equal to its proportion of the total laboratory (fixed or frozen) wet weight. Additional photographs for the purposes of identification and documentation were collected. All specimens are currently catalogued and stored at the Bedford Institute of Oceanography, Dartmouth, Nova Scotia.

3.2.4. Biological Data

Unadjusted catch data for all species from all sets the Gully Main Station are presented and arranged taxonomically. Epipelagic adjusted catch data (see Chapter 2, Appendix C) from sets fishing 0-250m, 0-750m and 0-1250m, are used to generally describe species' vertical distributions, day and night, and annual variations at the Gully Main Station. Data for less common species are considered valuable, as sparse catch data may still suffice to indicate some features of species' ecology (Foxton 1970a, b). Though well documented in the literature for many species, evidence for diel vertical migration will be incorporated, as its presence or absence and possible variations from published reports may be pertinent to the results. Following this, estimated nominal stratum catch data (see Chapter 2, Appendix C) are typically summarized for comparison with patterns observed in unadjusted catch data. Catches from estimated nominal strata were calculated by subtracting estimated average shallow catches from deeper sets to estimate actual catch within deeper nominal depth strata. Data from the one deep exploratory set to 1500m are incorporated when information indicates presence of species below 1250m.

Species' known geographical distributions are restated in brief from the scientific literature, with new or rare occurrences indicated for the general area of Atlantic Canada and Canada's Exclusive Economic Zone. Reported diel vertical distributions are compiled and reviewed for comparison with the results at the Gully Main Station, including depths at which species may be concentrated in the water column. Most species synonymies and some generic combinations are listed, and key reviews referenced, most useful as an introduction to the sometimes complex taxonomic histories of the various species. Significant or interesting aspects of species' taxonomy are also remarked upon. The taxonomic authority used was the World Registry of Marine Species (WoRMS).

3.3. Results

3.3.1. General Description of the Gully Main Fauna

The Crustacea comprise a major but variable part of the pelagic fauna sampled at the Gully Main Station in late summer, accounting for approximately 50%, 27%, and 43% of the total catch in 2007, 2008, and 2009, respectively (T. Kenchington personal communication). At least 69 species (plus one variant) from eight orders of Crustacea, including four large (meroplanktonic) larval forms, were identified from the 41 Gully Main Station fishing sets (Table 3.3 and 3.4). No species was unique to the one deep exploratory 1500m set, and though results are included, this sampling effort was not sufficient to describe the fauna from depths below 1250m. A large proportion of the total catch of smaller species of euphausiids (not *M. norvegica* or *Thysanopoda acutifrons*) could not be confidently assigned to species due to physical state (damage) of specimens, and were grouped together as Euphausiacea spp. The northern krill, *M. norvegica*, and the decapod *Sergestes arcticus* dominated overall catch (Table 3.3).

The Decapoda were the most speciose group, with 32 species and three meroplanktonic larval forms, followed by the Amphipoda with at least 18 species but typically very low abundances (Table 3.3). Overall species richness based on estimated nominal depth stratum catch during both day and night was quite consistent throughout most of the water column, with maxima occurring across the deeper two nominal depth strata 250-750m and 750-1250m, each with 46 or 47 of the 69 taxa recorded (Table 3.5). Richness only showed notable diel change above 250m, with 14 species by day vs. 25 species at night. Total number of species increased with depth to a maximum of 58 species observed in the 750-1250m stratum. The vertical distributions of the most abundant species are summarized Appendix A.

The total numbers of species recorded at the Gully Main Station increased over the three year period, from 47 in 2007 to 48 in 2008 and 54 in 2009, with fewest species present at the cold extreme in 2007 and most species at the warm extreme in 2009. The annual variations of the most abundant species are summarized Appendix B.

Table 3.3 (in part) Pelagic Crustacea collected at the Gully Main Station 2007 - 2009: Eucarida. Raw (unadjusted catch data). New Canadian records in red, Atlantic Canadian in Blue

Order	Suborder	Family	Species or Lowest Taxon	Wet Weight (g)	Count
Decapoda	Dendrobranchiata	Benthesicymidae	*Bentheogennema intermedia*	7	21
			Altelatipes falkenhaugae	46	14
			Gennadas bouvieri	4	10
			Gennadas capensis	16	30
			Gennadas elegans	1,980	3,699
			Gennadas scutatus	<1	2
			Gennadas talismani	1	2
			Gennadas tinayeri	4	19
			Gennadas valens	80	119
		Solenoceridae	*Hymenopenaeus laevis*	6	5
		Sergestidae	*Sergestes arcticus*	57,651*	77,125*
			Sergestes henseni	<1	1
			Sergia grandis	6	4
			Sergia japonica	601	1085
			Sergia robusta	333	285
			Sergia tenuiremis	4	3
	Pleocyemata	Oplophoridae	*Acanthephyra eximia*	108	4
			Acanthephyra pelagica	6,302	2005
			Acanthephyra pelagica var.	5	1
			Acanthephyra purpurea	451	276
			Ephyrina bifida	1	1
			Hymenodora gracilis	8	29
			Meningodora miccyla	1	5
			Meningodora mollis	11	7
			Meningodora vesca	34	32
			Notostomus elegans	73	5
			Notostomus robustus	104	23
			Oplophorus spinosus	1	2
			Systellaspis debilis	1	1
		Pasiphaeidae	*Eupasiphaea serrata*	5	1
			Parapasiphaea sulcatifrons	716	529
			Pasiphaea multidentata	12,356	4269
			Pasiphaea tarda	111	7
		Palinuridae/ Scyllaridae	phyllosoma larvae+	2.21	13
		Galatheidae	Galatheidae juvenile	7.3	8
			Brachyura juvenile	0.46	2

Table 3.3 (continued) Pelagic Crustacea collected at the Gully Main Station 2007 - 2009: Eucarida. Raw (unadjusted catch data). New species records for Canada in red, new records for Atlantic Canada in Blue

Order	Suborder	Family	Species or Lowest Taxon	Wet Weight (g)	Count
Euphausiacea		Bentheuphausiidae	*Bentheuphaisia amblyops*	0.15	1
		Euphausiidae	*Meganyctiphanes norvegica*	108,103*	436,802*
			Thysanopoda acutifrons	260	352
			Unidentified Euphausiacea+	808*	9,618*

* total biomass and abundance estimated

+ more than one species present

Table 3.4 Pelagic Crustacea collected at the Gully Main Station 2007-2009: Peracarida, Hoplocarida & Ostracoda. Raw (unadjusted) catch data. New species records for Canada in red, new records for Atlantic Canada in Blue

Order	Suborder	Family	Species	Wet Weight (g)	Count
Lophogastrida		Eucopiidae	*Eucopia australis*	228	778
			Eucopia sculpticauda	81	112
		Lophogastridae	*Gnathophausia zoea*	328	200
			Gnathophausia gigas	389	246
Mysida		Mysidae	*Boreomysis arctica*	3	24
			Boreomysis semicoeca	1	22
Amphipoda	Gammaridea	Cyphocarididae	*Cyphocaris richardi*	<1	1
		Lysianassidae	*Eurythenes obesus*	17	34
			Paracllisoma sp.	2	3
		Stegocephalidae	*Parandania boecki*	11	43
	Hyperiidea	Cystisomatidae	*Cystisoma* spp.	20	8
		Hyperiidae	*Hyperia galba*	12	48
			Hyperia medusarum	1	3
			Hyperia spinigera	<1	1
			Pegohyperia princeps	<1	1
			Themisto gaudichaudii	5,102*	40,817*
			Themisto libellula	28*	152*
		Phronimidae	*Phronima sedentaria*	8	22
		Phrosinidae	*Phrosina semilunata*	3	6
		Platyscelidae	*Platyscelus ovoides*	1	8
		Lanceolidae	*Lanceola* spp.[+]	18	37
			Megalanceola stephenseni	151	71
		Scinidae	*Scina* spp.	<1	1
Isopoda		Anuropidae	*Anuropus panteni*	<1	1
		Idoteidae	*Idotea metallica*	4	6
Stomatopoda		Squillidae	antizoea larvae	1	5
Myodocopida		Cyprdinidae	*Gigantocypris muelleri*	11	17

* total biomass and abundance estimated
[+] more than one species present

Table 3.5 Crustacean species richness in estimated nominal depth strata by day and night. Presence of species only inferred by estimated nominal stratum catch data

	Depth Strata				
	0-250 m	**250-750 m**	**750-1250 m**	**1250-1500 m**	**Totals**
Day	14	46	47	25	60
Night	25	47	47		61
Totals	27	51	58		

3.3.2. The Species

Crustacea

Decapoda: Dendrobranchiata: Penaeoidea

Benthesicymidae

Altelatipes falkenhaugae Crosnier & Vereshchaka, 2008

WoRMS AphiaID: 514089

Identification: Crosnier & Vereshchaka, 2008, p. 400, fig. 2, 3, 4, 5, 6a-c, 7a-c.

Reported geographical and depth distribution: The first Canadian records and just the second worldwide, only recently described from the North Atlantic from over the Mid Atlantic Ridge distributed down to at least 2300m (Crosnier & Vereshchaka 2008). The closely related genus, *Benthesicymus*, is generally restricted below 600m, possibly extending to depths exceeding 5000m (Lagardere 1978, Hargreaves 1985b, Tiefenbacher 2001).

Catch at Gully Main Station: A total of 15 specimens collected, absent from sets fishing above 250m, with most records (10) from deep sets to 1250m. Estimated stratum catch indicated a population concentrated somewhere between 750-1250m by day, broadening to include depths above 750m at night, with a total range extending into the bathypelagic below 1250m. Present in all three years, with most collections (8) in 2008.

Figure 3.2. *Altelatipes falkenhaugae*

Bentheogennema intermedia (Bate, 1888)

WoRMS AphiaID 107086

Identification: Burkenroad, 1936, p. 56, fig. 50; Tirimizi, 1960, p. 338, fig. 36-38; Crosnier, 1978, p. 30, fig. 13a-b, 14a-c; Lagardere, 1978, p. 9, fig. 7.

Synonyms and other generic combinations: *Gennadas intermedius* Bate, 1888; *Gennadas alicei* Bouvier, 1906; reviewed by Crosnier (1978).

Reported geographical and depth distribution: First Canadian records, but reported from the eastern North Atlantic (Lagardere 1978) and to the south, off Bermuda, Bahamas, and Gulf of Mexico (Burkenroad 1936, Kensley 1981), also from the South Atlantic and Indo-Pacific, at a minimum depth of 500m to a possible maximum of 4000m (Crosnier 1978, Hargreaves 1985b, Hendryx & Estrada-Navarrete 1989).

Catch at Gully Main Station: A total of 13 specimens collected, all deep, absent from sets above 750m. The single specimen from the one exploratory set to 1500m was large relative to the average size of specimens collected above 1250m, based on total biomass divided by abundance. Estimated stratum catch indicated a distribution restricted somewhere below 750m, extending into the bathypelagic deeper than 1250m. Present during all three years, but rare at the depths surveyed, a majority of records (9) from 2009.

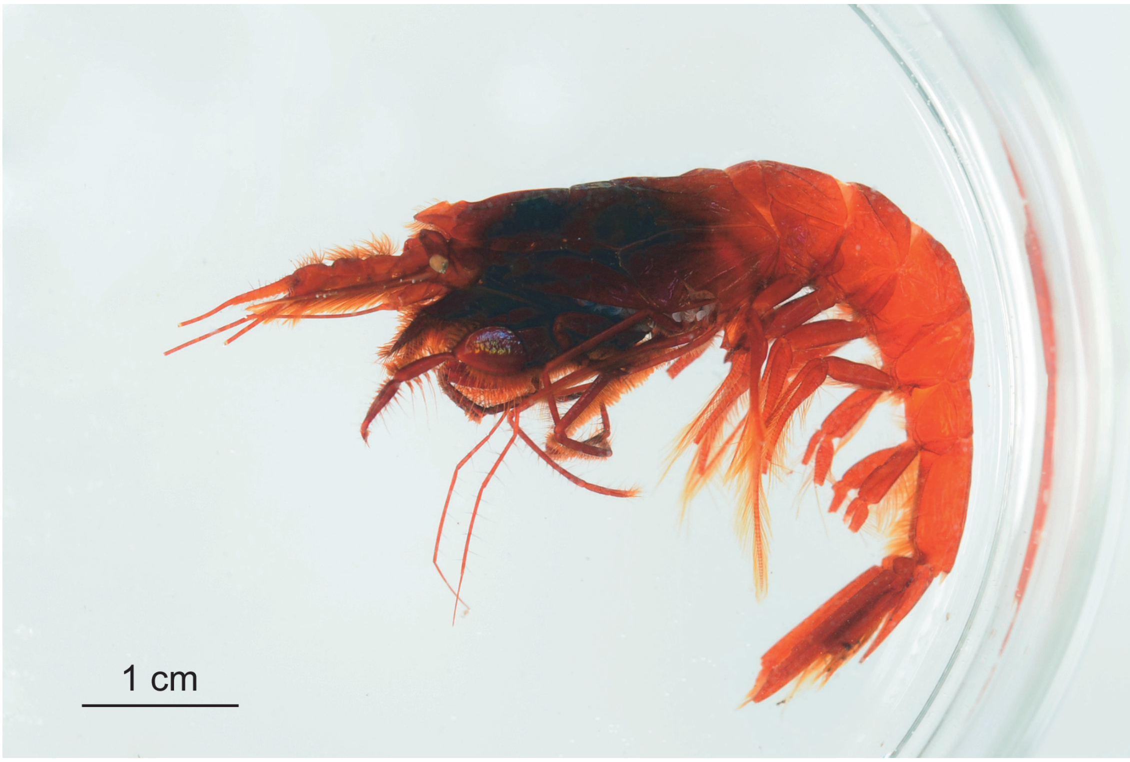

Figure 3.3. *Bentheogennema intermedia*

Gennadas bouvieri Kemp, 1909

WoRMS AphiaID: 240798

Identification: Tirmizi, 1960, p. 360, fig. 70-74; Roberts & Pequegnat, 1970, p. 36, fig. 3-2bc; Kensley, 1971, p. 273, fig. 1; Crosnier, 1978, p. 34, fig. 15a, 18a-b.

Synonyms and other generic combinations: *Amalopenaeus bouvieri* Balss, 1927; reviewed by Crosnier (1978).

Reported geographical and depth distribution: Northern range extension and the first Canadian records, reported from the eastern North Atlantic (Fasham & Foxton 1979) and to the south, off the north eastern U.S., Bermuda, Caribbean and Gulf of Mexico (Burkenroad 1936, Roberts and Pequegnat 1970, Kensley 1971), in general more common at lower latitudes in the North Atlantic (Fasham & Foxton 1979); also reported from the South Atlantic and Indo-Pacific (Crosnier 1978, Kensley 1981, Kensley et al. 1987). A weak vertical migrator, at depths of 250-950m by day, 250-800m at night (Aizawa 1974, Heffernan and Hopkins 1981, Hopkins et al. 1994) with a total depth range extending into the bathypelagic, possibly to depths of 3400-5000m (Kensley 1971, Gore 1985, Burghardt et al. 2007).

Catch at Gully Main Station: A total of 10 specimens collected, most records (7) from sets fishing to 750m. Just one individual from a shallow 250m set, at night in 2009, however, the set previous to this was to 1250m, so the record may have been the result of net contamination (assuming the flaccid benthesicymid body would persist the duration in a state identifiable to species). Estimated stratum catch indicated a population concentrated somewhere between 250-750m, day and night, with a total depth range extending below 750m. Not collected in 2007.

Remarks: Bate (1881) had originally grouped *G. bouvieri* and three other species with *G. parvus*, which were recognized and separated by Kemp (1910) in a revision of the Challenger material (see Tirmizi 1960). But the taxonomy was not completely resolved until 1936 when Burkenroad finally identified *G. alcocki* as the male of *G. bouvieri* (Burkenroad 1936, Roberts & Pequegnat 1970).

Figure 3.4. *Gennadas bouvieri*

***Gennadas capensis* Calman, 1925**

WoRMS AphiaID: 107094

Identification: Burkenroad, 1936, p. 67, fig. 53; Roberts & Pequegnat, 1970, P. 34, fig. 3-2a; Kensley, 1971, p. 277, fig. 3; Crosnier, 1978, p. 36, fig. 18c; Lagardere, 1978, p. 6, fig. 9.

Reported geographical and depth distribution: Northern range extension and the first Canadian records, reported from the eastern North Atlantic (Lagardere 1978) and to the south, off the north eastern U.S., Bermuda, Caribbean and Gulf of Mexico (Burkenroad 1936, Roberts and Pequegnat 1970), in general more common at lower latitudes in the North Atlantic (Fasham & Foxton 1979); also reported from the South Atlantic and Indo-Pacific (Gore 1985, Kensley et al. 1987). A weak vertical migrator, at depths of 400-1000m by day, 250-950m at night (Kensley 1971, Heffernan and Hopkins 1981, Hopkins et al. 1994), with a total depth range extending into the bathypelagic to depths of 1800m, possibly to 3500m (Lagardere 1978, Gore 1985).

Catch at Gully Main Station: A total of 32 specimens collected, one of the most common of the species recorded as new for Canadian waters. Unlike its congeners, absent from all shallow sets to 250m, day and night. With the largest catches in sets fishing to 1250m during the day, largest catches in sets fishing to 750m at night, this possibly indicating some diel vertical migration. Based on total biomass divided by abundance, the largest animals were from deep sets to 1250m, day and night. Estimated stratum catch indicated a population concentrated somewhere between 750-1250m during the day, 250-750m at night, extending into the bathypelagic deeper than 1250m. Present in all three years but not abundant, the majority of records (20) from 2009, with just two from 2007.

Figure 3.5. *Gennadas capensis*

***Gennadas elegans* (Smith, 1882)**

WoRMS AphiaID: 107095

Identification: Burkenroad 1936, p.71, fig. 55; Kensley 1971, p. 279. fig. 5; Lagardere 1978, p. 6, fig. 11)

Synonyms and other generic combinations: *Amalopenaeus elegans* Smith, 1882; reviewed by Burkenroad (1936).

Reported geographical and depth distribution: Very common and abundant in the North Atlantic (Sund 1920), also reported from the Mediterranean and South Atlantic (Burkenroad 1936, Kensley 1971, Fanelli et al. 2007). A weak vertical migrator, as shallow as 100m during the day, but the population concentrated between 600-1000m, to 10m at night, but concentrated at 400-900m (Foxton 1970b, Omori 1974, Hargreaves 1985b), with a total depth range extending into the bathypelagic to 2100m, possibly to 3000m (Hargreaves 1984, 1985b, Squires 1990).

Catch at Gully Main Station: The most abundant benthesicymid, nearly 3900 specimens collected, with more than half of the total catch from sets fishing to 750m day and night. Rare in shallow sets to 250m, with just 8 records, the one day collection a relatively large individual, probably due to contamination from the preceding set to 750m (assuming the flaccid benthesicymid body could persist the duration in a state identifiable to species). The few shallow night time records indicate a limited diel vertical migration, its weak musculature (Hargreaves & Herring 1992) unlikely able to effect an active daytime avoidance of the net. Based on total biomass divided by abundance, the smallest animals were from shallow night sets fishing 0-250m, largest from sets to 750m, not deeper (possibly due to an increase in the relative number of fragmented and incomplete specimens in the longer duration deep sets to 1250m). Overall, catch during the day somewhat larger than night, indicating some shoaling at greater depths during the day, with a dispersal at night. Estimated stratum catch indicated a population concentrated at 250-750m, day and night, extending into the bathypelagic deeper than 1250m (Appendix A). Present in all years, common and relatively abundant below 250m, with a trend of slightly larger catches in 2008 (Appendix B).

Remarks: Like *G. bouvieri*, part of the original *G. parvus* group (Burkenroad 1936).

Figure 3.6. *Gennadas elegans*

***Gennadas scutatus* Bouvier, 1906**

WoRMS AphiaID: 107096

Identification: Burkenroad 1936, p. 83, fig. 59; Tirmizi 1960, p. 358, fig. 67-68; Kensley 1971, p. 288, fig. 10; Crosnier & Forest 1973, p. 281, fig. 94a & 95a-b; Crosnier, 1978, p. 43, fig. 17a, 19c.

Synonyms and other generic combinations: *Amalopenaeus scutatus* Balss, 1927; reviewed by Crosnier (1978).

Reported geographical and depth distribution: First Canadian records, but reported to the south of the Grand Banks, Newfoundland (Crosnier 1978). Also from the eastern North Atlantic (Crosnier & Forest 1973, Fasham & Foxton 1979) and to the south off the north eastern U.S., Bermuda, Caribbean and Gulf of Mexico (Burkenroad 1936, Roberts and Pequegnat 1970), in general more common at lower latitudes in the North Atlantic (Fasham & Foxton 1979). Also reported from the South Atlantic and Indo-Pacific (Tirmizi 1960, Aizawa 1974, Kensley 1971, 1981), a shallow-living benthesicymid, 100-600m by day, reported at the surface at night (Crosnier & Forest 1973, Heffernan and Hopkins 1981, Hopkins et al. 1994), with a total depth range possibly extending to depths of 3400m (Crosnier & Forest 1973, Kensley 1981).

Catch at Gully Main Station: A total of just two specimens collected, both in sets fishing to 750m, one each at day and night, only recorded in 2009.

Remarks: Originally part of the *G. parvus* group, also with early taxonomic confusion based on the identification of males and females (Burkenroad 1936).

Figure 3.7. *Gennadas scutatus*

***Gennadas talismani* Bouvier, 1906**

WoRMS AphiaID: 240799

Identification: Roberts & Pequegnat 1970, p. 37, fig. 3-3; Kensley 1971, p. 289, fig. 11; Crosnier & Forest 1978, p. 285, fig. 94g & 95e-f.

Synonyms and other generic combinations: Reviewed by Crosnier & Forest (1973).

Reported geographical and depth distribution: Northern range extension and the first Canadian records, reported from the eastern North Atlantic and to the south in the Gulf of Mexico (Roberts & Pequegnat 1970, Fasham & Foxton 1979), in general more common at lower latitudes in the North Atlantic (Fasham & Foxton 1979). Also from the South Atlantic (Kensley 1971), a shallow-living benthesicymid and weak vertical migrator (in the Gulf of Mexico) at depths from 325-750m by day and 325-650m by night (Heffernan & Hopkins 1981), with a total depth range extending into the bathypelagic, possibly to 4000m (Crosnier & Forest 1973).

Catch at Gully Main Station: A total of just two specimens collected, both in sets fishing to 750m, one each at day and night, only recorded in 2009.

No photo presently available.

***Gennadas tinayeri* Bouvier, 1906**

WoRMS AphiaID: none

Identification: Burkenroad, 1936, p. 73, fig. 56; Tirmizi, 1960, p. 24, fig. 81-82; Kensley, 1971, p. 290, fig. 11; Crosnier, 1978, p. 44, fig. 17b, 19d; Lagardere, 1978, p. 6, fig. 8.

Synonyms and other generic combinations: *Amalopenaeus tinayeri* Sund, 1920; reviewed by Crosnier (1978).

Reported geographical and depth distribution: First Canadian records, but reported to the south of the Grand Banks, Newfoundland, off Bermuda and the Caribbean, and in the eastern North Atlantic (Sund 1920, Burkenroad 1936, Hargreaves 1985b). Also from the South Atlantic, and Indo-Pacific (Kensley 1971, Aizawa 1974, Krygier & Wasmer 1988), a shallow-living benthesicymid at depths of 100-600m (Krygier & Pearcy 1981, Hargreaves 1985b, Kensley et al. 1987), with a total depth range extending into the bathypelagic, possibly to depths of 3000m (Tirmizi 1960, Lagardere 1978, Kensley 1981).

Catch at Gully Main Station: A total of 19 specimens collected, 17 from sets fishing deeper than 250m. A surprising 16 of the total 19 collections were at night, including the only records from shallow sets fishing 0-250m, indicating some night time shoaling. Active daytime net avoidance or a diel vertical migration with individuals originating from below 1250m is unlikely due to the relatively flaccid musculature of the genus (Hargreaves & Herring 1992). Estimated stratum catch indicated a concentration somewhere between 250-750m, day and night, with a total range extending deeper. The majority of records (14) were in 2009, with just one in 2007.

Figure 3.8. *Gennadas tinayeri*

***Gennadas valens* (Smith, 1884)**

WoRMS AphiaID: 107098

Identification: Burkenroad, 1936, p. 75, fig. 57; Kensley, 1971, p. 291, fig. 13; Lagardere, 1978, p. 6, fig. 12.

Synonyms and other generic combinations: *Amalopenaeus valens* Smith, 1884; reviewed by Burkenroad (1936).

Reported geographical and depth distribution: Very common in the North Atlantic, also reported from the Gulf of Mexico, Mediterranean (though not throughout), South Atlantic, and Indo-Pacific (Kensley 1971, Lagardere 1978, Heffernan & Hopkins 1981). Strong vertical migrator, 500-1000m during the day, concentrated at 600-950m, to 10m night, concentrated at 200-500m (Foxton 1970b, Hargreaves 1985b, Hopkins et al. 1994); with total depth range trailing into the bathypelagic, possibly as deep as 1500-2000m (Murray & Hjort 1912, Omori 1974, Squires 1990).

Catch at Gully Main Station: Just over 100 specimens collected, more than half of the total catch from sets fishing to 750m. Not recorded from shallow daytime sets to 0-250m, with the appearance of 9 individuals at night indicative of a diel vertical migration, active daytime net avoidance unlikely because of the flaccid musculature of the genus (Hargreaves & Herring 1992). Catch during the day somewhat greater than at night, indicating some shoaling at greater depths during the day, with dispersal at night. Larger animals from deeper day sets fishing to 750 and 1250m, based on total biomass divided by abundance, with no pattern at night, possibly due to the dispersal upwards of larger individuals. Estimated stratum catch indicated a population restricted somewhere below 250m by day, concentrated at 250-750m but extending deeper, with evidence for a diel vertical migration above 250m at dusk. Present in all three years, somewhat common but not abundant, smallest catches in 2007.

Figure 3.9. *Gennadas valens*

Solenoceridae

***Hymenopenaeus laevis* (Bate, 1881)**

WoRMS AphiaID: 183205

Identification: Crosnier & Forest, 1973, p. 253, fig. 82a, 83b; Perez-Farafante, 1977.

Synonyms and other generic combinations: *Haliporus laevis* Bate, 1881; *Hymenopenaeus microps* Smith, 1884; reviewed by Crosnier & Forest (1973).

Reported geographical and depth distribution: The second Canadian record, previous surveys along the Scotian Slope with bottom trawls collected one other specimen to the west of The Gully, at a bottom depth of 1100-1200m (Markle et al. 1988). Reported to the south from along the east coast of the U.S. (Burkenroad 1936, Perez-Farafante 1977) and found elsewhere in the North Atlantic and Indo-Pacific at tropical and temperate latitudes (Burkenroad 1936, Crosnier & Forest 1973, Cartes et al. 2000), typically above 1000m, but possibly as deep as 4750m (Crosnier & Forest 1973).

Catch at Gully Main Station: A total of 5 specimens collected, with 4 from day sets fishing to 1250m, absent from sets fishing to 250m, not recorded in 2008.

Figure 3.10. *Hymenopenaeus laevis*

Decapoda: Dendrobranchiata: Sergestoidea

<u>Sergestidae</u>

Sergestes arcticus **Kroyer, 1855**

WoRMS AphiaID: 107125

<u>Identification</u>: Sund, 1920, p. 8, fig. 5; Yaldwyn, 1957, p. 9, fig. 1-5; Kensley, 1971, p. 232, fig. 7; Lagardere 1978, p. 6, fig. 14.

<u>Synonyms and other generic combinations:</u> Reviewed by Kemp (1910) and Sund (1920).

<u>Reported geographical and depth distribution</u>: Very common in the North Atlantic, to 70^0N north in the Davis Straight, off Iceland, and the Norwegian Sea, with a distribution similar to *P. multidentata* (Sund 1920, Squires 1990), also reported from the Mediterranean, South Atlantic, and Indo-Pacific (Yaldwyn 1957, Lagardere 1978, Kensley 1981). A strong vertical migrator, 100-1000m by day, but concentrated below 600m, 10-600m at night, but concentrated at 100-400m (Omori 1974, Hargreaves 1985b, 1999) with a total depth range trailing into the bathypelagic to 1700m, possibly to 4500m (Hargreaves 1984, Squires 1990).

<u>Catch at Gully Main Station</u>: The most abundant sergestid, tens of thousands of specimens collected, estimated at nearly 80,000 in total, with sub samples (only) retained to estimate total abundance and for cataloguing. Present in all but one of the shallow 0-250m daytime sets, probably throughout the water column above 1250m, with the largest total catches from sets fishing deeper than 250m during the day. Catch dramatically greater at night in shallow 250m sets (by several orders of magnitude), indicating dramatic active daytime net avoidance or a marked diel vertical migration. Catch in sets fishing to 750m at night just slightly less than daytime levels, but deeper sets to 1250m

with about half the daytime catch, indicating the deepest-dwelling animals move upwards at dusk, replacing individuals migrating to above 250m. Larger animals from deeper day sets fishing to 750 and 1250m, based on total biomass divided by abundance, with the smallest animals in shallow 250m sets, day and night. Interestingly, the average size of animals from the one exploratory day set to 1500m was considerably larger than any calculated from shallower set totals, suggesting only the largest animals inhabit the greatest depths. Estimated stratum catch indicated a population extending to 1250m, concentrated somewhere between 250-750m during the day, with a pronounced diel vertical migration to above 250m at dusk (Appendix A). A disproportionate amount of biomass relative to abundance persisted at 250-750m during the night, suggesting the largest animals remained deeper than 250m. Present with large catches in all three years, and though average catch tended to be lower in 2008 (Appendix B), total catch in 2008 was the greatest of all the larger crustaceans, surpassing even that of the northern krill, *M. norvegica*.

Remarks: Only two congenerics recorded at Gully main from a typically more specious oceanic *Sergestes* group (Donaldson 1975, Walters 1976).

Figure 3.11. *Sergestes arcticus*

***Sergestes henseni* (Ortmann, 1893)**

WoRMS AphiaID: none

Identification: Sund, 1920, p. 25, fig. 44-47; Crosnier & Forest, 1973, p. 310, fig. 106a-b, e; Lagardere, 1978, p. 6, fig. 13.

Synonyms and other generic combinations: *Sergia henseni* Ortmann, 1893; reviewed by Crosnier & Forest (1973).

Reported geographical and depth distribution: Widely distributed in the North Atlantic, also reported from the Mediterranean, Gulf of Mexico, and South Atlantic (Lagardere 1978, Hopkins et al. 1994, Perez-Farafante & Kensley 1997), at depths of 100-700m by day, 100-600m at night (Hopkins et al. 1994), with a total depth range trailing into the bathypelagic zone to 2300m (Lagardere 1978).

Catch at Gully Main Station: Only one specimen collected, in a set fishing to 750m at night in 2008.

Remarks: Only two congenerics recorded at Gully Main from a typically more specious oceanic *Sergestes* group (Donaldson 1975, Walters 1976).

Figure 3.12. *Sergestes henseni*

***Sergia grandis* (Sund, 1920)**

WoRMS AphiaID: 107134

Identification: Sund, 1920, p. 16, fig. 22-26; Crosnier & Forest, 1978, p. 331, fig. 113a, 116a-c; Lagardere, 1978, p. 7, fig. 24; Vereshchaka 2000, p. 127, fig. 36-37.

Synonyms and other generic combinations: *Sergestes grandis* Sund, 1920; reviewed by Crosnier & Forest (1973).

Reported geographical and depth distribution: First Canadian collections, but recorded to the south of the Grand Banks, Newfoundland (Crosnier & Forest 1973, Lagardere 1978), also reported from the central North Atlantic, Caribbean, Gulf of Mexico and South Atlantic (Crosnier & Forest 1973, Flock & Hopkins 1992, Vereshchaka 1994, 2000). Restricted below 500-600m by day but concentrated at 200-500m at night, as shallow as 30m (Crosnier & Forest 1973, Donaldson 1975, Vereshchaka 1994); with a total depth range extending into the bathypelagic to 2300m, possibly deeper (Crosnier & Forest 1973, Lagardere 1978, Vereshchaka 2000).

Catch at Gully Main Station: A total of 4 specimens collected, all from sets fishing to 750m, three from night sets, present in all three years.

Remarks: Records from South Africa and Indo-Pacific are probably not *S. grandis* (Vereshchaka 2000).

Figure 3.13. *Sergia grandis*

***Sergia japonica* (Bate, 1881)**

WoRMS AphiaID: 107135

Identification: Sund, 1920, p. 20, fig. 34; Crosnier & Forest, 1973, p. 341, fig. 113c, 117; Lagardere, 1978, p. 7, fig. 25; Vereshchaka, 2000, p. 91, fig. 9-10.

Synonyms and other generic combinations: *Sergestes japonica* Bate 1881; *Sergestes mollis* Smith, 1884; reviewed by Vereshchaka (2000).

Reported geographical and depth distribution: First Canadian records, but widely distributed in the North Atlantic, reported to the east and south of the Grand Banks, Newfoundland (Sund 1920), also reported from the south Atlantic and Indo-Pacific (Vereshchaka 1994, 2000). Indo-West Pacific and north-eastern Pacific distributions are apparently disjunct, possibly the result of low sampling effort in between (Vereshchaka 2000). As shallow as 300m, but typically concentrated around 1000m, with some indication of diel vertical migration (Foxton 1970b, Donaldson 1975, Vereshchaka 1994, 2000). Total depth range extends into the bathypelagic to 2000-2500m, possibly deeper (Omori 1974, Lagardere 1978).

Catch at Gully Main Station: Over 1200 specimens collected, with the majority (over 1000) from deep sets fishing to 1250m or 1500m. Catch from day sets to 1250m was nearly double the night catch, while catch in sets fishing to 750m was similar day and night, indicating shoaling below 750m during the day, with dispersal at night. Rare in shallow sets to 250m, just two records during the day, possibly due to contamination from the preceding set to 1250m (assuming the soft body of *S. japonica* could persist in a state identifiable to species). Six night records from shallow sets to 250m indicated a limited diel vertical migration, active daytime net avoidance unlikely because of the flaccid musculature similar to *Gennadas* (Hargreaves & Herring 1992). Smaller animals on average in shallow night sets to 250m, larger from deep sets fishing to 1250m day and night, with the average size of animals from the one exploratory day set to 1500m even larger. Estimated stratum catch indicated a population concentrated somewhere between 750-1250m day and night, with a large part of the population extending into the bathypelagic below 1250m. Present in all years, probably common and relatively abundant deeper than 750m.

Remarks: One of the most distinct sergestids with its relatively small eyes and soft body. Not so abundant in absolute or relative terms in other pelagic surveys (Foxton 1970b, Donaldson 1975, Walters 1976, Burghardt et al. 2007).

Figure 3.14. *Sergia japonica*

***Sergia robusta* (Smith, 1882)**

WoRMS AphiaID: 107136

Identification: Sund, 1920, p. 11, fig. 11-13; Crosnier & Forest, 1973, p. 327, fig. 111d-f, 112c-d; Lagardere, 1978, p.7, fig. 23; Vereshchaka, 2000, p. 153, fig. 55-56.

Synonyms and other generic combinations: *Sergestes robustus* Smith, 1882; *Sergestes dissimilis* Bate, 1888; *Sergestes mediterraneus* Hansen, 1896; *Sergestes inermis* Hansen, 1903; reviewed by Vereshchaka (2000).

Reported geographical and depth distribution: North Atlantic, Mediterranean, and Gulf of Mexico (Hopkins et al. 1994, Vereshchaka 1994, 2000). Population concentrated below 700m during the day (Foxton 1970b, Donaldson 1975, Hopkins et al. 1994), possibly deeper (Vereshchaka 1994), but with records from as shallow as 10-300m (Hargreaves 1985b, Hopkins et al. 1994); concentrated above 800m at night, with the vast majority of the population typically remaining below 200m. Records extending into the bathypelagic to at least 2000m, possibly deeper to 5000m (Lagardere 1978, Vereshchaka 1994, Squires 1990).

Catch at Gully Main Station: A total of 285 specimens collected, with largest day catches in sets fishing 0-750m, largest night catches in sets to 1250m, possibly resulting from a migration of individuals from below 1250m, though similar overall day vs. total night catches contradict this scenario. Not recorded in sets fishing to 250m during the day, but 15 individuals recorded at night indicated daytime net avoidance or a diel vertical migration from below 250m. Estimated stratum catch indicated a population restricted deeper than 250m by day, concentrated somewhere between 250-750m, above 250m at night, concentrated between 250-1250m (deepening and shallowing), with considerably greater catch below 750m. Present in all years, not abundant at the depths surveyed, least abundant in 2007.

Remarks: Reports from the South Atlantic are doubtful (Vereshchaka 2000).

Figure 3.15. *Sergia robusta*

***Sergia tenuiremis* (Kroyer, 1855)**

WoRMS AphiaID:107138

Identification: Sund, 1920, p. 18, fig. 27-33; Lagardere, 1978, p. 7, fig. 26; Vereshchaka, 2000, p. 84, fig. 3-4.

Synonyms and other generic combinations: *Sergestes tenuiremis* Kroyer, 1885; *Sergestes kroyeri* Bate, 1881, *Sergestes junceus* Bate, 1888; *Sergestes longicollis* Bate, 1888; *Sergestes tropicus* Sund, 1920; reviewed by Krygier & Wasmer (1988) and Vereshchaka (2000).

Reported geographical and depth distribution: First Atlantic Canadian records, more common in the central North Atlantic (Sund 1920, Lagardere 1978, Vereshchaka 2000), also reported from the Gulf of Mexico and Pacific (Flock & Hopkins 1992, Vereshchaka 1994, 2000), with Atlantic and Pacific distributions apparently disjunct. A wide depth distribution, below 700m during the day, concentrated between 800-2000m, below 200m at night, concentrated between 300-2000m (Walters 1976, Flock & Hopkins 1992, Vereshchaka 1994, 2000) with a total depth range possibly extending to 4700m (Lagardere 1978).

Catch at Gully Main Station: A total of three specimens collected, all from deep sets fishing 0-1250m, not recorded in 2008.

Remarks: Mature adults are reportedly rare, resultantly described under several names (Krygier & Wasmer 1988, Vereshchaka 2000). Records from the Indian Ocean are probably not *S. tenuiremis* (Vereshchaka 2000).

Figure 3.16. *Sergia tenuiremis*

Decapoda: Pleocyemata: Caridea

Oplophoridae

***Acanthephyra eximia* Smith, 1884**

WoRMS AphiaID: 564909

Identification: Crosnier & Forest, 1973, p. 34, fig. 7c; Chace, 1940, p. 147, fig. 24; Chace, 1986, p. 18; Cardoso & Young, 2005, p.14, fig. 8-9.

Synonyms and other generic combinations: (?) *Alpheus pelagicus* Risso, 1816; *Acanthephyra eximea* Smith, 1884, *Acanthephyra agusta* Bate, 1888; *Acanthephyra edwardsi* Bate, 1888; *Acanthephyra brachytelonsis* Bate, 1888; (?) *Acanthephyra pulchra* A. Milne-Edwards, 1890; reviewed by Crosnier & Forest (1973) and Chace (1986).

Reported geographical and depth distribution: Just the second Canadian records (Pohle 1992), but cosmopolitan, tropical and temperate North Atlantic, Mediterranean, Gulf of Mexico, South Atlantic, and Indo-Pacific (Crosnier & Forest, 1973, Chace, 1986, Cardosos & Young 2005, Pequegnant & Wicksten 2006). Adults reported to be nektobenthonic or benthonic, 200-4700m (Chace 1986, Cardosos & Young 2005, Pequegnat & Wicksten 2006). Though just the second report of *A. eximia* in the primary scientific literature for the western North Atlantic north of Cape Hatteras (Pohle 1992, Cardosos & Young 2005), it appears the species may actually prove to be more common in Atlantic Canada. Additional collections from near the head of the Gully are more abundant and include a wide range of sizes, including gravid females (MacIsaac, unpublished data). A comprehensive review of the Decapoda of Atlantic Canada in 1990 and benthic and pelagic surveys in previous decades indicate that this may represent the consolidation of a recent expansion into the region (Sivertsen & Holtuis 1956, Markle et al. 1988, Squires 1990, Pohle 1992, MacIsaac, unpublished data). A search of various sources of “grey literature” from Atlantic Canada is currently underway.

Catch at Gully Main Station: A total of 4 specimens collected from sets fishing to 750m and 1250m, three of the records during the day, not recorded in 2009.

Remarks: Chace (1986) questioned the traditional assignment of some older, junior taxonomic synonymies currently assigned to *Acanthephyra pelagica*, suggesting that they could be *A. eximia*. And the dorsum of the carapace is typically more sinuous in our specimens than that figured by Crosnier & Forest (1973).

Figure 3.17. *Acanthephyra eximia*

***Acanthephyra pelagica* (Risso, 1816)**

WoRMS AphiaID: 107581

Identification: Chace, 1940, p. 140, fig. 18; Rice, 1967, p. 6, fig. 10; Crosnier & Forest, 1973, p. 29; Chace 1986, p. 8.

Synonyms and other generic combinations: *Alpheus pelagicus* Risso, 1816; *Ephyra haeckelii* von Martins, 1868; *Acanthephyra agassizii* Smith, 1884; *Acanthephyra sica* Bate, 1888; *Acanthephyra rectirostris* Riggio, 1901; *Acanthephyra purpurea* var. *multispina* Coutiere, 1905; *Acanthephyra parva multidens* Coutiere, 1905; reviewed by Crosnier & Forest (1973).

Reported geographical and depth distribution: Cosmopolitan, common in the North Atlantic, a cold-water *Acanthephyra*, extending further north than any of its congeners, to Baffin Island, Greenland and Iceland (Chace 1940, Foxton 1972); also reported from the Mediterranean, Gulf of Mexico, South Atlantic, and Indo-Pacific (Chace, 1940, Crosnier & Forest, 1973, Pequegnat & Wicksten 2006). North and South Atlantic distributions appear to be disjunct. Restricted to below 600m depth during the day, typically concentrated at 700-1100m, but as deep as 1600m (Chace 1940, Foxton 1972, Omori 1974, Roe 1984), as shallow as 200m at night, typically concentrated at 450-700m, but as deep as 1500m; total depth range extending into the bathypelagic to 2500m (Sivertsen & Holthuis 1956, Omori 1974, Pequegnat & Wicksten 2006). Collected along the Nova Scotian Slope in bottom trawls at depths below 736m to the maximum depth trawled of 1200m (Markle et al. 1988).

Catch at Gully Main Station: The most abundant oplophorid, a total of 2100 specimens collected, the vast majority from sets fishing to 750m and 1250m, with slightly greater catch at greatest depths fished. Catch above 750m increased notably at night, indicating a limited diel vertical migration or some shoaling. Just one sub-adult/juvenile recorded from a set fishing 0- 250m by day, possibly representing contamination from the previous set at night to 750m. Present in all nighttime sets to 250m except one, indicating active net avoidance during the day or a limited diel vertical migration at dusk. Average size based on biomass divided by abundance increased with depth, day and night. Estimated stratum catch indicated a population concentrated somewhere between 250-750m, day and night, with a large part of the population extending into the bathypelagic below 1500m (Appendix A). A disproportionately large amount of biomass relative to abundance estimated below 750m at night suggested the largest animals did not migrate to shallower depths. *Acanthephyra pelagica* was common and relatively abundant in all years below 250m, with somewhat larger catches in 2008 (Appendix B).

Remarks: *Acanthephyra pelagica* was not recognized as species distinct from *A. purpurea* until 1905 (see Kemp 1939, Sivertsen & Hothuis 1956).

Figure 3.18. *Acanthephyra pelagica*

***Acanthephyra pelagica* short rostrum variant**

Identification: Chace, 1940, p. 140, fig. 18; Rice, 1967, p. 6, fig. 10; Crosnier & Forest, 1973, p. 29; Chace 1986, p. 8.

Catch at Gully Main Station: The one specimen collected in a set fishing 0-1250m at night in 2008.

Remarks: A rare but recurrent form (MacIsaac unpublished data), with some slight morphological differences, but genetically identical to *A. pelagica* (Anstey & Kenchington, unpublished data). Rostrum typically short and unarmed, ventrally and dorsally, but integument thick and body firm (vs. *A. tenuipes*, Chace 1986); other diagnostic features, such as abdominal spination and telson length and spination identifiable as *A. pelagica*.

Figure 3.19. *Acanthephyra pelagica* short rostrum variant

Acanthephyra purpurea **A. Milne-Edwards, 1881**

WoRMS AphiaID: 107582

Identification: Chace, 1940, p. 134, fig 11; Rice, 1967, p. 6, fig. 9; Chace 1986, p. 8.

Synonyms and other generic combinations: See review by Kemp (1939).

Reported geographical and depth distribution: Common in the North Atlantic, also in the Gulf of Mexico (Chace 1940, Sivertsen & Holthuis 1956, Pequegnat & Wicksten 2006), more abundant in the central North Atlantic, less common at higher latitudes (Chace 1940, Foxton 1972) with the Gulf Stream/Subtropical Gyre somewhat of a barrier, at least in the west (Chace 1940, Sivertsen & Holtuis 1956). As shallow as 150m depth during the day (Hopkins et al. 1989), but usually below 550m, typically concentrated at 600-1000m, but as deep as 1500m (Chace 1940, Foxton 1972, Omori 1974, Hopkins et al. 1994). A strong vertical migrator, to 10m at night, typically concentrated between 100-500m, but as deep as 900m (Foxton 1972, Omori 1974, Hargreaves 1985b), with a total depth range extending into the bathypelagic, possibly to 3200m (Omori 1974, Kensley et al. 1987, Pequegnat & Wicksten 2006). Collected along the Nova Scotian Slope in bottom trawls at depths below 732m to the maximum depth trawled of 1200m (Markle et al. 1988).

Catch at Gully Main Station: Nearly 300 specimens collected, the majority from sets fishing to 750m, with greatest catch from sets to 750m during the day. Absent from sets fishing to 250m during the day, similarly absent from most shallow sets at night: not recorded in 2007, just one record in 2008, but with 30 records in 2009, most (25) from a single set. The set previous to this large catch in 2009 was deep, to 1250m, suggesting the shallow records may have been the result of net contamination. Average size of animals based on total biomass divided by abundance greatest in sets to 750m at night, otherwise similar throughout, indicating larger adults migrated or were at least present throughout the entire range from above 250m at night to below 750m. Curiously, the smallest average size observed was with the small number of animals (5) collected in the one deep exploratory set to 1500m. Estimated stratum catch indicated a population restricted below 250m during the day, concentrated somewhere between 250-750m, with a broadened area of concentration at night, to both above 250m and below 750m, with a total depth range extending into the bathypelagic below 1250m. Relatively common in all years, catches generally increasing from 2007-2009.

Remarks: Several closely related species previously confused with *A. purpurea* (see Kemp 1939).

Figure 3.20. *Acanthephyra purpurea*

***Ephyrina bifida* Stephensen, 1923**

WoRMS AphiaID: 107586

Identification: Chace, 1940, p. 173, fig. 45; Rice, 1967, p. 6, fig. 15; Crosnier & Forest, 1973, p. 66, fig. 19b; Chace, 1986, p. 33.

Synonyms and other generic combinations: Reviewed in Crosnier & Forest (1973).

Reported geographical and depth distribution: First Canadian records, previously recorded from the central and eastern North Atlantic (Sivertsen & Holthuis 1956, Crosnier & Forest 1973, Fasham & Foxton 1979, Hargreaves 1985b), more abundant to the south off Bermuda and the Bahamas (Chace 1940, 1947), also at low latitudes in the South Atlantic, with a depth range of 700-4400m.

Catch at Gully Main Station: Rare at the depths surveyed, just two specimens collected, one from a deep set to 1250m in 2008, the other from the one deep exploratory set to 1500m in 2007, both sets during the day. The specimen from the deep exploratory set was considerably larger.

Remarks: Records from the Indian Ocean noted in Chace (1940) are not *E. bifida* (see Sivertsen & Holthuis 1956, Crosnier & Forest 1973, Chace 1986). Just the second record for the genus in Canadian waters, with *E. figueirai* reported by Pohle (1992).

Figure 3.21. *Ephyrina bifida*

***Hymenodora gracilis* Smith, 1886**

WoRMS AphiaID: 107591

<u>Identification</u>: Sivertsen & Holthuis, 1956, p. , fig. 12-13; Rice 1967, p. 7, fig. 17; Crosnier & Forest, 1973, p. 83, fig. 25a-b.

<u>Synonyms and other generic combinations:</u> Reviewed in Crosnier & Forest (1973).

<u>Reported geographical and depth distribution</u>: Reported as rare in Canadian waters (Pohle 1992), just the second record for Atlantic Canada (Steele and Montevecchi 1994), but abundant in the North Atlantic in general (Steele and Montevecchi 1994 and references therein). Widely distributed, from Greenland south, including to the east and south of the Grand Banks, Newfoundland (Sivertsen & Holthuis 1956), also reported from the South Atlantic and Indo-Pacific (Sivertsen & Holthuis 1956, Krygier & Wasamer 1988). Inhabits depths from 600-5400m, concentrated in the upper bathypelagic at 1100-2000m (Crosnier & Forest 1973, Krygier & Pearcy 1981, Hargreaves 1985b), but one specimen reported from the stomach of a surface-feeding storm petrel (*Oceanodroma leucorhoa*) off Newfoundland, indicating *H. gracilis* must occasionally reach the surface, however infrequent, by whatever mechanism (Steele and Montevecchi 1994).

<u>Catch at Gully Main Station</u>: A total of 45 specimens collected, all from deep sets fishing to 1250m or 1500m. In 2007, just three individuals from sets fishing above 1250m, but with the largest single set catch of 16 individuals from the one exploratory set to 1500m, indicating a non-migrating population extending into the bathypelagic below 1250m. Largest animals on average from the deep exploratory set to 1500m. Present in all years, but not abundant at the depths surveyed, increasing in abundance in replicated sets fishing above 1250m from three specimens in 2007 to 19 in 2009.

Remarks: Historical confusion of *H. gracilis* with its deeper living congener, *H. glacialis*, but current specimens clearly lack the crescent-shaped groove in the hepatic region of the carapace indicative of the latter (Sivertsen & Holthuis 1956, Rice 1967, Butler 1980). The two species are also separated by depth, with *H. glacialis* rarely reported above 1500-2000m (Domanski 1986, Hendrickx & Estrada-Navarette 1989).

Figure 3.22. *Hymenodora gracilis*

***Meningodora miccyla* (Chace, 1940)**

WoRMS AphiaID: 107595

Identification: Chace, 1940, p. 161, fig. 35. Crosnier & Forest, 1973, p. 43, fig. 10a-b, 11; Chace, 1986, p. 50; Kikuchi, 1991, fig. 2d.

Synonyms and other generic combinations: *Notostomus miccyla* Chace, 1940; *Meningodora miccylus* (Chace, 1940).

Reported geographical and depth distribution: Rare, just the second Canadian collections, previously recorded from along the continental slope to the north of the Grand Banks, Newfoundland (Atlantic Reference Centre 2002). Also from the central and eastern North Atlantic (NMNH Invertebrate Zoology Collections 1969, 1970, 1972), the Caribbean, and parts of the Indian Ocean from along South Africa, from depths of 250-1800m (Chace 1940, Kensley 1981). Previously reported restricted below 900m in western North Atlantic (Chace 1940).

Catch at Gully Main Station: A total of 5 specimens, absent from sets fishing to 250m, 4 collected during the day, not recorded in 2007.

Figure 3.23. *Meningodora miccyla*

***Meningodora mollis* Smith, 1882**

WoRMS AphiaID: 107596

Identification: Chace 1940, p.164, fig. 38; Rice 1967, p. 6, fig. 12; Crosnier & Forest, 1973, p. 44, fig. 10c; Kikutchi, 1991, p. 32, fig. 2e, 6a-h.

Synonyms and other generic combinations: *Hymenodora mollis* Bate, 1888; *Notostomus fragilis* Faxon, 1893; *Acanthephyra mollis* De Man, 1920; *Notostomus mollis* Balss, 1925; reviewed by Crosnier & Forest (1973).

Reported geographical and depth distribution: First Canadian records, but widely distributed in the North Atlantic, including to the east of the Grand Banks, Newfoundland (Sivertsen & Holthius 1956) and the central and eastern North Atlantic (Rice 1967, Foxton 1970a), to the south off Bermuda, Bahamas, the Gulf of Mexico (Chace 1940, 1947, Hopkins et al. 1989), and the South Atlantic and Indo-Pacific (Crosnier & Forest 1973, Chace 1986, Krygier & Wasmer 1988). Found at depths as shallow as 500m (Chace 1940, Krygier & Pearcy 1981), but typically deeper (Foxton 1970a, Hargreaves 1985b, Hopkins et al. 1989, Kikuchi 1991), with a total depth range extending into the bathypelagic to at least 3300m, possibly to 5000m (Crosneir & Forest 1973, Hargreaves 1985b).

Catch at Gully Main Station: A total of 8 specimens, absent from sets fishing to 250m, one from a night set to 750m, the remaining from deep sets to 1250m, most of these at night. A majority of collections at night suggests a migration of individuals from below 1250m, the soft integument (similar to that of the jelly-associated *Notostomus*) not suggestive of an active animal able to avoid a net. Distribution almost definitely extends into the bathypelagic below 1250m, with the average size of individuals increasing with depth. Not abundant at the depths surveyed, but present in all years, with the majority (5) collected in 2009.

Figure 3.24. *Meningodora mollis*

***Meningodora vesca* (Smith, 1886)**

WoRMS AphiaID: 107597

Identification: Chace 1940, p.153, fig. 29; Rice 1967, p. 6, fig. 11; Crosnier & Forest, 1973, p46, fig, 10d; Kikuchi, 1991, p. 34, fig. 2f, 7a-h.

Synonyms and other generic combinations: *Notostomus viscus* Smith, 1886; *Notostomus vescus* Smith, 1887; *Acanthephyra brevirostris* Bate, 1888; *Acanthephyra batei* faxon, 1895; *Acanthephyra parvirostris* Coutiere, 1911; reviewed by Crosnier & Forest (1973).

Reported geographical and depth distribution: First Canadian records, but widely distributed in the North Atlantic, including to the south of the Grand Banks, Newfoundland (Sivertsen & Holthius 1956) and the central and eastern North Atlantic (Rice 1967, Foxton 1970a), off Bermuda, the Gulf of Mexico (Chase 1940, 1947, Hopkins et al. 1989), and the Indo-Pacific (Crosnier & Forest 1973, Kensley et al. 1987, Kikuchi 1991). Restricted below depths of 875m during the day (Chace 1940, Foxton 1970a, Hopkins et al. 1989) possibly concentrated deeper, below 1100m (Chace 1940), as shallow as 600m at night (Foxton 1970a), total depth range extending into the bathypelagic, possibly to 5400m (Sivertsen & Holtuis 1956, Crosnier & Forest 1973, Kensley et al. 1987). An unusually shallow distribution is reported from the western North Pacific, 400-700m, day and night (Kikuchi 1991).

Catch at Gully Main Station: A total of 33 specimens collected, one of the most common of the species recorded as new for Canadian waters. Absent from sets fishing to 250m, more than half from sets to 750m. The total number of daytime records outnumbered those at night, possibly indicating some daytime shoaling, with larger animals on average from day sets to 750m. Estimated stratum catch indicated a population concentrated somewhere between 250-750m, with a total range extending into the bathypelagic below 1250m. Not abundant at the depths surveyed but present during all years, with slightly fewer collected in 2009.

Figure 3.25. *Meningodora vesca*

***Notostomus elegans* A. Milne-Edwards, 1881**

WoRMS AphiaID: 107600

Identification: Crosnier & Forest, 1973, p. 56, fig. 15, 16a-b; Chace, 1986, p. 56, fig. 30; Squires, 1990, p. 80, fig. 37-38.

Synonyms and other generic combinations: *Notostomus patentissimus* Bate, 1888; *Notostomus longirostris* Bate, 1888; *Notostomus westergreni* Faxon, 1893; *Notostomus atlanticus* Lenz & Strunk, 1914; reviewed by Crosnier & Forest (1973).

Reported geographical and depth distribution: Reported from the North Atlantic, Gulf of Mexico, South Atlantic, and Indo-Pacific (Hopkins et al. 1989, Crosnier & Forest 1973, Chace 1986). As shallow as 300m depth at night (Hopkins et al. 1989), but typically restricted below 450m or deeper (Chace 1986, Kensley et al. 1987), total depth range extending into the bathypelagic, possibly to over 5000m (Crosnier & Forest 1973).

Catch at Gully Main Station: A total of 5 specimens collected, absent from sets fishing to 250m, with 4 collected from sets to 750m, and all but one collection during the day. The smallest animals were from 750m sets, one collected during the day and one at night, with the largest individual from a set fishing to 1250m. Not abundant at the depths surveyed, not recorded in 2008, with just one collection in 2007.

Remarks: A species associated with pelagic jellyfish (Moore et al. 1993).

Figure 3.26. *Notostomus elegans*

***Notostomus robustus* Smith, 1884**

WoRMS AphiaID: 107601

Identification: Chace, 1940, p.169, fig. 41; Chace, 1986, p. 53; Squires, 1990, p. 85, fig. 40-41.

Synonyms and other generic combinations: (?) *Notostomus beebei* Boone, 1930; reviewed by Chace (1940).

Reported geographical and depth distribution: Reported from the western and central North Atlantic, near the Azores, and Caribbean, at depths of 850-3000m (Chace 1940, 1986, Sivertsen & Holthuis 1956, Squires 1990). Known only from the western North Atlantic until 1956 (Sivertsen & Holthuis 1956).

Catch at Gully Main Station: A total of 23 specimens collected, absent from sets fishing to 250m, with overall catch maxima from deep sets to1250m during the day and night sets to 750m, possibly indicating a diel vertical migration, the soft integument of this jellyfish associated species (Moore et al. 1993) not suggestive of an active animal able to avoid a net. On average, smaller animals from sets to 750m at night, larger animals from deep 1250m sets during the day, with the largest single individual from the one deep exploratory set to 1500m. Not abundant at the depths surveyed, but present during all years.

Remarks: Chace (1986) still reports *N. robustus* restricted to the western North Atlantic. A species associated with pelagic jellyfish (Moore et al. 1993).

Figure 3.27. *Notostomus robustus*

***Oplophorus spinosus* (Brulle, 1839)**

WoRMS AphiaID: 107602

Identification: Chace, 1940, p. 187, fig. 55; Sivertsen & Holthuis, 1956, p. , fig. 15; Squires, 1990, p. 90, fig. 43-44.

Synonyms and other generic combinations: *Palaemon spinosus* Brulle, 1839; *Hoplophorus grimaldi* Coutiere, 1905; reviewed by Crosnier & Forest (1973).

Reported geographical and depth distribution: Widely distributed, North Atlantic, Gulf of Mexico, South Atlantic, and Indo-Pacific (Crosnier & Forest 1973, Chace 1986, Pequegnat & Wicksten 2006). Restricted to depths below 100m during the day, concentrated below 500m (Chace 1940, Foxton 1970a), to 10m at night, concentrated below 300m (Chace 1940, Omori 1974); total depth range extending into the bathypelagic to 2700m (Omori 1974, Kensley 1981).

Catch at Gully Main Station: A total of two specimens collected from a deep daytime set fishing to 1250m in 2008.

Figure 3.28. *Oplophorus spinosus*

***Systellaspis debilis* (A. Milne-Edwards, 1881)**

WoRMS AphiaID: 107605

Identification: Chace, 1940, p. 181, fig. 51; Rice, 1967, p. 7, fig. 19; Crosnier & Forest, 1973, p. 87, fig. 26b, 27b.

Synonyms and other generic combinations: *Acanthephyra debilis* A. Milne-Edwards, 1881; *Miersia gracilis* Smith, 1882; *Systellaspis bouvieri* Coutiere, 1905; reviewed by Crosnier & Forest (1973).

Reported geographical and depth distribution: Widespread, North Atlantic, with the Gulf Stream/Subtropical Gyre somewhat of a barrier to distribution, at least in the west (Chace 1940, Sivertsen & Holthuis 1956), into the Gulf of Mexico, South Atlantic, and Indo-Pacific (Sivertsen & Holthuis 1956, Crosnier & Forest 1973, Chace 1986). Typically concentrated below 500m during the day, but as shallow as 150m, strong vertical migrator, with most of the population above 200m at night (Foxton 1970a, Hargreaves 1985b, Hopkins et al. 1994). Total depth range extending into bathypelagic to 1500m (Omori, 1974, Kensley et al. 1987, Hargreaves 1985b), possibly as deep as 3200m (Pequegnat & Wickensten 2006).

Catch at Gully Main Station: One specimen from a deep 1250m set at night in 2008.

Figure 3.29. *Systellaspis debilis*

Pasiphaeidae

***Eupasiphaea serrata* (Rathburn, 1902)**

AphiaID: 107667

Identification: Rathburn 1904, p. 25, fig7; Schmitt, 1921, p. 31, fig. 18; Crosnier, 1988, p. 788, fig. 2b.

Synonyms and other generic combinations: *Parapasiphaea serrata* Rathburn, 1902.

Reported geographical and depth distribution: First Canadian record and northern range extension; rarely reported, but widely distributed, in the eastern North Atlantic between the Azores and the Strait of Gibraltar (Gordillo et al. 2001), in the west off Venuzuela (NMNH Invertebrate Zoology Collections, date unknown), also from the South Atlantic and Indo-Pacific (Rathburn 1904, Hendickx & Estrada-Navarrete 1989), bathypelagic to benthonic, distributed from depths below 970m, possibly to 1800m (Hendrickx and Estrada-Navarrete 1989).

Catch at Gully Main Station: One specimen from a deep 1250m day set in 2009.

Remarks: Dorsal carina of carapace not as concave in the middle as figured and indicated by Rathburn (1904), but match that of Crosnier (1988); rostrum similar but not identical to either, slightly more elevated than Rathburn (1904), slightly more rounded than Crosnier (1988); fouth pereiopod much longer than figured or indicated by Rathburn (1904), extending almost to the dactyl of pereiopd 5; telson apical spines and second pereiopods missing on our specimen, colour bright orange.

Figure 3.30. *Eupasiphaea serrata*

***Parapasiphae sulcatifrons* Smith, 1884**

WoRMS AphiaID: 107673

Identification: Chace, 1940, p. 126, fig. 6; Rice, 1967, p. 5, fig. 1; Crosnier & Forest, 1973, p. 142, fig. 41.

Synonyms and other generic combinations: Reviewed by Crosnier & Forest (1973).

Reported geographical and depth distribution: Widely distributed, North Atlantic, Gulf of Mexico, South Atlantic, Indo-Pacific (Chase 1940, Pequegnat 1970, Kensley et al. 1987). As shallow as 500m depth (Sivertsen & Holthuis 1956, Pequegnat 1970, Krygier & Pearcy 1981), but probably restricted below 700m during the day (Hargreaves 1985b, Hopkins et al. 1989), with the bulk of the population concentrated deeper, between 900-1600m (Chase 1940, Omori 1974). Total depth range extends to at least 2200m (Hargreaves 1985b), possibly to 5400m (Sivertsen & Holthuis 1956, Kensly et al. 1987). From along the continental slope of Nova Scotia, reported in bottom trawls at depths below 1020m to the maximum depth trawled of 1200m, where it was identified as a rare occurrence for the area (Markle et al. 1988).

Catch at Gully Main Station: Nearly 600 specimens collected, all but 39 individuals from deep sets fishing to 1250m. Absent from sets fishing to 250m during the day, with just two specimens from above 250m at night, but these moderately large individuals were possibly the result of net contamination, the previous sets in both cases having fished to 1250m. Total catch biomass from deep 1250m sets constant between the day and night, however considerably more, and therefore on average smaller individuals during the day. This seems to indicate a shoaling of smaller individuals during the day at greater depths, but the pattern was exaggerated by an unusually large daytime catch of 125 small (on average) individuals from a single set in 2009 fishing to 1250m. Overall average size of animals based on total biomass divided by abundance consistently increased with depth fished, despite the unusual catch of small animals in 2009, with the largest animals on average from the one deep exploratory set to 1500m. Estimated stratum catch indicated a population concentrated somewhere between 750-1250m, day and night, with a large part of the population extending into the bathypelagic below 1250m. Biomass was estimated to be constant between day and night, but abundance was greater during the day, indicating more, smaller animals. Present during all years, probably common and abundant below 750m.

Figure 3.31. *Parapasiphae sulcatifrons*

***Pasiphaea multidentata* Esmark, 1866**

WoRMS AphiaID: 107676

<u>Identification</u>: Sivertsen & Holthuis, 1956, p. 27, fig. 19-20; Rice, 1967, p. 5, fig. 3; Squires, 1990, p. 116, fig. 58-59.

<u>Synonyms and other generic combinations:</u> *Pasiphae norvegica* M. Sars, 1866; Pasiphae sicula Riggio, 1896; *Pasiphae multidentata* sicula Zariquiey Alvarez, 1946; reviewed by Sivertsen & Holthuis (1956).

<u>Reported geographical and depth distribution</u>: North Atlantic, with a distribution similar to *S. arcticus* (Sund 1920), as far north as Iceland and the Norwegian Sea, also in the Mediterranean (Sivertsen & Holthuis 1956, Mattiews & Pinnoi 1972, Koukouras 2000). Found at depths from the near-surface to over 2000m (Sivertsen & Holthuis 1956, Cartes & Sarda 1993), with a population concentrated between 300-800m (Mattiews & Pinnoi 1972, Cartes 1993, Aguzzi et al. 2007), at least along continental margins. From along the continental slope of Nova Scotia, in bottom trawls fishing below 375m, but not deeper than 840m (Markle et al. 1988). With smaller individuals undergoing a diel vertical migration, at least along continental margins, but the largest animals not migrating vertically, reportedly adopting a benthic or nektobenthic existence out of synchrony with the smaller pelagic or benthopelagic individuals in the population (Aguzzi et al. 2007). These larger individuals (>30mm carapace length) still display a rhythmic displacement of the population, but it is horizontal, occupying areas on the upper slope (and canyons) at night, descending to greater depth by day (Aguzzi et al. 2007, Aguzzi and Company 2010).

Catch at Gully Main Station: The most abundant pasiphaeid, nearly 4400 specimens collected, with a total biomass only surpassed by *S. arcticus* and *M. norvegica*. One of the few large Crustacea (occasionally) collected above 250m during the day, and probably occurring throughout the water column to at least 1500m. With active daytime net avoidance or a pronounced diel vertical migration, the largest total catch from sets fishing 0-750m during the day and 0-250m at night. Catch in 1250m sets fairly constant, day and night. Overall, catch was greater in nighttime sets, indicating shoaling at shallower depths at night or active daytime net avoidance. Despite being abundant and distributed across a wide depth range, a clear size-depth trend was not observed. Average size of individuals in the upper 250m was less than all other sample depths, but there was no change from sets to 750m, 1250m or the one deep exploratory set to 1500m. The largest individuals of *P. multidentata* may have been deeper than our sampling efforts, 1250-1500m, possibly in association with the bottom and/or sides of the canyon. Estimated stratum catch indicated a population concentrated somewhere between 250-750m during the day, 0-250m at night, extending into the bathypelagic below 1250m (Appendix A). *Pasiphaea multidentata* was common and abundant in all years, with slightly greater catches in 2008 (Appendix B).

Remarks: Very small individuals of *P. multidentata* (less than about 10mm carapace length) are difficult to confidently distinguished morphologically from very small *Pasiphaea tarda* (Mattiews & Pinnoi 1972). Because large *P. tarda* were relatively rare in collections, the few very small animals were assigned to *P. multidentata*, and a few *P. tarda* may have been misidentified.

Figure 3.32. *Pasiphaea multidentata*

***Pasiphaea tarda* Kroyer, 1845**

WoRMS AphiaID: 107678

Identification: Sivertsen & Holthuis, 1956, p. 23, fig. 17; Rice, 1967, p. 5, fig. 4; Squires, 1990, p. 121, fig. 61-62.

Synonyms and other generic combinations: *Pasiphae princeps* Smith, 1884; *Pasiphaea principalis* Sund, 1913; reviewed by Sivertsen & Holtuis (1956).

Reported geographical and depth distribution: North Atlantic, to Hudson Strait, Greenland and the Norwegian Sea (Mattiews & Pinnoi 1972, Squires 1990), also western North Pacific (Sivertsen & Holthuis 1956, Krygier & Wasamer 1988), at depths as shallow as 200m, but concentrated deeper, possibly extending to depths of 3000m (Sivertsen & Holthuis 1956; Krygier & pearcy 1981, Cartes 1993). From along the continental slope of Nova Scotia, reported in bottom trawls at depths below 552m to 1150m, not deeper (Markle et al. 1988). Appears to have a lifestyle similar to congener *P. multidentata*, with both pelagic and benthic members of the population, and although the depth distributions of the two overlap (Markle et al. 1998, Cartes 1993 and references within) the former is generally distributed deeper (Mattiews & Pinnoi 1972, Markle et al. 1998).

Catch at Gully Main Station: A total of 7 specimens collected, absent from sets fishing to 250m, 4 from sets to 1250m. The majority of collections (5) at night, indicating active net avoidance during the day, some swarming at night, or a migration if individuals from below 1250m. The largest animals were from sets fishing to 750m at night. Not recorded in 2009, most frequently encountered in 2007.

Remarks: Very small individuals of *P. tarda* (less than about 10mm carapace length) are difficult to separate morphologically from very small *P. multidentata* (Mattiews & Pinnoi 1972). Because *P. tarda* was relatively rare in collections, the few very small animals were assigned to *P. multidentata*, and a few *P. tarda* may have been misidentified.

Figure 3.33. *Pasiphaea tarda*

Decapoda: Pleocyemata: Brachyura

Family undetermined

pelagic juvenile crab larvae

WoRMS AphiaID: 106673

Identification: Johnson & Allen, 2005, p. 191, fig. 24.

Reported geographical and depth distribution: No attempt was made to summarize the regional or world-wide distribution of crab larvae in general.

Catch at Gully Main Station: A total of two specimens collected, both in 2009. One from a set to 250m during the day, a larger individual from a 1250m set at night.

Remarks: Identified to lowest practical taxon at sea, awaiting identification to lowest taxonomic level possible.

Figure 3.34. Pelagic juvenile crab larva

Decapoda: Pleocyemata: Anomura

Galatheidae

pelagic juvenile larvae

WoRMS AphiaID: 106671

Identification: Pike and Williamson, 1972; educated guess.

Reported geographical and depth distribution: No attempt was made to summarize the regional or world-wide distribution of galatheid larvae in general.

Catch at Gully Main Station: A total of 8 specimens collected, all but one recorded from deep sets fishing to 1250m, with larger individuals from night sets, possibly due to daytime net avoidance. Present in all years, but most frequently encountered in 2008.

Remarks: Identified to lowest practical taxon at sea, awaiting identification to lowest taxonomic level possible.

Figure 3.35. Pelagic Galatheidae juvenile larva

Decapoda: Macrura Repantia: Achelata

Panuliridae & Scyllaridae

Phyllosoma larvae

WoRMS AphiaID:

Identification: Johnson & Allen, 2005, p. 208-209, with fig.

Reported geographical and depth distribution: No attempt was made to summarize the world-wide distribution of phyllosoma larvae. In the western North Atlantic from South America, the Caribbean, and surrounding areas, along the east coast of North America in the Gulf Stream northward, with a very long larval period of weeks to months and the capacity for wide dispersal (Robertson 1969, Johnson & Allen 2005, Butler et al. 2011).

Catch at Gully Main Station: A total of 12 specimens collected, with most collected from 0-750m sets during the day. Only present in 2009.

Remarks: Both panulirid (spiny lobster) and scyllarid (slipper lobster) larvae were observed, grouped simply as phyllosoma at sea, awaiting identification to lowest taxonomic level possible.

Figure 3.36. Phyllosoma larva

Euphausiacea

Bentheuphausiidae

Bentheuphausia amblyops **G.O. Sars, 1885**

WoRMS AphiaID: 110681

Identification: Mauchline, 1971, p. 6, fig. 1; Kathman et al., 1986, p. 282, fig. on p. 283; Baker et al., 1990, p. 20, Plate 4, fig. 4a.

Synonyms and other generic combinations: Reviewed by Mauchline (1971).

Reported geographical and depth distribution: First Canadian Atlantic record, but one of the most widely distributed euphausiids species, from the North Atlantic, Gulf of Mexico, South Atlantic and Indo-Pacific (Banner 1950, Brinton 1962, Mauchline 1971, Kathmann et al. 1986), reportedly more common in the Pacific (Mauchline 1971). Population concentrated between 800-2000m, ranging from 400-3300m, possibly as deep as 5000m (Hargreaves 1985b, Kathmann et al. 1986, James 1987).

Catch at Gully Main Station: Just one individual from a deep set to 1250m at night in 2009.

Remarks: A monospecific, nearly cosmopolitan genus.

Figure 3.37. *Bentheuphausia amblyops*

Euphausiidae

***Meganyctiphanes norvegica* (M. Sars, 1857)**

WoRMS AphiaID: 110690

Identification: Mauchline, 1971, p. 6, fig. 4; Baker et al., 1990, p. 22, Plate 5, fig. 7a.

Synonyms and other generic combinations: *Thysanopoda norvegica* M. Sars, 1857; *Nictiphanes norvegica* G.O. Sars, 1884; *Meganyctiphanes calmani* Colosi, 1918; reviewed by Einarsson (1945), Mauchline (1971) and Tarling et al. (2010).

Reported geographical and depth distribution: Endemic to the North Atlantic, very common and abundant at mid-to-high latitudes, with at least one local population and therefore ecological considerations drawing comparisons to the vast swarms of Antarctic krill, *Euphausia superba* (Simard & Lavoie 1999, Tarling et al. 2010). To Baffin Island in the west, Greenland, further north to 80^0 N in the Norwegian Sea, also from the Mediterranean (Einarsson 1945, Brinton 1962, Mauchline 1971). In the open ocean, but principally associated with continental margins in areas with bathymetries exceeding 100m (Einarsson 1945, Cochrane et al. 1994, Tarling et al. 2010). Concentrated from 200m to 500-600m during the day, but with daytime surface swarming reported, a strong vertical migrator with most of the population moving into the upper 100m at night (Einarsson 1945, Mauchline 1971, James 1987, Sameoto et al. 1993). It is known to occur close to and aggregate at the sea bottom during the day (Mauchline 1971, Sameoto et al. 1993). May take on a benthonic or benthopelagic habit in some areas (and times?), with high density, near bottom concentrations persisting night and day, at least to depths of several hundred metres, including within submarine canyons (Greene et al. 1988, Youngbluth et al. 1989, Kaartvedt 2010). Total depth range extending into the bathypelagic below 1000m (Einarsson 1945, Angel et al. 1982, Hargreaves 1985b), with one, possibly doubtful record from 2000m (James 1987).

Catch at Gully Main Station: The most abundant species of large pelagic crustacean at the Gully Main Station, hundreds of thousands of specimens collected, estimated at nearly 440,000 in total, with sub samples (only) retained to estimate total abundance and for cataloguing. This was the only species of larger crustacean present in every set, including all of the shallow day sets to 250m, and it probably occurred throughout the water column above 1250m, day and night. Night catches at all depths were dramatically greater than day catches (6-21 times), the bulk of this difference resulting from the catch in sets fishing above 750m. Active net avoidance has been reported for *M. norvegica*, with up to 95% of the population evading capture by a towed net during the day (Sameoto et al. 1993). Though commonly reported elsewhere (Hovekamp 1989, Ian McQuinn personal communication), the evidence for such significant active avoidance by pelagic crustaceans is not universal (Hargreaves & Herring 1992, Hargreaves et al. 1993) especially when relatively large nets are used (Tarling et al. 2010). *Meganyctiphanes norvegica* is a swarming/schooling species, and this behaviour at night could contribute to the uneven diel catch pattern observed.

Daytime depth dependant size distributions have been reported from relatively shallow locations, in shelf basins shoreward of the slope, with animals near the bottom of acoustic scattering layers larger than those at the top (Sameoto et al. 1993). At night, *M. norvegica* concentrated at shallow depths above the basins, but with no size segregation. At the Gully Main Station, the average size of animals was slightly greater in sets fishing deeper, day and night, indicating a persistent depth dependant size distribution, possibly because depth was sufficient enough to allow it. Estimated stratum catch indicated a population concentrated in the upper 250m day and night, with a relatively small number of animals extending to below 750m during the day, but the entire population above 750m at night (Appendix A).

Present and abundant in all years, but unlike most species, a large variation in annual catch, with overwhelming catches in 2007 during the cold intermediate event, a fairly dramatic decrease in 2008, and a rebound in 2009, but not to the amounts observed in 2007 (Appendix B). This result is confounded by the use of a solid aquarium cod-end in 2008 and 2009, which may have systematically undersampled *M. norvegica* in shallow sets to 250m by over 30% (Kenchington et al. 2009, Chapter 2).

Remarks: A monospecific genus most closely related to the genus *Thysanopoda* (Tarling et al. 2010).

Figure 3.38. *Meganyctiphanes norvegica*

***Thysanopoda acutifrons* Holt & Tatterstall, 1905**

WoRMS AphiaID: 110712

Identification: Mauchline, 1971, p. 6, fig. 2; Kathman et al., 1986, p. 352, fig. on p. 355; Baker et al., 1990, p. 32, Plate 10, fig. 8b.

Synonyms and other generic combinations: *Thysanoopda pectinata* Hansen, 1905; *Thysanopoda jahnstoni* Sheard, 1942; *Thysanopoda dubia* Banner, 1949; reviewed by Einarsson (1945) and Mauchline (1971).

Reported geographical and depth distribution: Widespread, in the North Atlantic to 70^0 N, Davis Straight, Iceland and Norway (Einarsson 1945, Mauchline 1971), also in the South Atlantic, and Indo-Pacific, 400-2000m by day, concentrated at 900-1000m, slightly shallower at 200-2000m by night (Einarsson 1945, Brinton 1962, Kathmann et al. 1986, James 1987); with one report to 4000m (Brinton, 1962).

Catch at Gully Main Station: Nearly 400 specimens collected, absent from sets fishing shallower than 250m, with the largest catches from sets fishing to 1250m during the day, double that observed at night. This large daytime catch at depth may be the result of shoaling at greater depths during the day, with the catch from sets to 750m relatively constant day and night. A substantial catch in the one exploratory set to 1500m. Average size of animals slightly greater at night compared to day in both sets fishing to 750m and 1250m, suggesting a nighttime migration of some larger animals from below 1250m. With considerably larger animals from the one deep exploratory set to 1500m. Estimated stratum catch indicated a population concentrated above 750m at night, below 750m during the day, but with total daytime catch much larger than night, evidence for both diel vertical migration and daytime shoaling of individuals below 750m. A large part of the population was also estimated to extend into the bathypelagic below 1250m. *Thysanopoda acutifrons* was present in all years and common in deeper sets, but not abundant at the depths surveyed.

Figure 3.39. *Thysanopoda acutifrons*

Euphausiacea spp. unidentified

WoRMS AphiaID: 1128

Identification: Mauchline, 1971; Kathman et al., 1986; Baker et al., 1990.

Reported geographical and depth distribution: Widespread and abundant, but no attempt was made to summarize the regional or world-wide distribution euphausiids in general.

Catch at Gully Main Station: A total estimate of over 9000 based on the retained subsamples of *M. norvegica*. Largest catches from sets fishing to 250m and 750m, with notably larger overall catch at night. During the day, the largest catches were from the 0-250m stratum, indicating the diel change in overall catch was not exclusively due to active net avoidance, evidence for shoaling or swarming at night. Largest average size of animals was in sets to 1250m during the day, but otherwise there was no clear depth dependant size distribution. Estimated stratum catch indicated a population concentrated above 250m both day and night, extending below 750m during the day, but with the entire population above 750m at night. Catch tended to be greatest in 2009, but with highly unusual absences from night sets in 2007, probably due to processing errors during this first year in the laboratory at sea.

Remarks: A mixture of smaller species (e.g. *Thysanoessa*, *Nematoscelis*, ect.) largely undersampled with the 12mm cod end net mesh, the majority physically damaged to the point where counts and biomass for species could not be estimated.

No photo presently available.

Lophogastrida

<u>Eucopiidae</u>

***Eucopia australis* Dana, 1852**

WoRMS AphiaID: 119916

<u>Identification</u>: Banner, 1954, p. 13, pl. 1; Tattersall, 1955, p. 48, fig. 4c-d; Kathman et al., 1986, p. 140, fig. on p. 141.

<u>Synonyms and other generic combinations:</u> *Chalaraspis unguiculata* Willemoes-Suhm, 1875; *Eucopia ungiculata* (Willemoes-Suhm, 1875); *Eucopia major Hansen*, 1910; reviewed by Tattersall & Tattersall (1951).

<u>Reported geographical and depth distribution</u>: First Atlantic Canadian record but unidentified *Eucopia* sp. have been reported from off Nova Scotia and Newfoundland. Wide spread, reportedly more abundant in the eastern North Atlantic (Steel & Montevecchi 1994 and references therein), into the Gulf of Mexico, South Atlantic, and Indo-Pacific (Banner 1954, Kathman et al. 1986, Krygier & Murano 1988). Broad depth range, 600-6000m (Mauchline & Murano 1977, Kathman et al. 1986, Burghart et al. 2007), but with the population concentrated below 1000m and into the bathypelagic zone (Banner 1954). *Eucopia australis* has been reported restricted below 2500m in the eastern North Atlantic (Hargreaves 1985b).

<u>Catch at Gully Main Station</u>: The most abundant lophogastrid with a total of nearly 900 specimens collected, the majority from deep sets fishing to 1250m day and night. Overall somewhat greater catch at night, but this because of one unusually large catch in a set to 1250m in 2009: with over 200 individuals and more than twice the biomass of any other set, except the one deep exploratory set to 1500m. With 5 specimens recorded from sets

fishing to 250m, including three during the day, but all had been preceded by sets fishing to at least 750m, and therefore all shallow records possibly the result of net contamination. Overall, largest animals on average from day sets to 1250m, even greater in the one exploratory set to 1500m, with the smallest size in night sets to 250m, but no consistent pattern of size with depth. Estimated stratum catch indicated a population concentrated somewhere below 750m, day and night, with no diel vertical migration, and a large part of the population extending into the bathypelagic below 1250m. Present in all years, with the largest total and largest single catch in 2009, common and relatively abundant in the deepest sets.

Remarks: A relatively small, deep-dwelling genus with a soft carapace. All identifiable specimens were positively identified as *E. australis*, so all damaged specimens were assigned to this species as well. The genus may be in need of revision because of intraspecific morphological variation and the rarity of undamaged specimens in reference and type collections (Mauchline 1980, Roe 1984). At least two species of *Eucopia* are recognized in the North Atlantic; *E. australis* and *E. grimaldii* (Steele & Montevecchi 1994 and references therein). However, several species have at times been synonymized with *E. australis*, including *E. grimaldii* (Banner 1954, Krygier & Murano 1988), though many authors have not agreed (Hargreaves 1985b, Steele & Montevecchi 1994, Burghart et al. 2007). Our specimens correspond well with the description and figures for *E. australis* presented by Kathman et al. (1986).

Figure 3.40. *Eucopia australis*

***Eucopia sculpticauda* Faxon, 1893**

WoRMS AphiaID: 119920

Identification: Nouvel, 1950, p. 3, fig. 22-24; Tattersall & Tattersall, 1951, p.109, fig. 12-13; Kathman et al., 1986, p. 142, fig. on p. 143.

Synonyms and other generic combinations: *Eucopia australis* G.O. Sars, 1885 (in part); *Eucopia sculpticauda* Faxon, 1883; *Eucopia intermedia* Hansen, 1905; reviewed by Tattersall & Tattersall (1951).

Reported geographical and depth distribution: First Atlantic Canadian records, but widely distributed in the North Atlantic, also from the Gulf of Mexico, South Atlantic, and Indo-Pacific at depths below 600m to at least 2500m (Banner 1954, Tattersall 1955, Kathman et al. 1986, Krygier & Murano 1988, Burghart et al. 2007).

Catch at Gully Main Station: Over 100 specimens collected, all from deeper sets fishing below 250m, the majority from sets to 1250m. With larger animals on average deeper. Estimated stratum catch indicated a population concentrated somewhere below 750m with no diel vertical migration. Present in all years, but not abundant at the depths surveyed, and curiously absent from daytime sets to 750m in 2007.

Remarks: The most morphologically distinct species of *Eucopia* (Tattersall 1955).

Figure 3.41. *Eucopia sculpticauda*

Lophogastridae

***Gnathophausia zoea* Willemoes-Suhm, 1895**

WoRMS AphiaID: 119930

Identification: Nouvel, 1950, p. 3, fig. 17-19; Tattersall & Tattersall, 1951, p.82, fig. 3-5.

Synonyms and other generic combinations: *Gnathophausia willemoesii* G.O. Sars, 1885; *Gnathophausia sarsii* Wood-Mason & Alcock, 1891; *Gnathophausia cristata* Illig, 1906; reviewed by Tattersall & Tattersall (1951).

Reported geographical and depth distribution: Widely distributed, North Atlantic, Gulf of Mexico, South Atlantic, and Indo-Pacific (Tattersall & Tattersall 1951, Tattersall 1955, Burghart et al. 2007), at depths from 200-2400m, possibly to 3000m, with the population concentrated below 700m (Pequegnat 1965, Hargreaves 1985b, 1989).

Catch at Gully Main Station: Over 200 specimens collected, most from deep sets fishing to 1250m. With just one specimen recorded above 250m in a nighttime set, and with more biomass at night at all depths, indicating some diel vertical migration or active daytime net avoidance. Larger animals on average at night, based on total biomass divided by abundance, with the largest animals from the one deep exploratory set to 1500m. Estimated stratum catch indicated a population concentrated somewhere below 750m during the day, a diel vertical migration, at least part of the population spreading upwards at night, or active net avoidance during the day. Present in all years, with the largest catches in 2007, smallest in 2009, common in the deepest sets, but not abundant at the depths surveyed.

Remarks: One of the larger pelagic Crustacea and probably a very long-lived species (Childress & Price 1978).

Figure 3.42. *Gnathophausia zoea*

***Gnathophausia gigas* Willemoes-Suhm, 1873**

WoRMS AphiaID: 119927

Identification: Nouvel, 1950, p. 3, fig. 13-16; Tattersall & Tattersall, 1951, p.77, fig. 1-2; Pequegnat, 1965, p. 408, fig. 5; Kathman et al., 1986, p. 158, fig. on p. 159.

Synonyms and other generic combinations: *Gnathophausia drepanephora* Holt & Tattersall, 1905; *Neognathophausia gigas* (Willemoes-Suhm, 1895); reviewed by Tattersall & Tattersall (1951).

Reported geographical and depth distribution: Widely distributed, North Atlantic, Gulf of Mexico, South Atlantic, and Indo-Pacific, with one report as shallow as 100m (Krygier & Murano 1988) but typically restricted to deeper than 600m (Tattersall 1955, Hargreaves 1985b, Kathman et al. 1986) to a maximum depth of 4400m (Kathman et al. 1986); Reported rare above 1500m in the eastern North Atlantic (Hargreaves 1989). Historically considered exclusively pelagic (Tattersall & Tattersall 1951), but one individual observed within a few meters of bottom in the deep water off the Grand Banks, Newfoundland, by the remotely operated submersible ROPOS (K. MacIsaac personal observation).

Catch at Gully Main Station: Over 200 specimens collected, the majority from deep sets to 1250m, absent from sets fishing to 250m. With notably larger catches during the day in sets fishing to 1250m, possibly indicating some shoaling during the day. Estimated stratum catch indicated a population essentially restricted below 750m night and day, with no evidence for a diel vertical migration, extending into the bathypelagic below 1250m. Present in all years, common in the deepest sets, but not abundant at the depths surveyed.

Remarks: One of the larger pelagic Crustacea and probably a very long-lived species (Childress & Price 1978).

Figure 3.43. *Gnathophausia gigas*

Mysida

<u>Mysidae</u>

***Boreomysis arctica* (Kroyer, 1861)**

WoRMS AphiaID: 119962

<u>Identification</u>: Nouvel, 1950, p. 4, fig. 32-38; Tattersall & Tattersall, 1951, p.132, fig. 21b, 22; Kathman et al., 1986, p. 104, fig. on p. 105.

<u>Synonyms and other generic combinations</u>: *Mysis arctica* Kroyer, 1861; *Arctomysis arctica* Czerniavsky, 1883; reviewed by Tattersall & Tattersall (1951).

<u>Reported geographical and depth distribution</u>: Circumpolar, North Atlantic and into the Mediterranean, where it is one of the most common and abundant of deep-dwelling mysids (Mauchline & Murano 1977; Kathman et al. 1986, Cartes & Sorbe 1998). Also reported from the South Atlantic and Indo Pacific, benthopelagic or benthonic at depths from 200-1900m, possibly as deep as 2500m (Mauchline 1986), may be more abundant on or near bottom (Mauchline 1986, Cartes & Sorbe 1998).

<u>Catch at Gully Main Station</u>: A total of 26 specimens collected, absent from sets to 250m, with nearly half of individuals from day sets to 1250m. Present in all years, with the smallest catch in 2009, not common or abundant at the depths surveyed.

Figure 3.44. *Boreomysis arctica*

***Boreomysis semicoeca* Hanson, 1905**

WoRMS AphiaID: 161369

Identification: Nouvel, 1950, p. 4, fig. 50-52; Hargreaves & Murano, 1996, p. 670, fig. 3.

Reported geographical and depth distribution: First Canadian records, reported from the eastern North Atlantic, the Mediterranean, and Indo- Pacific, found at depths below 1000m to at least 3700m (Mauchline & Murano 1977, Hargreaves & Murano 1996).

Catch at Gully Main Station: A total of 22 specimens collected, absent from shallow sets to 250m, with 21 individuals from deep sets to 1250m and 1500m. Present in all years, but not common or abundant at the depths surveyed.

No photo presently available.

Amphipoda

Gammaridea

Cyphocarididae

***Cyphocaris richardi* Chevroux, 1905**

WoRMS AphiaID: 102557

Identification: Shoemaker, 1945, p. 187, fig. 1d; Barnard, 1954, p.53, pl. 2-3.

Reported geographical and depth distribution: First Canadian records, but reported elsewhere in the North Atlantic, also South Atlantic and South Pacific, from 76m to 4900m (Shoemaker 1945, Barnard 1961, Brusca 1967).

Catch at Gully Main Station: Just two individuals collected, one in a set to 1250m in 2009 and one in the deep exploratory set to 1500m in 2007, both during the day.

Remarks: Congenerics *C. challengeri* and *C. anonyx* both reported on the west coast of Canada.

Figure 3.45. *Cyphocaris richardi*

Lysianassidae

***Eurythenes obesus* (Chevreux, 1905)**

WoRMS AphiaID: 102564

Identification: Barnard, 1961, p.38, fig. 8; Stoddart and Lowry, 2004, p.445, fig 12-14; Senna, 2009, p. 88, fig. 3.

Synonyms and other generic combinations: *Katius obesus* Chevreux, 1905; *Eurythenes obesus* Schellenburg, 1955, reviewed by Stoddart and Lowry (2004).

Reported geographical and depth distribution: Wide distribution, North & South Atlantic, Indo-Pacific, at depths from 128-5610m, but typically below 500m (Barnard 1961, Stoddart and Lowry 2004), including on or near bottom (Barnard 1961, Brusca 1967).

Catch at Gully Main Station: A total of 34 specimens collected, essentially restricted to depths somewhere below 250m with most individuals from sets to 1250m. One fairly large individual from a set to 250m may have been the result of net contamination from the set immediately prior to 1250m. Overall catch was greater at night in sets to 1250m, suggesting some nighttime shoaling at depth or individuals migrating from below 1250m. Estimated stratum catch indicated a distribution extending into the bathypelagic below 1250m. Present in all years, one of only two regularly occurring gammarid amphipod species, not abundant at the depths presently surveyed.

Figure 3.46. *Eurythenes obesus*

***Paracallisoma* sp.**

WoRMS AphiaID: 101636

Identification: Holmes, 1908, p. 500-502, fig. 10-12; Barnard, 1954, p.54, pl. 4-5; Barnard, 1964, p. 319, fig. 3.

Synonyms and other generic combinations: *Scopelocheirus* Bate, 1856

Reported geographical and depth distribution: First Canadian Atlantic records, just the third occurrence in the western North Atlantic (Shoemaker 1945, Brusca 1967, Thurston 1990), including a specimen tentatively identified as "*Paracallisoma* sp.?" from the stomach of a *Halosauropsis macrochir* collected at 1400-2700m (Sedberry and Musick 1978). Probably meso- to abyssopelagic, but congeneric *Paracallisoma coeca* has been reported as a significant food for surface feeding seabirds in the western North Pacific (Vermeer and Devito 1988).

Catch at Gully Main Station: A total of three specimens collected, all from deep sets to 1250m during the day, two in 2007, one in 2009.

Remarks: There has been considerable confusion around this genus in the Atlantic and Pacific (Hurly 1963, Barnard 1964). At least two species occur in the Atlantic: *P. alberti* Chevreux, 1903, to date restricted to the eastern Atlantic, and *P. platyepistomum* Andres, 1977, only once recorded from the western North Atlantic (as *Scopelocheirus coecus*), and apparently more closely related to forms in the southern ocean (Shoemaker 1945, Thurston 1990 and references therein). Our specimens fit the brief description by Shoemaker (1945) for *P. platyepistomum* in that the first urosome segment is clearly notched, more so than for *P. coeca* figured by Holmes (1908). Work continues on the identification of our specimens.

Figure 3.47. *Paracallisoma sp.*

Stegocephalidae

Parandania boecki **(Stebbing, 1888)**

WoRMS AphiaID: 214747

Identification: Stebbing, 1888, p. 735, pl. 36; Barnard, 1932, p. 77, fig. 35; Barnard, 1961, p. 57, fig. 27; Moore 1992, p. 923, fig. 6.

Synonyms and other generic combinations: *Andania boecki* Stebbing, 1888; reviewed by Barnard (1961).

Reported geographical and depth distribution: First Atlantic Canadian records but widespread, reported to the north in Baffin Bay, to the south off Bermuda, and in the eastern North Atlantic (Shoemaker 1945, Thurston 1976), also the South Atlantic and Indo-Pacific, at depths as shallow as 200m, but typically below 550m, to 3000-4000m (Barnard 1961, Thurston 1976, Barnard and Karaman 1991, Moore 1992, Dauvin and Bellan-Santini 2004).

Catch at Gully Main Station: A total of 44 specimens collected, absent from sets fishing above 250m, with the majority of records (28) and largest individuals on average from sets to 750m. Estimated stratum catch indicates a population concentrated somewhere between 250-750m, extending into the bathypelagic below 1250m. Present in all years, one of only two regularly occurring gammarid amphipod species, not abundant at the depths presently surveyed.

Remarks: The full range of morphological variation may not be known (Barnard 1961, Moore 1992), and sibling species may exist.

Figure 3.48. *Parandania boecki*

Hyperiidea

Cystisomatidae

***Cystisoma* spp.**

WoRMS AphiaID:101793

Identification: Woltereck, 1903, p. 447, fig. 1-4; Vinogradov et al., 1996, p. 244, fig. 121-125.

Synonyms and other generic combinations: *Thaumatops* Bouvallius, 1886; reviewed by Vinogradov et al. (1996).

Reported geographical and depth distribution: First Atlantic Canadian records, but reported to the south near Bermuda and in the eastern North Atlantic (Barnard 1932, Shoemaker 1945, Thurston 1976), also from the South Atlantic and Indo-Pacific, probably meso- to abyssopelagic (Thurston 1976, Vinogradov et al. 1996).

Catch at Gully Main Station: A total of 8 specimens collected, absent from above 250m, with the largest catch from sets fishing to 1250m during the day in 2008. Unexpectedly absent in 2007, possibly due to processing errors during this first year in the laboratory at sea.

Remarks: Much has been reported concerning the difficulty of identification of species, because of the fragility of specimens, variable morphological characters, and insufficient descriptions (Barnard 1932, Shoemaker 1945, Thurston 1976, Vinogradov et al. 1996). Work continues on the identification of our specimens. A species probably associated with pelagic jellyfish (Gasca and Haddock 2004).

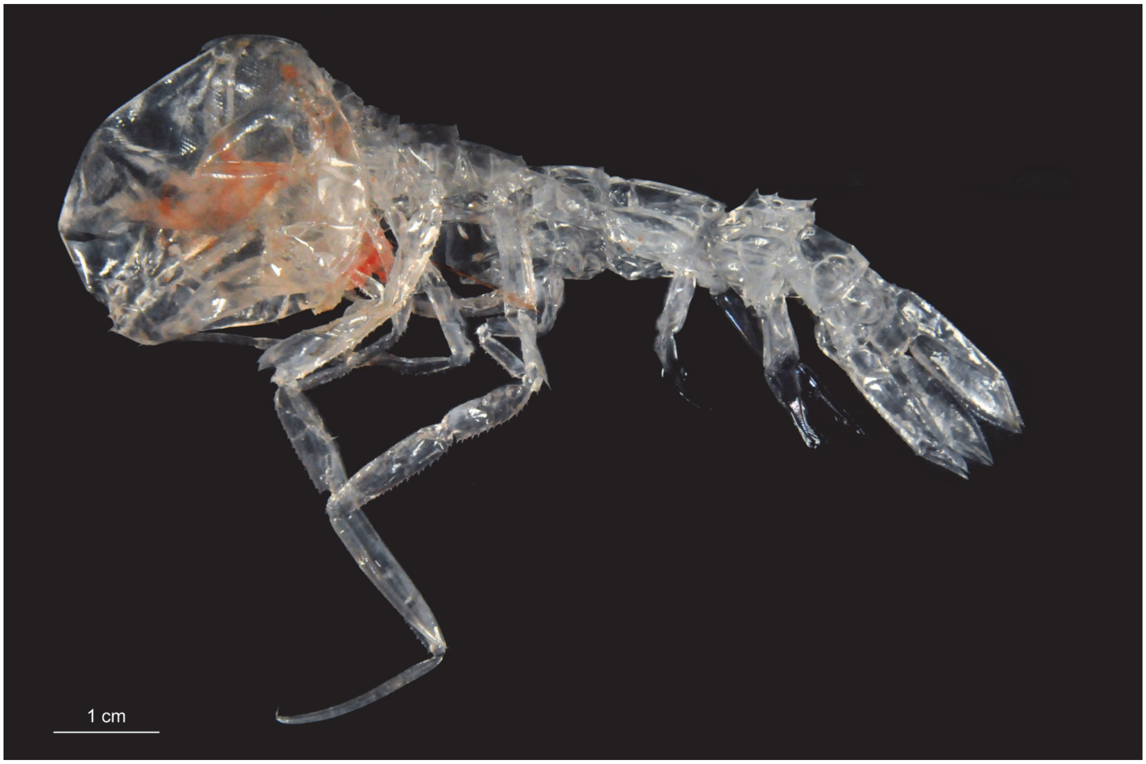

Figure 3.49. *Cystisoma spp.*

Hyperiidae

***Hyperia galba* (Montagu, 1815)**

WoRMS AphiaID: 103251

Identification: Sars, 1895, pl. 2-3(1); Dunbar, 1963, p.3, fig. 1; Bowman, 1973, p. 10, fig. 7; Vinogradov et al., 1996, p. 323, fig. 129-130.

Synonyms and other generic combinations: *Cancer gammarus galba* Montagu, 1815; *Hyperia latreille* Milne-Edwards, 1830; reviewed by Vinogradov et al. (1996).

Reported geographical and depth distribution: North Atlantic into the Arctic, possibly the Mediterranean, also the North Pacific, at depths from 0-2000m (Barnard 1932, Bowman 1973, Vinogradov et al. 1996, Couwelaar 2003).

Catch at Gully Main Station: A total of 48 specimens collected, probably throughout the water column above 1250m, most frequently encountered in sets to 250m day and night. Estimated stratum catch indicating a population concentrated in the upper 250m, day and night, extending to somewhere below 750m. Present in all years, not abundant, with smallest catch in 2008.

Remarks: A species associated with pelagic jellyfish (Gasca and Haddock 2004).

No photo presently available.

***Hyperia medusarum* (Muller, 1776)**

WoRMS AphiaID: 103253

Identification: Sars, 1895, pl. 3(2); Dunbar, 1963, p.3, fig. 2; Bowman, 1973, p. 6, fig. 2-5; Vinogradov et al., 1996, p. 323, fig. 131.

Synonyms and other generic combinations: *Cancer medusarum* O.F. Muller, 1776; *Hyperia sueri* Latreille, 1823; reviewed by Vinogradov et al. (1996).

Reported geographical and depth distribution: North and South Atlantic, Pacific (bipolar), at depths from 200-1800m, concentrating at shallower depths at night (Brusca 1967, Bowman 1973, Vinogradov et al. 1996, Couwelaar 2003).

Catch at Gully Main Station: Just three specimens collected, all from night sets to 1250m, 1 in 2008, two in 2009.

Remarks: A species associated with pelagic jellyfish (Gasca and Haddock 2004).

No photo presently available.

Hyperia spinigera **Bovallius, 1889**

WoRMS AphiaID: 103254

Identification: Stephensen, 1942, p. 460, fig. 78; Bowman, 1973, p. 20, fig. 15; Vinogradov et al., 1996, p. 328, fig. 133; Zeidler, 1992, p. 98, fig. 11.

Synonyms and other generic combinations: *Hyperia antarctica* Spandl, 1927; reviewed by Thurston (1977) and Zeidler and DeBroyer 2009.

Reported geographical and depth distribution: Widely distributed, North and South Atlantic, Indo-Pacific, at depths from 25-2000m, most abundant at 600-900m in the North Atlantic (Stephensen 1942, Bowman 1973, Thurston 1977, Vinogradov et al. 1996).

Catch at Gully Main Station: Just one specimen collected, from a set fishing to 750m during the day in 2009.

Remarks: A species associated with pelagic jellyfish (Gasca and Haddock 2004).

No photo presently available.

***Pegohyperia princeps* K.H. Barnard, 1931**

WoRMS AphiaID: 325390

Identification: Barnard, 1932, p. 276, fig 162-164, pl.1, fig. 5-5a; Vinogradov et al., 1996, p. 372, fig. 158.

Reported geographical and depth distribution: First Canadian record and first published report from the North Atlantic, only known from a few scattered records, from the South Atlantic, Antarctic, and Pacific, 0-2000m (Vinogradov et al. 1996, Zeidler & DeBroyer 2009).

Catch at Gully Main Station: Just one specimen recorded at Gully Main, from a set fishing to 1250m at night in 2007.

Remarks: Additional specimens collected from other sampling stations throughout the Gully (MacIsaac unpublished data).

Figure 3.50. *Pegohyperia princeps*

***Themisto gaudichaudii* Guerin, 1825**

WoRMS AphiaID: 325384

Identification: Sars, 1895, pl. 5(2), 6(2); Dunbar, 1963, p.2, fig. 5, 7; Vinogradov et al., 1996, p. 367, fig. 155-156.

Synonyms and other generic combinations: *Themisto gaudichaudii* Goes, 1865; *Parathemisto gracilipes* (Norman, 1869); *Themisto bispinosa* Boeck, 1871; *Euthemisto bispinosa* (Boeck, 1871); reviewed by Zeidler and DeBroyer (2009).

Reported geographical and depth distribution: A cold water species, North Atlantic to about 72^0N, Mediterranean, South Atlantic, Pacific (bipolar), circum-Antarctic (Dunbar 1963, Bowman 1960, Vinogradov et al. 1996), to depths of at least 1400m, but mainly above 500m. Daytime layers reported at 25-50m, 100-200m and 200-500m, shallower at night, and can be very abundant at the surface (Bowman et al. 1982, Williams & Robins 1981, Vinogradov et al. 1996, Zeidler & DeBroyer 2009).

Catch at Gully Main Station: The most abundant amphipod, tens of thousands of specimens collected, estimated at over 40,000 in total, with sub samples (only) retained to estimate total abundance and for cataloguing. Greatest catches were from sets fishing to 750m during the day and 250m at night, indicating a diel vertical migration or active net avoidance during the day. These catch maxima also corresponded with decreased frequency of occurrence over these depth ranges relative to other times of day and depths, representative of increased patchiness, indicating a shoaling of individuals day and night in the upper 750m during the day and upper 250m at night. Overall catch was considerably greater at night, suggesting increased shoaling or schooling at night or active net avoidance during the day. Estimated stratum catch indicated a population as much above as below 250m during the day, but concentrated above 250m at night, with considerably greater catch at night (Appendix A). Present in all years, common and abundant, generally with largest day catches in 2007, largest night catches in 2008, and typically lowest overall catches in 2009 (Appendix B).

Remarks: A long history of synonymies, chief among these the specific status of northern vs. southern forms (Schneppenheim & Weigmann-Haass 1986), but also variation within the northern form, particularly that of dorsal spination (Sheader & Evans 1974).

Figure 3.51. *Themisto gaudichaudii*

***Themisto libellula* Lichtenstein, 1882**

WoRMS AphiaID: 156452

Identification: Sars, 1895, pl. 6(1); Dunbar, 1963, p.2, fig. 6; Vinogradov et al., 1996, p. 364, fig. 153-154.

Synonyms and other generic combinations: *Parathemisto libellula* (Lichtenstein, 1882); reviewed by Bowman (1960) and Vinogradov et al. (1996).

Reported geographical and depth distribution: Circumpolar, North Atlantic, North Pacific and South Atlantic (Bowman 1960, Dunbar 1963), to 1000m but concentrated in the upper 100m (Vinogradov et al. 1996, Dalpadado et al. 2001). This species is a good indicator of the presence of Arctic water or, in Atlantic Canada, the cold Labrador Current (Bousfield 1951, Dunbar 1963).

Catch at Gully Main Station: A total of 155 specimens collected from the retained subsamples of *P. gaudichaudii*, all from 2007, with largest catches from sets fishing 0-250m, day and night. Its appearance was coincident with a large cold intermediate layer of water originating from the Labrador Current/Gulf of St Lawrence outflow (Kenchington et al. 2009). Historically reported from the Arctic and Labrador Current (Bousfield 1951), *T. libellula* has recently established a permanent population in the Gulf of St Lawrence (Marion et al. 2008), and is probably a regular but episodic member of the Gully pelagic fauna.

Remarks: The only other species of *Themisto* observed, with *T. abyssorum* predicted to be present but not recorded, possible due to smaller size.

No photo presently available.

Phronimidae

***Phronima sedentaria* (Forskal, 1775)**

WoRMS AphiaID: 103272

Identification: Shih and Dunbar, 1963, p. 3, fig. 2, 7; Shih 1991, key only; Vinogradov et al., 1996, p. 415, fig. 178-179.

Synonyms and other generic combinations: *Cancer sedentarius* Forskål, 1775; *Gammarus sedentarius* Schousboe, 1802, *Phronima custos* Risso, 1816; *Phronima atlantica* Guérin-Meneville, 1836; reviewed by Zeidler and DeBroyer (2009).

Reported geographical and depth distribution: Cosmopolitan, North Atlantic, Mediterranean, Caribbean and Gulf of Mexico, South Atlantic, and Indo-Pacific (Shih and Dunbar 1963, Vinogradov et al. 1996, Zeidler & DeBroyer 2009), at depths from the surface to at least 1500m, possibly to 1800m, concentrated between 0-600m during the day, 0-300m at night (Shih 1969, Thurston 1976, Zeidler and DeBroyer 2009).

Catch at Gully Main Station: A total of 22 specimens collected, somewhat greater catch in sets fishing to 750m, but probably throughout the water column. Considerably more animals during the day, nearly triple the catch at night, essentially identical to observations in the eastern North Atlantic (Thurston 1976). Present in all years but not abundant, smallest catches in 2007, more frequently recorded in 2008.

Figure 3.52. *Phronima sedentaria*

Phrosinidae

***Phrosina semilunata* Risso, 1882**

WoRMS AphiaID: 103273

Identification: Bowman and Gruner, 1973, p. 39, fig. 50; Vinogradov et al., 1996, p. 431, fig. 187.

Synonyms and other generic combinations: Reviewed by Zeidler and DeBroyer (2009).

Reported geographical and depth distribution: Cosmopolitan in tropical and temperate waters, North Atlantic, Mediterranean, Caribbean and Gulf of Mexico, and Indo-Pacific. Discontinuously distributed from the surface to 1000m (rarely deeper), most frequent in surface layers where it may form large local surface concentrations or swarms (Shoemaker 1945, Vinogradov et al. 1996; Thurston 1976). It is reported to be one of the most common amphipods in the central North Atlantic and Indo-Pacific (Grice & Hart 1962, Thuston 1976, Vinogradov 1999).

Catch at Gully Main Station: A total of six specimens collected, all from 2009. Three specimens from sets fishing to 750m at night, no more than one at any other depth range.

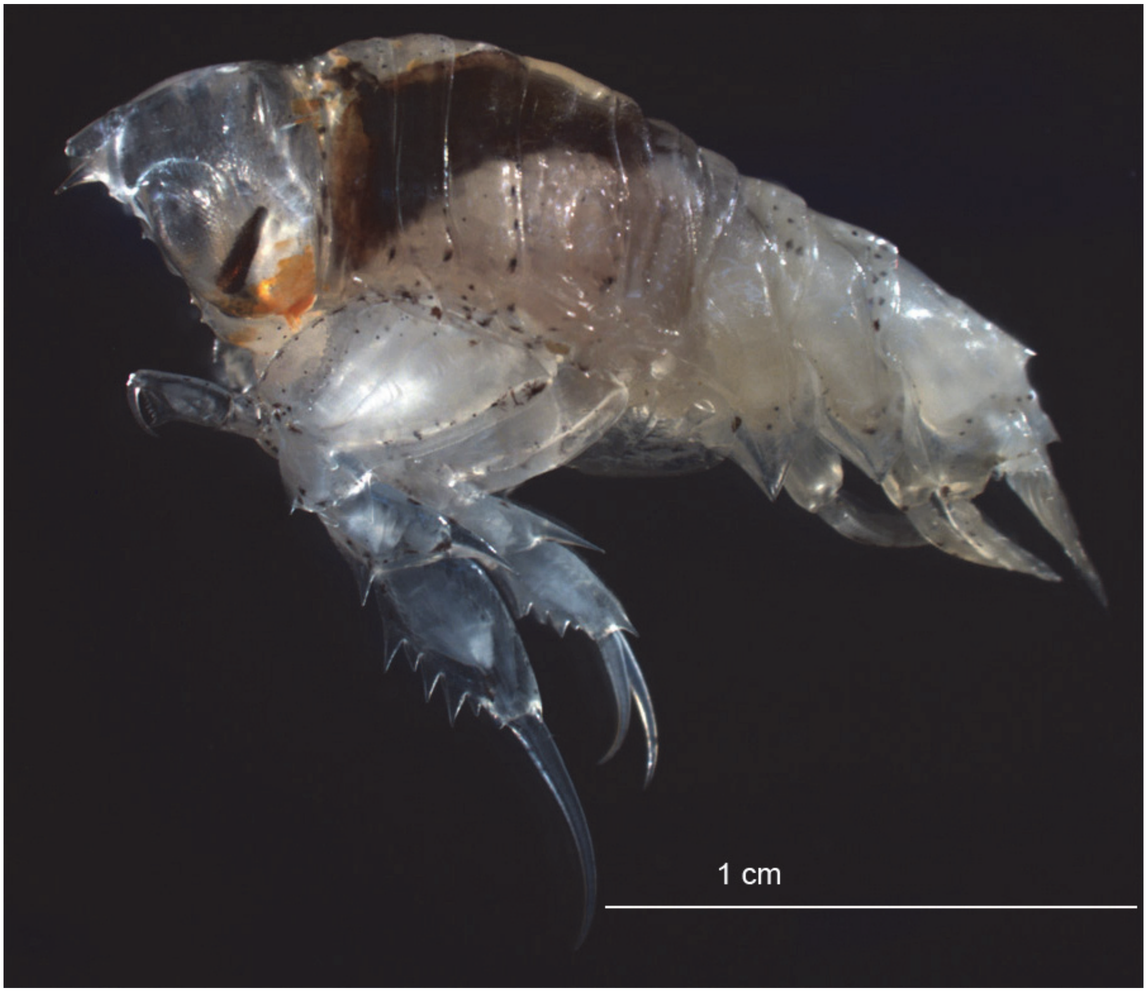

Figure 3.53. *Phrosina semilunata*

Platyscelidae

***Platyscelus ovoides* (Risso, 1816)**

WoRMS AphiaID: 103275

Identification: Bowman and Gruner, 1973, p. 54 fig. 74-75; Vinogradov et al., 1996, p. 547, fig. 235.

Synonyms and other generic combinations: *Typhus ovoides* Risso, 1816; *Typhis ferus* Milne-Edwards, 1830; *Platyscelus intermedius* Thompson, 1879; *Eutyphus globosus* (Claus, 1979); *Platyscelus globosus* Claus, 1879; reviewed by Zeidler and DeBroyer (2009).

Reported geographical and depth distribution: Circumtropical, Atlantic, Caribbean, Mediterranean, Indo-Pacific, typically epipelagic, but to 800m (Vinogradov et al. 1996, Gasca 2009).

Catch at Gully Main Station: A total of eight specimens collected, all from 2008. With six specimens from sets fishing to 750m day and night.

Figure 3.54. *Platyscelus ovoides*

Lanceolidae

***Lanceola* spp. Say, 1818**

WoRMS AphiaID: 101801

Identification: Bowman and Gruner, 1973, p. 20 fig. 23; Vinogradov et al., 1996, p. 57, fig. 5-21; Zeidler, 2009, p. 10, fig. one-20.

Synonyms and other generic combinations: Reviewed by Vinogradov et al. (1996) and Zeidler and DeBroyer (2009).

Reported geographical and depth distribution: Widespread, Arctic, North Atlantic, South Atlantic, Indo-Pacific, and Antarctic, epi- to bathypelagic (Vinogradov et al. 1996, Zeidler & DeBroyer 2009).

Catch at Gully Main Station: A total of 39 specimens collected, with the majority (27) from deeper sets to 1250m, and slightly greater catches overall at night. Two records in sets fishing 0-250m at night, but both had been preceded by sets to 750m and 1250m, so the could represent net contamination. Present in all years, smallest catches in 2008.

Remarks: A speciose genus with approximately 15 species reported world-wide, at least two species present in the Gully with work continuing on the identifications for this genus. Species associated with pelagic jellyfish.

No photo presently available

***Megalanceola stephenseni* (Chevreux, 1920)**

WoRMS AphiaID: 325364

Identification: Bowman and Gruner, 1973, p. 20 fig. 24; Vinogradov et al., 1996, p.95, fig. 25; Zeidler, 2009, p. 76, fig. 27.

Synonyms and other generic combinations: *Lanceola stephenseni* Chevreux, 1920; *Megalanceola terrae-novae* Pirlot, 1935; *Megalanceola terranovae* Herring, 1981; reviewed by Zeidler (2009) and Zeidler and DeBroyer (2009).

Reported geographical and depth distribution: North Atlantic, Indo-Pacific, and Antarctic, meso- to bathypelagic, with most collections from depths of around 1000m (Vinogradov et al. 1996, Zeidler & DeBroyer 2009). Relatively rare, as of 2009 only seven previous reports in the scientific literature for a total 31 individuals collected world-wide, but the North Atlantic between Nova Scotia, Bermuda and the Azores is one of its known locales (Zeidler 2009).

Catch at Gully Main Station: A total of 74 specimens collected, more or less eclipsing the total number of specimens previously reported world-wide. The majority of records (53) were from deeper sets to 1250m, with slightly greater catches overall at night. One record in a set fishing 0-250m at night, but it had been preceded by a set to 1250m, so could represent net contamination. Present in all years, with smallest catches in 2007.

Remarks: A wide range of sizes present, with material to eventually be re-examined more closely for variations in morphology. Additional specimens from this reportedly rare amphipod were collected from other sampling stations in the Gully (MacIsaac unpublished data). Remarks: A species associated with pelagic jellyfish.

Figure 3.55. *Megalanceola stephenseni*

Scinidae

***Scina* sp. Prestandrea, 1883**

WoRMS AphiaID: 101810

Identification: Vinogradov et al., 1996, p.157, fig. 59-93.

Synonyms and other generic combinations: Full synonymies in Zeidler & DeBroyer 2009.

Reported geographical and depth distribution: Widespread, Arctic, North Atlantic, Mediterranean, South Atlantic, Indo-Pacific, and Antarctic, epi- to bathypelagic (Vinogradov et al. 1996, Zeidler & DeBroyer 2009).

Catch at Gully Main Station: Just one specimen collected, in a set fishing to 750m at night in 2009.

Remarks: One of the most speciose groups of hyperiid amphipods, with the number of species worldwide nearing 40, and the family in need of taxonomic revision (Zeidler & DeBroyer 2009). The present specimen is damaged, but work on the identification will continue.

Figure 3.56. *Scina sp.*

Isopoda

<u>Anuropidae</u>

***Anuropus panteni* Brandt & Retzlaff, 2002**

WoRMS AphiaID: 257922

<u>Identification</u>: Brandt & Retzlaff, 2002, p. 128, fig. 1- 7 (identification provided by Dr. Eric Lazo-Wasem, Yale Peabody Museum of Natural History).

<u>Reported geographical and depth distribution</u>: First Canadian record, second for the North Atlantic, a recently described species from east Greenland, 63^0N, from a bottom trawl to 450m depth (Brandt & Retzlaff, 2002). Species of this genus are rarely encountered (Kensley & Chan 2001) but as a genus *Anuropus* it is widespread, meso- to bathypelagic, occasionally occurring near the surface (Jansen 1981 and references therein); a parasite on pelagic jellies using them for feeding and transport (Barham & Pickwell 1969, Ohtsuka et al. 2009).

<u>Catch at Gully Main Station</u>: Just one specimen collected, from a set fishing to 750m at night in 2007.

<u>Remarks</u>: Ten species of the genus *Anuropus* are known to science, but with very few specimens, typically only one sex described (Kensley & Chan 2001). Additional specimens of *A. panteni* were collected during the course of the broader survey program (MacIsaac unpublished data). Photo presented here is of a juvenile specimen.

Figure 3.57. *Anuropus panteni* (juvenile)

<u>Idoteidae</u>

Idotea metallica **Bosc, 1802**

WoRMS AphiaID: 119047

<u>Identification</u>: Richardson, 1905, p. 362, fig. 392.

<u>Synonyms and other generic combinations:</u> *Idotea algirica* Lucas, 1949; *Idotea annulata* Dana, 1849; *Idotea argentea* Dana, 1849; *Idotea atrata* Costa, 1838; *Idotea brevicornis* Rathke, 1843; *Idotea margaritacea* Dana, 1853*; Idotea peloponesiaca* Roux, 1830; *Idotea robusta* Kroyer, 1846; *Idotea rugosa* Milne-Edwards, 1840; reviewed by Richardson (1905).

<u>Reported geographical and depth distribution</u>: Drifting widely in the neuston, among Sargassum and other flotsam in the Gulf Stream and North Atlantic Drift, occasionally reaching the North Sea from the east coast of North America, also reported from the Mediterranean, South Atlantic, and Indo-Pacific (Naylor 1957).

<u>Catch at Gully Main Station</u>: A total of 6 specimens, all from 2007, in sets fishing to 750m and 1250m during the daytime only. Most true neuston would be displaced from capture by the net by the ship itself. Collections only during the day may indicate the existence of a small diel vertical migration, bringing at least some of the animals just below any displacement effect by the ship.

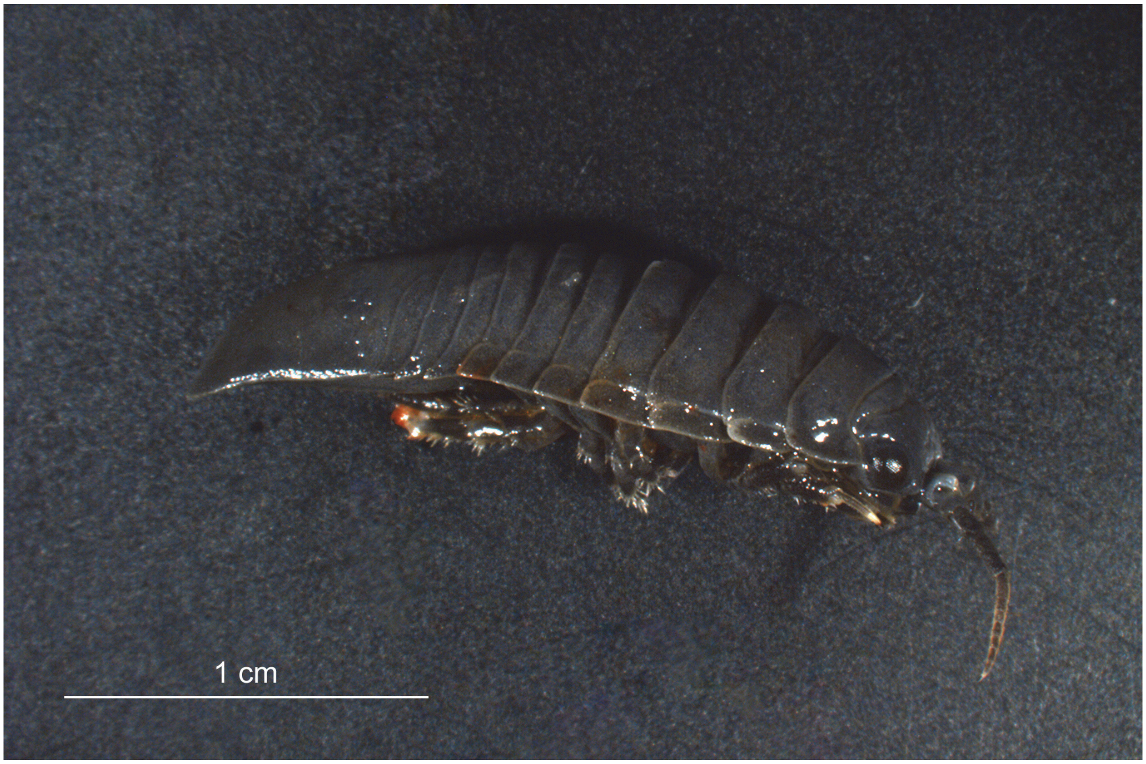

Figure 3.58. *Idotea metallica*

Stomatopoda

<u>Squillidae</u>

Stomatopod larvae

WoRMS AphiaID: 136113

Identification: Johnson & Allen, 2005, p. 226-227, with fig.

Reported geographical and depth distribution: No attempt was made to summarize the worldwide distribution of stomatopod larvae in general. In the western North Atlantic, Gulf of Mexico, east coast U.S., in the Gulf Stream northward, with a long larval period of weeks and the capacity for dispersal (Cox & Wiebe 1979, Morgan & Goy 1987, Johnson & Allen 2005).

Catch at Gully Main Station: A total of five specimens collected, present in all years, with three from a set fishing to 1250m at night in 2008.

Remarks: Grouped simply as antizoea larvae at sea, awaiting identification to lowest taxonomic level possible.

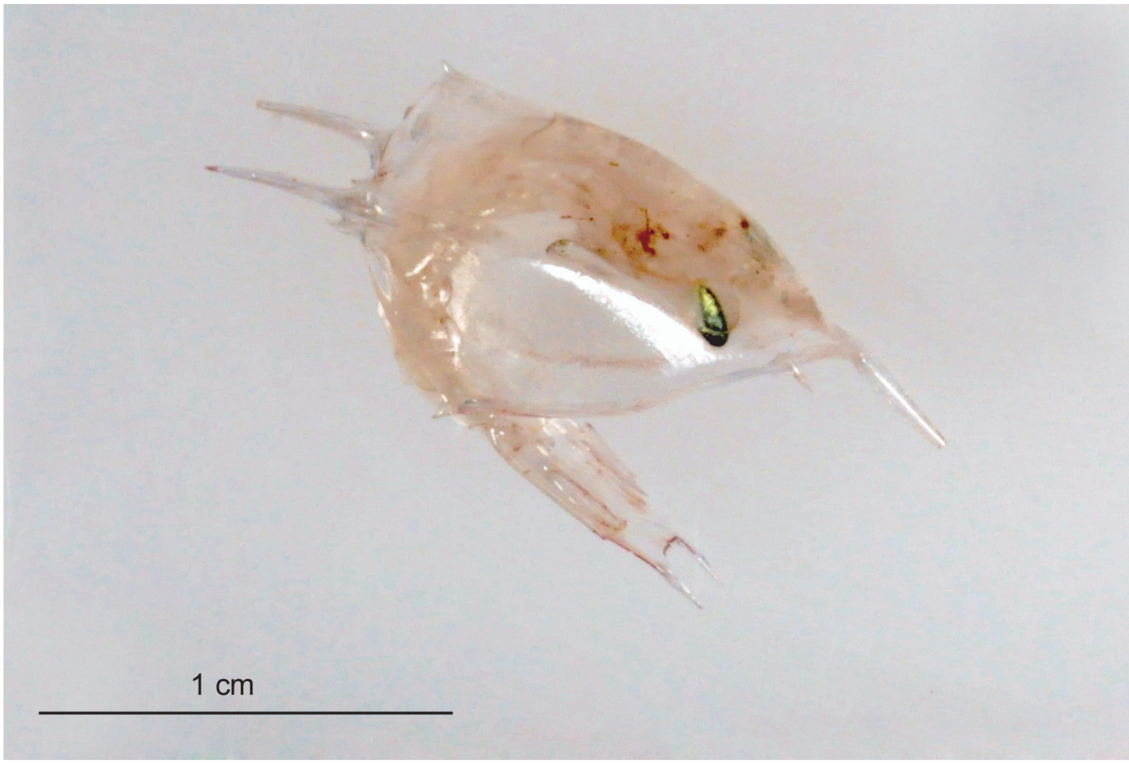

Figure 3.59. Stomatopod larva

Myodocopida

<u>Cypridinidae</u>

***Gigantocypris muelleri* Skogsberg, 1920**

WoRMS AphiaID: 127715

<u>Identification</u>: Poulsen, 1969, p. 3, fig. 5(one).

<u>Reported geographical and depth distribution</u>: First records for Nova Scotia and the Canadian Maritimes, but widely distributed in the North Atlantic, also in the Caribbean, South Atlantic, Indo-Pacific and Antarctic (Poulsen 1969, Blachowiak-Samolyk & Angel 2004), at depths from 700-2500m but with a maximum abundance around 1000-1500m.

<u>Catch at Gully Main Station</u>: A total of 17 specimens collected, all but one from deep sets to 750m and 1250m. With two records from a set fishing 0-250m at night, but it had been preceded by a set to 1250m, so could represent net contamination. Present in all years, with larger catches in 2008.

Figure 3.60. *Gigantocypris muelleri*

3.3.3. Overview of Species

The dominant members of the Gully Main Station fauna are northern temperate species that are generally widespread in the North Atlantic but more abundant in cold or moderately cold water: *G. elegans*, *S. arcticus*, *P. multidentata*, *A. pelagica*, *M. norvegica* and *T. gaudichaudii*. The Gully lies just to the north of the Gulf Stream, part of the North Atlantic Subtropical Gyre, but it is also under the influence of the cold Labrador Current, and the area may be considered one of transition and variability, at least physically (Chapter 2). Twenty-four species are reported from Atlantic Canada for the first time, with 17 of these new to Canadian waters (Table 3.3 & 3.4). This investigation represents the first pelagic survey in over two decades in the region, and the first to deal with the Crustacea in a comprehensive manner, undoubtedly the main reason behind such a large number of new species records. Additional species from all major taxonomic groups can be predicted to occur deeper in the Gully.

Only one record may represent a new species from the north, the isopod *A. panteni*, recently described from Greenland, but this is also only the second record for the species worldwide. Similarly, this is only the second report of the decapod, *A. falkenhaugae,* newly described from the North Atlantic Ridge (although older collections should be examined as I had this species labeled "*Benthesicymus* sp. A" for five years). The fact that such species are being described from the relatively well studied North Atlantic indicates they are rare, but little more can be said of the significance of their occurrence in the Gully. Truly enigmatic is the hyperiid amphipod *P. princeps*, known only from a few scattered observations worldwide. As with the previous two rarities, it appears unusually common in the Gully (MacIsaac unpublished data). The tally of rare species and numbers of individuals at the Gully Main Station and other smapling stations in the Gully and surrounding water (MacIsaac unpublished data) may suggest the Gully is somewhat of a “hot spot” for these rare species.

Most of the new Canadian records are uncommon, deep-sea species, and though some would have been predicted to occur in the region (*S. grandis*, *E. bifida*, *M. Mollis*, *M. vesca*) these first reports are not insignificant. A few, mainly the benthesicymids *G. bouvieri*, *G. capensis*, and *G. talismani*, but also including *E. serrata*, are northern range extensions. At least two species, *S. japonica* and *M. stephenseni*, may be more abundant in the Gully than elsewhere in the world. New Atlantic Canadian records are those that have only been previously recorded on the west coast or in the Arctic, and include some of the most taxonomically interesting species: *S. tenuiremis*, *Paracallisoma* sp. and *Cystisoma* spp.

Several species, though previously observed in Canadian waters, are rare in the area, and are just the second or third known observation, including the decapods *H. laevis*, *H. gracilis*, and *M. miccyla*. *Acanthephyra eximia*, with a few individuals first recorded in Atlantic Canada decades ago, appears to have increased in abundance and is for the first time reported ovigerous in the Gully. With the exception of the Isopoda and a few other taxa, several rarely reported species and meroplanktonic larvae, including some new species records, were typically recorded in either 2008 or 2009, not in the presence of the large cold intermediate layer observed in 2007 (Chapter 2).

The speciose dendrobranchiate family Benthesicymidae was dominated by *G. elegans*, but well represented in the Gully assemblage with nine species, a rich compliment of benthesicymids similar to other areas in the North Atlantic and adjoining seas (Heffernan & Hopkins 1981, Krygier & Pearcy 1981, Burghart et al. 2007). The Gully benthesicymids are largely a deep mesopelagic group, with distributions of several species extending into the bathypelagic. Biogeographic affinities are reported to range widely from northern latitudes to the tropical North Atlantic (Fasham and Foxton 1979). At least four of the nine can be considered warm water species: *G. bouvieri*, *G. capensis*, *G. scutatus* and *G. talismani*, with *G. capensis* a regular part of the Gully fauna, but *G. scutatus* and *G. talismani* possibly only associated with warm water events, such as may have occurred in 2009 (Chapter 2). At greater depths, the Gully is a relatively warm water environment, mostly filled with warm slope water or North Atlantic Central Water (Chapter 2), at least partially explaining the rich compliment of benthesicymids.

The dominance of *G. elegans* is generally rivalled to the east and in the south by *G. valens*, and the two species also somewhat separated by vertical distribution, with *G. elegans* deeper (Sund 1920, Foxton 1970b, Fasham & Foxton 1979). The Gully population of *G. elegans* was centred above 750m, rather shallow and coincident with the distribution of *G. valens*. Catch of *G. elegans* was also estimated to extend deeper in the bathypelagic below 1250m, and a deeper living part of the population has been suggested by Foxton (1970b).

All of the characteristic pelagic decapod families were well represented at the Gully Main Station with the exception of the Sergestidae. This typically speciose oceanic family (Donaldson 1975, Walters 1976, Hopkins et al. 1994) included just six species, two species of *Sergestes* and four of *Sergia*, and was overwhelmingly dominated by *S. arcticus*, a common and widespread species in the North Atlantic (Sund 1920). The Gully sergestids are a broadly epipelagic to deep mesopelagic group, with distributions of several species extending into the bathypelagic. Biogeographically only *S. japonica* may have some affinities to the tropical North Atlantic (Fasham and Foxton 1979), but it is also known to range north to the Grand Banks off Newfoundland. The low diversity sergestid assemblage in the Gully, dominated by one species, most resembled the Pacific "transitional" decapod fauna, also dominated by one, congener *S. similis* (Krygier & Pearcy 1981, Nishida et al. 1988). Transitional is a term that has also been used to describe the (mesopelagic fish) fauna of the ocean near the Gully to the south (Themelis 1996), close to the Gulf Stream and boundary of the Atlantic subtropical gyre.

The continental slope itself may truncate distributions where vertical ranges intersect the seafloor (Hargreaves 1999), but proximity to continental margins does not limit the distribution of all species (Merrett 1986). Bottom depths at Gully Main are still considerable, and oceanic species even penetrate the shallow waters of the continental shelf (Hopkins et al. 1981, Benoit-Bird & Au 2006). Species of the genus *Sergia*, and in general "all-red" species, are well-documented to occur deeper than the genus *Sergestes* or "half-red" species (Donaldson 1975, Foxton 1970b, Walters 1976). The four species of the genus *Sergia* at the Gully Main Station suggests a depth-related explanation. The deeper waters within the canyon, depths occupied by *Sergia*, are composed of relatively stable warm slope water or North Atlantic Central water. Shallower depths generally occupied by species of *Sergestes* appear colder and more variable (Chapter 2), possibly limiting the number of species to two. It has been argued that decapod species in the South Atlantic Central Water largely ignore the boundary with the North Atlantic Central Water because they are primarily associated with Antarctic Intermediate water underlying both, migrating into shallower depths at night regardless of overlying water mass (Fasham & Foxton 1979). A similar situation may exist for species of Sergia in the Gully.

With 12 species, the Oplophoridae was the most species rich group of larger pelagic crustaceans in the Gully, and although many species could be characterized as uncommon, biomass and abundance were more evenly distributed among oplophorids than either the Benthesicymidae or Sergestidae. The Oplophoridae are a predominantly a northern temperate, deep mesopelagic to bathypelagic group, with just one species with biogeographic affinities to the tropics, *M. mollis* (Fasham and Foxton 1979).

The depth distribution of the dominant oplophorid for the depths surveyed, *A. pelagica*, is expected to be both deepest and broadest at these latitudes, extending to at least 2000m (Foxton 1972), which agrees with the dominance of this species to at least 1500m in the Gully, but not the apparently shallow concentration of animals above 750m. The dominance of *A. pelagica* is rivalled in the North Atlantic by the congeneric *A. purpurea*, especially to the south or east of the Atlantic subtropical gyre (Chace 1940, Sivertsen & Holthius 1956, Foxton 1970a), but the species are also typically separated by vertical distribution, with *A. pelagica* deeper across a wide range of latitudes (Foxton 1972). The Gully population of *A. pelagica*, however, had a daytime concentration above 750m, shallower than typical and coincident with the distribution of *A. purpurea*, which itself was somewhat shallow in the Gully (Foxton 1970a, Foxton 1972). Both species have also been collected in bottom trawls to the east and west of the Gully (Markle et al. 1988), and though occurring as shallow as 730m, both species were concentrated deeper than 800m.

Other less common oplophorids may also live relatively shallow at Gully Main, with most of the catch of *M. vesca* and *N. elegans* from sets fishing to 750m. And *A. eximia*, a species thought to live on or near bottom with juveniles only taken occasionally in midwater nets (Chace 1947, 1986, Pequegnant & Wicksten 2006), was collected well off-bottom at the Gully Main Station.

The pelagic Pasiphaeidae are not a speciose group in the North Atlantic or adjacent seas, but as is the case for the Gully, they can be important members of a local or regional fauna (Aguzzi et al. 2007). This is a group of northern temperate species with a broad epi- to bathypelagic distribution, with one species, *E. serrata*, previously known only from tropical and warm temperate waters in the North Atlantic.

The other group of pelagic Eucarida in the study area was the Euphausiacea, overwhelmingly dominated by *M. norvegica*, with three species identified and each with different depth and geographic distributions. The group as a whole was dramatically under-sampled by our relatively large-mesh net, mostly smaller species grouped together as Euphausiacea. Even *M. norvegica*, which grows to between 40-50mm, has (mature) adults less than 25mm, too small to be effectively captured by the IYGPT (Chapter 2), and therefore a portion of the population may not have been effectively sampled.

The dominant euphausiid, *M. norvegica*, was the only abundant large crustacean species with significant annual variations in catch. Exceptionally large catches in 2007 coincided with a cold intermediate water layer, including *T. libellula*, a species indicative Arctic or Labrador Current water. *Meganyctiphanes norvegica* also displayed the greatest diel variation in catch, an observation accounted for by a combination of active net avoidance during the day and possibly schooling or increased swarming at night. A daytime vertical migration of the bulk of the population to below our maximum depth sampled of 1500m is unlikely, but such a phenomenon has been postulated to explain abyssal swarms of the large Antarctic krill *Euphausia superba* at 3000m (Clarke & Tyler 2008). It was estimated that *E. superba* could migrate at 20cm/s from 3000m to the surface in six hours, making a diel migration to these depths possible. Smaller in size, swimming speeds for *M. norvegica* are reported in the 3-8cm/s range (Tarling et al. 1998, Thomasson et al. 2003, Kaartvedt 2010), less than half the speed of *E. superba*, and would need somewhere in the range of six to ten hours to move from the surface to the bottom of the Gully Main at 1300-2000m. The broad geographical success of *M. norvegica* has been attributed to its feeding plasticity, apparently able to alter its feeding habits spatially and temporally to take advantage of a wide range of resources from phytoplankton to zooplankton and detritus. This geographical range also includes a vertical component, the deep sea, including submarine canyons and at least depths of a few hundred metres (Youngbluth et al. 1989). The euphausiid *Thysanopoda acutifrons* was distributed at depths more shallow than expected during the day.

Though not as speciose as the Decapoda, the Lophogastrida are common constituents of the deep sea (Mauchline 1986, Krygier & Pearcy 1988, Burghart et al. 2007). All are deep meso- to bathypelagic species with broad grographical distributions. Considering depths sampled, the lophogastrids as a group were well represented at the Gully Main Station, with a compliment of species similar to other areas surveyed in the North Atlantic and adjacent seas (Hargreaves 1985b, Hopkins et al. 1994, Burghardt et al. 2007). However, it is reasonable to predict more lophogastrid species with greater depths surveyed in the Gully (Mauchline 1986, Burghardt et al. 2007).

Both the biomass and individual size of *G. zoea* increased into the bathypelagic, a body size-depth relationship not observed in the eastern Atlantic in surveys to 2500m (Mauchline 1986). And species of *Gnathophausia* are some of the largest and long lived pelagic crustaceans, with a life span possibly up to eight years or more (Childress & Price 1978), representing years of bathypelagic feeding and growth.

Mysids were not abundant at Gully Main at the depths surveyed, with just two species, but may have been underestimated because of their small size or suprabenthic habits (Mauchline 1986, Cartes & Sorbe 1998). *Boreomysis arctica* is a northern species and can be a dominant member of the zooplankton, inculing the nearby Gulf of St. lawrence (Cartes & Sorbe 1998, Descroix et al. 2005). Observations of the bathypelagic *B. semicoaca* above 750m are shallow for the species (Mauchline & Murano 1977).

The pelagic Amphipoda were relatively species rich but individually depauperate, an observation that may not be out of the ordinary (see Thurston 1976, Roe et al. 1984). However, when compared to other areas, the Amphipoda were either relatively low in diversity or systematically undersampled (Shoemaker 1945, Thurston 1976, Gasca 2007). Many pelagic amphipod species are small, less than 25mm or the effective size for capture in the IYGPT, and I probably have only adults of the larger species (Roe et al. 1984, Thurston 1976). Those species retained by our net were dominated by the Hyperiidea, an abundant group of pelagic Crustacea and important trophic component in oceanic ecosystems, generally considered to rank third in terms of abundance behind the Copepoda and Euphausiacea (Bowman 1960, Dalpadado et al. 2001, Marion et al. 2008).

The jellyfish-associated hyperiid amphipods were well represented by at the Gully Main Station with three species of *Hyperia*, at least two species of *Lanceola*, *Cystisoma* spp., and *M. stephenseni* (along with the similarly associated isopod *A. panteni* and the decapods *N. elegans* and *N. robustus*). With 71 specimens, the very large and relatively rare *M. stephenseni* (Zeidler 2009) appears particularly common in the Gully, only surpassed in amphipod biomass and (with the exception of the 2007 cold water event of *T. libellula*) abundance by *T. gaudichaudii*. However, little more can be said concerning this component other than to say jellyfish must also be well represented in the Gully pelagic assemblage: cnidarian medusae, ctenophores and tunicates may be abundant, though would be under-sampled with most trawls, including the IYGPT. The contribution of the Gully jellyfish fauna is therefore still essentially unknown, as is typical of most pelagic ecosystems worldwide (Larson et al. 1991, Robison 2004, Pages et al. 2006).

3.3.4. Summary

1. Twenty-four species are reported from Atlantic Canada for the first time, with 17 of these also representing new Canadian records; several more species are rare occurrences.

2. A notable number of rare or uncommon species were collected at the Gully Main Station.

3. Several rarely reported species and meroplanktonic larvae, including some new species records, were recorded or were more common in either 2008 or 2009, not in the presence of the large cold intermediate layer observed in 2007.

4. The biomass and abundance of most common and abundant species at the Gully Main Station varies little from year to year, with the notable exception of the northern krill, *Meganyctiphanes norvegica*.

5. The vertical distributions and population centres of several species appear atypically shallow at the Gully Main Station compared with other geographical locations in the North Atlantic and elsewhere.

6. There is evidence that the distributions of many species extend deeper into the bathypelagic below 1250m, with additional species predicted to occur at greater depths.

Chapter 4. Conclusion

4.1. General Conclusion

Submarine canyons are numerous globally but very poorly sampled (DeLeo et al. 2010). Measurements of any kind in the steep slopes of submarine canyons are among the most difficult to make (Hickey 1995) and even more so biological collections with a large trawl. No other study known to date has examined this large size fraction of pelagic Crustacea at such great depths within a canyon, and most comparisons of species present and their distributions can at best be made with surveys in the open ocean or over continental slopes (essentially the eastern North Atlantic) and more recently the northern Mid Atlantic Ridge (Sutton et al. 2008). However, a few comparisons can be made. Euphausiids, shrimps and other micronekton have been observed aggregating in parts of canyons; we have observed greater overall biomass and abundance of all, if not aggregations per se, in the Gully, compared to an adjacent ocean area outside of the canyon. In a limited comparison, several species of pelagic Crustacea had notably greater catches inside the canyon compared to the adjacent continental slope, consistent with the results for at least one benthic shrimp in surveys with bottom trawls in the Mediterranean (Cartes et al. 1994). Several crustacean species were observed to be less abundant within the canyon in the same demersal comparison, and similar observations have been made for some benthic species. Some of the more generally abundant benthic species were observed less common in canyons (Hecker et al. 1983). The most abundant benthic species found at greater depths along the slope are adapted to a typical slope habitat of mud, but in a canyon, sediment heterogeneity typically increased, decreasing the relative amount of typical slope habitat available for the abundant slope species. It has been observed that the ecological significance of canyons is distinctive for a wide range of taxa from pelagic and benthic invertebrates to fish and whales. A “fjord-effect” was also observed for the abundant decapod *S. arcticus*, with individuals on average larger inside the canyon, similar to observations for *M. norvegica* in what may arguably be land-locked canyons (Cuzin-Roudy et al. 2004).

The geographical distributions of larger pelagic crustacean species are often widespread (Chapter 3), with many nearly cosmopolitan at temperate or tropical latitudes. Sporadic, widely dispersed occurrences of rare bathypelagic species should not be surprising, as only the continents themselves present any real barrier to wide dispersion, in the uniformly cold deep water. However their rarity means that very little is known about rare species, and nearly every occurrence is important. It took years to sort out the synonymies of *S. tenuiremis* because only a few adults had been collected from wide locations (Krygier & Wasmer 1988, Vereshchaka 2000). To date, many species of the giant pelagic isopod *Anuropus* are known only from one sex (Kensley & Chan 2001), a problem that plagued the early taxonomy of the genus *Gennadas* (Burkenroad 1936). There is no shortage of similar stories, and the occurrence and cataloguing of species such as *E. serrata* and *P. princeps* are noteworthy both scientifically and in terms of the natural history of the area.

Previous scientific reviews of the Gully have found it to be an area of high diversity for deep-sea corals and some demersal fish (Gordon & Fenton 2002), this diversity due in part to generally increased benthic habitat heterogeneity in canyons. Although increased benthic diversity has been reported from other submarine canyons (DeLeo et al. 2010), an increased number of pelagic species has not. The Gully may also be a “hot spot” for the occurrence and abundance of rare meso- and bathypelagic species. The lack of such observations for larger pelagic species in other canyons worldwide may be a sampling artefact of small gears used and shallower depths surveyed, or a paucity in the systematic treatment that large crustaceans have received in general (T. Sutton personal communication).

The temperature of the shallow water over the Gully varied between years, with both positive and negative effects on the occurrence of species. Species unique to the large volume cold intermediate water event were: the arctic hyperiid *T. linellula*, and the isopods *A. panteni*, described from off Greenland, and the wide ranging neustonic species, *I. metallica*. Similarly, there were species unique to 2008 and 2009, which could be described as warmer years. However, whether large or small, there is always a cold intermediate layer of water in the summer over the Gully, indicating that volume of the intrusion is key to any effect. Most of the abundant fauna appear associated with deeper water and experience little or no effect of the relatively shallow, cold water.

Several meso- to bathypelagic species have relatively shallow distributions at the Gully Main Station above 750m during the day, including the decapods *G. elegans*, *A. pelagica*, and *A. purpurea*, and the euphausiid *T. acutifrons* (Chapter 3). One of the weaknesses of our investigation was lack of resolution of the finer scale vertical patterns of species distribution with depth and the diel change in these patterns. This was due not only to the use of an open net, but also the vertically broad 250m and 500m nominal strata. In this case, species distributions could have straddled the boundary at 750m between the 250-750m and 750-1250m nominal strata, and concentrations could have actually been just above 750m, but even this would have been notably shallow.

Distributions of all three of these species are estimaextend to extend deeper than 1250m at the Gully Main Station, and two separate populations may exist, the deeper one associated with North Atlantic Central Water and the shallow one associated with the slope water. Alternately, significant parts but not all of the populations remain at unusually shallow depths during the day. Diel vertical migrations and vertical distributions of species can be modified, typically by varying light intensity but also food supply. A non-migrating acoustic layer of unknown taxonomic composition exists in the Gully, the details of which are emerging. If this layer represents a persistent, concentrated source of food, species or individuals may alter typical patterns to remain within or near. If such a situation exists in the Gully, it has not been reported previously in another canyon. Finer vertical resolution is needed to better observe the phenomenon. Other species may also be adjusting vertical distributions, but only those expected to concentrate deeper than 750m during the day would be noticed with our sampling design.

Many pelagic animals undoubtedly go their entire lives without encountering the hard physical boundary of the sea floor. However, when encountered, such topography also has profound effects on the fauna, the results of which may be a widespread influence on marine pelagic (and benthic) ecosystems worldwide (Sutton et al. 2008). Though less in spatial extent than ocean ridge systems (Sutton et al. 2008), continental margins may still have a disproportionate influence. They are shallower than ridge systems, within reach of a more abundant fauna. Local variations in the effect of margin topography will exist, some areas having more or less ecological impact on the local situation. One typically common type of local variation is submarine canyons along continental margins (Hickey 1995a), features long considered as areas of increased productivity (DeLeo 2010). One of the largest submarine canyons on the eastern margin of North America, and increasingly one of the most interesting, is the Gully.

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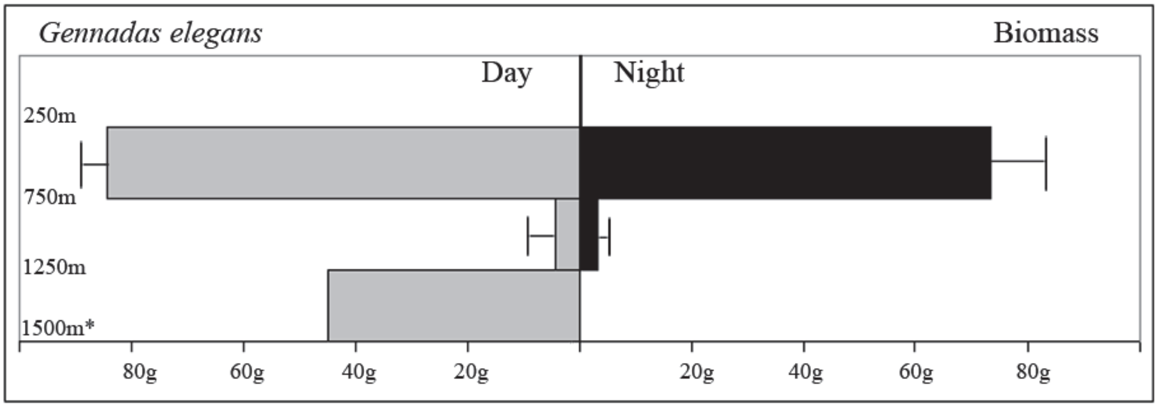
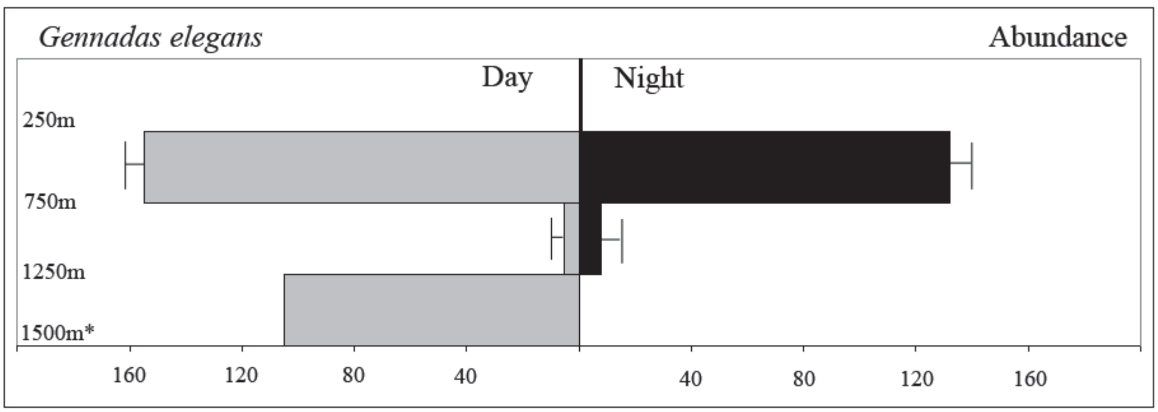
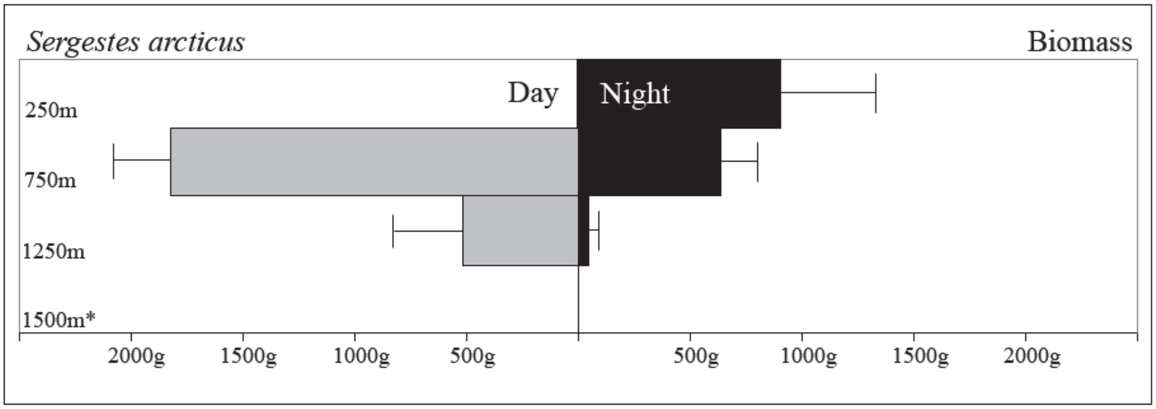
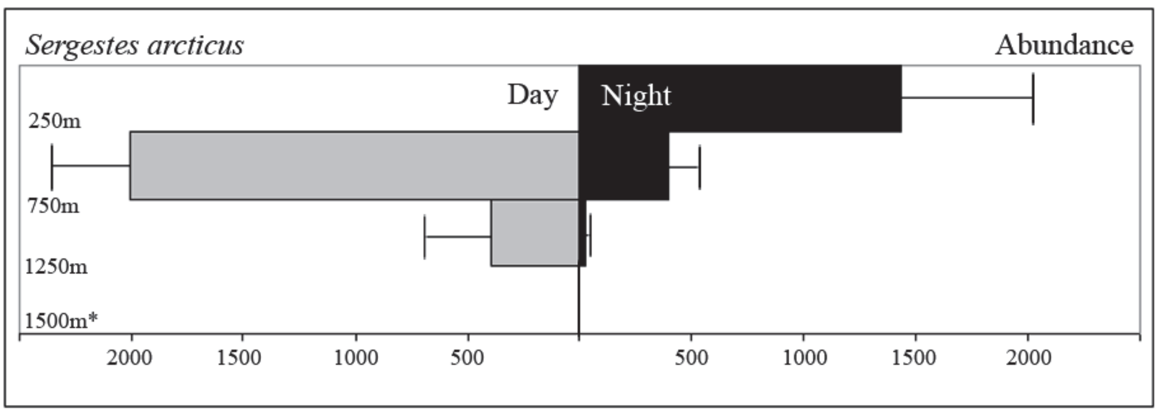
Appendix A. Estimated Vertical Distributions of More Abundant Species

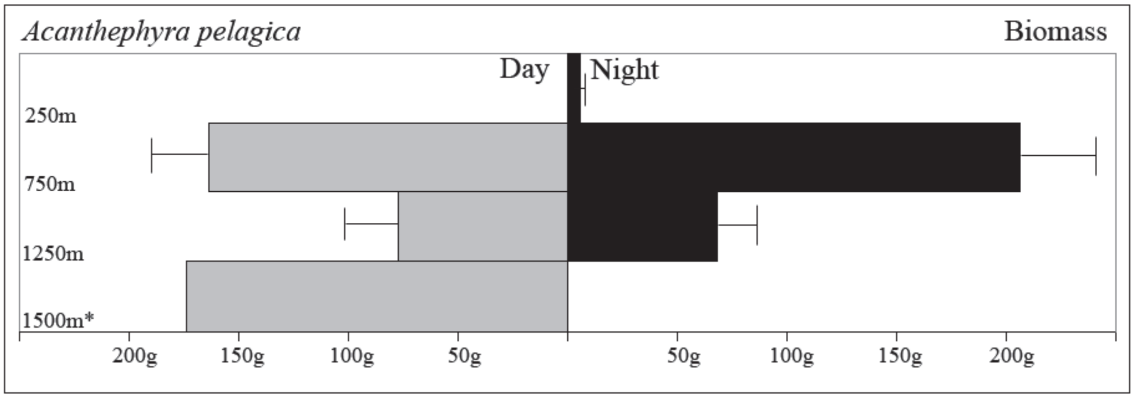
Vertical distribution of the more abundant species at the Gully Main Station based on estimated nominal stratum data. Mean biomass (top) and abundance (bottom) ± 1 standard error, data grouped by time of day and nominal depth stratum to show vertical distribution and diel change in catch, averaged across years 2007, 2008 and 2009 (* only 1 set to 1500m).


Gennadas elegans
Biomass
Day
Night
250m
750m
1250m
1500m*
80g
60g
40g
20g
20g
40g
60g
80g

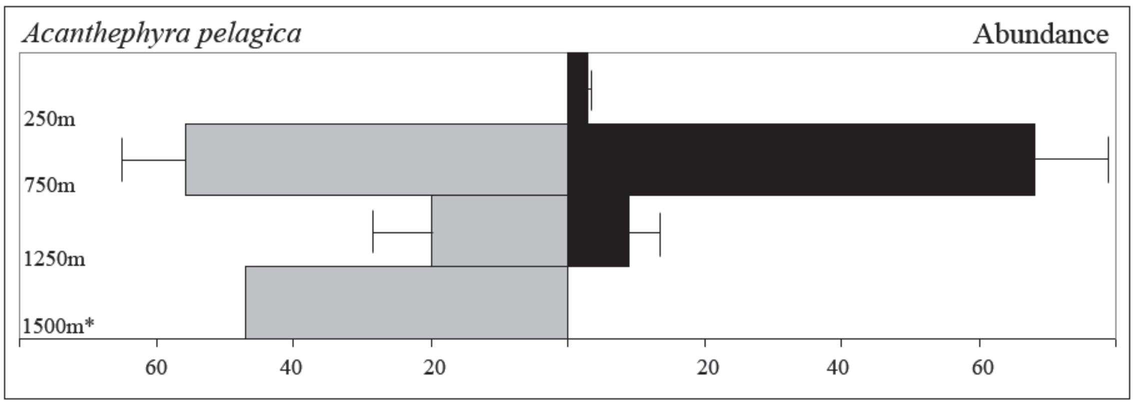

Gennadas elegans
Abundance
Day
Night
250m
750m
1250m
1500m*
160
120
80
40
40
80
120
160


Sergestes arcticus
Biomass
Day
Night
250m
750m
1250m
1500m*
2000g
1500g
1000g
500g
500g
1000g
1500g
2000g

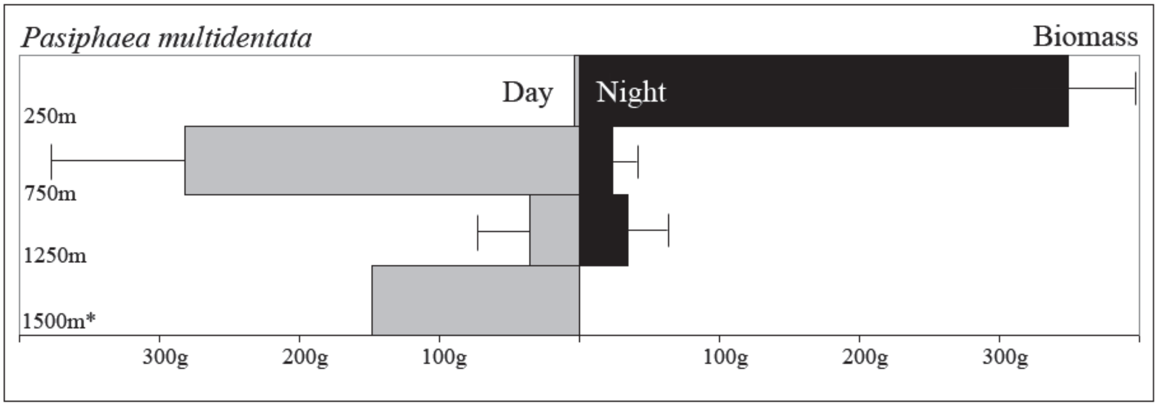

Sergestes arcticus
Abundance
Day
Night
250m
750m
1250m
1500m*
2000
1500
1000
500
500
1000
1500
2000



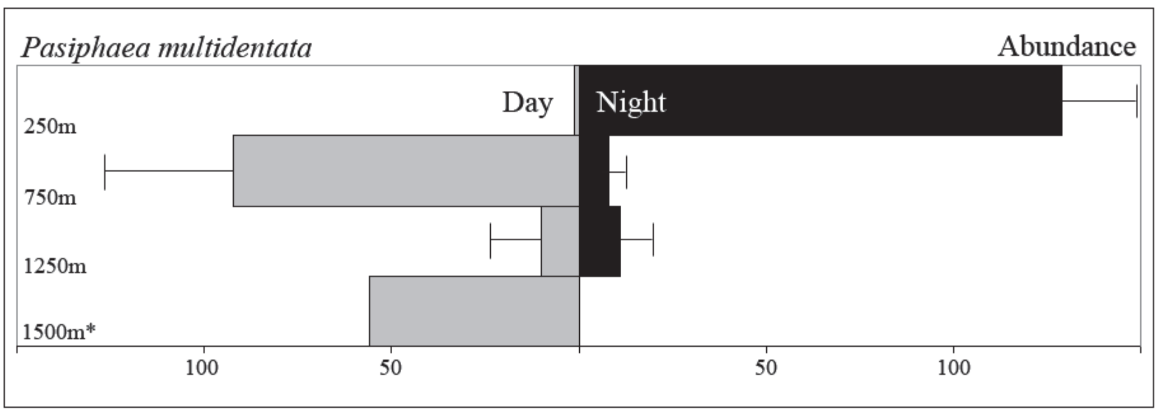
Acanthephyra pelagica
Biomass
Day
Night
250m
750m
1250m
1500m*
200g 150g 100g 50g 50g 100g 150g 200g



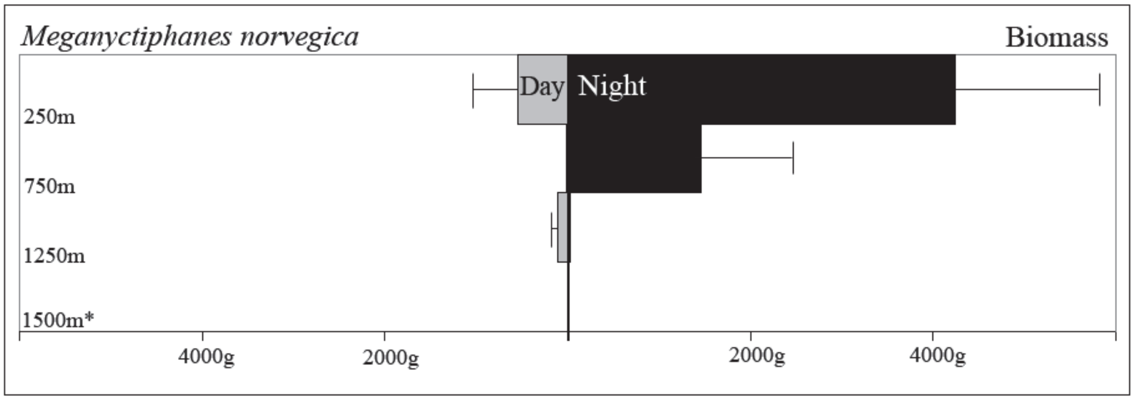
Acanthephyra pelagica
Abundance
250m
750m
1250m
1500m*
60 40 20 20 40 60

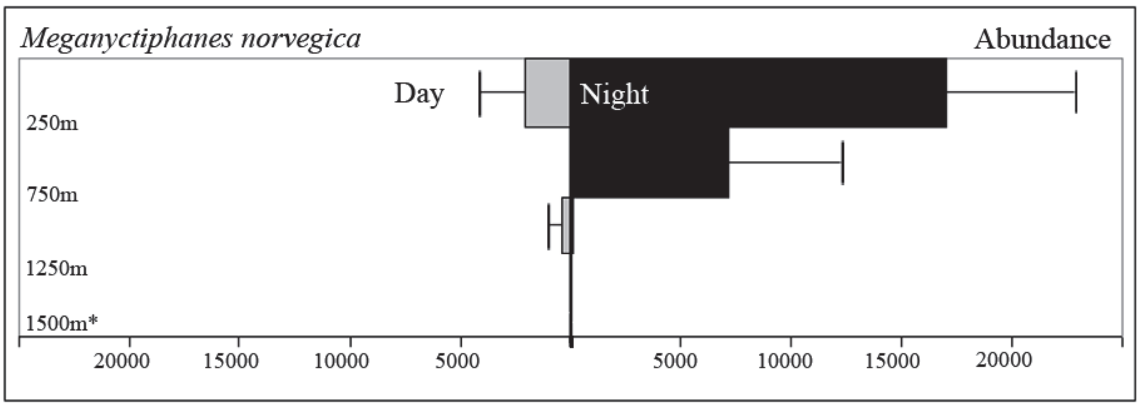


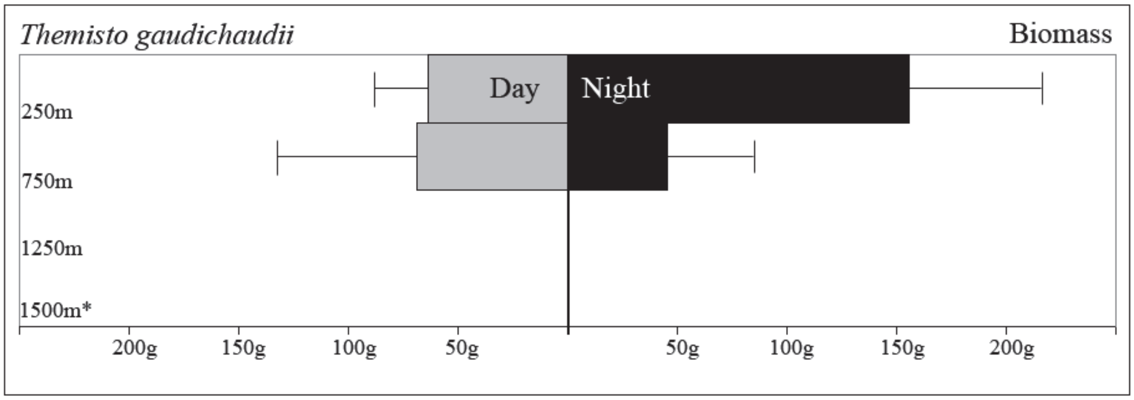
Pasiphaea multidentata
Biomass
Day
Night
250m
750m
1250m
1500m*
300g
200g
100g
100g
200g
300g

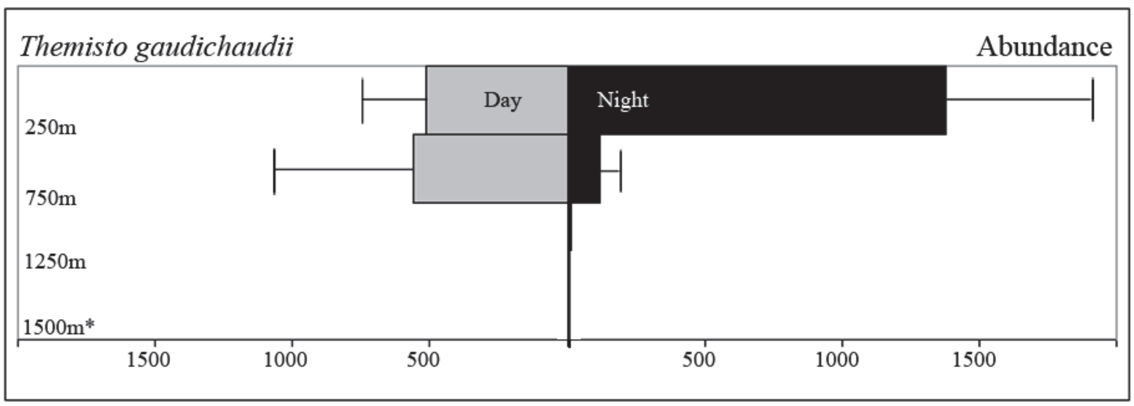


Pasiphaea multidentata
Abundance
Day
Night
250m
750m
1250m
1500m*
100
50
50
100


Meganyctiphanes norvegica
Biomass
Day
Night
250m
750m
1250m
1500m*
4000g
2000g
2000g
4000g

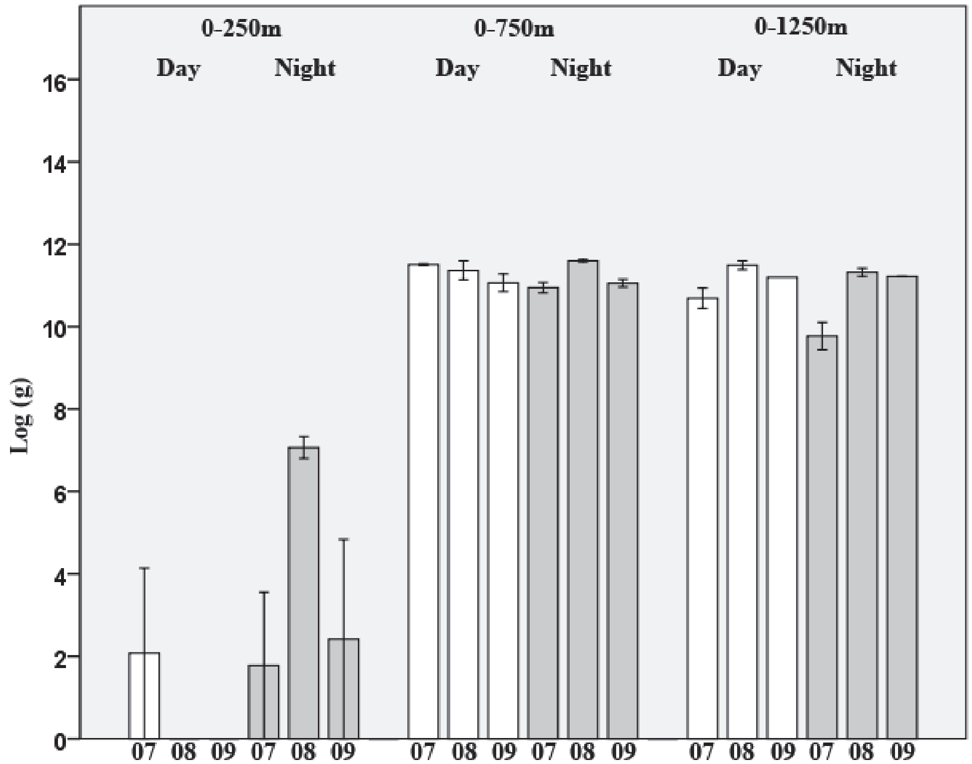

Meganyctiphanes norvegica
Abundance
Day
Night
250m
750m
1250m
1500m*
20000
15000
10000
5000
5000
10000
15000
20000

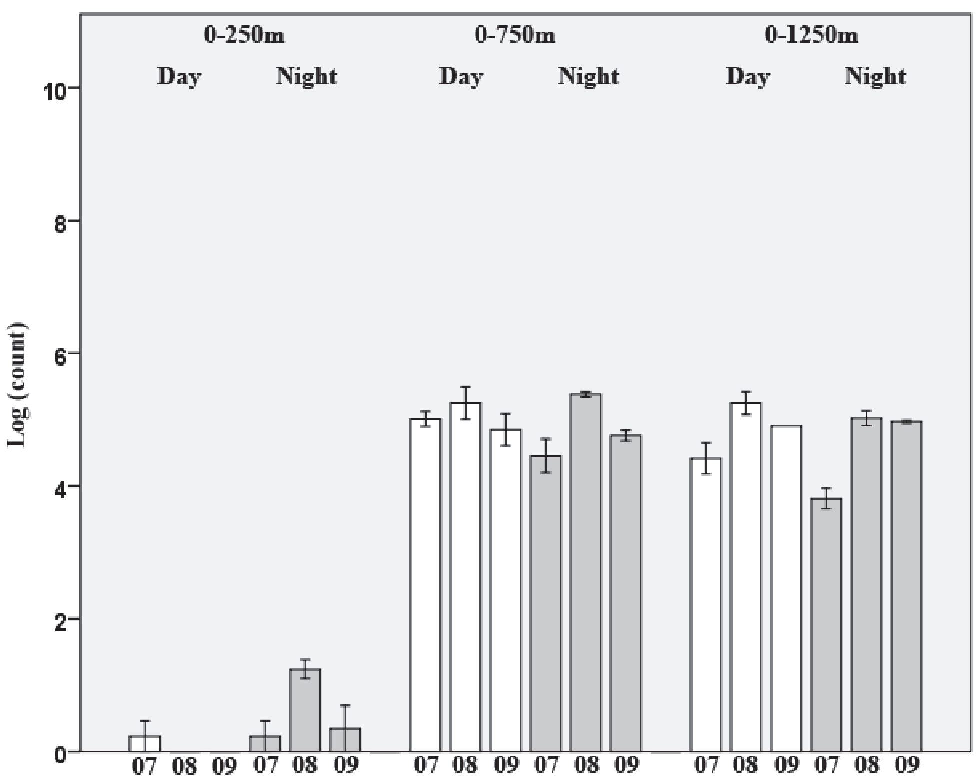

Themisto gaudichaudii
Biomass
Day
Night
250m
750m
1250m
1500m*
200g
150g
100g
50g
50g
100g
150g
200g


Themisto gaudichaudii
Abundance
Day
Night
250m
750m
1250m
1500m*
1500
1000
500
500
1000
1500

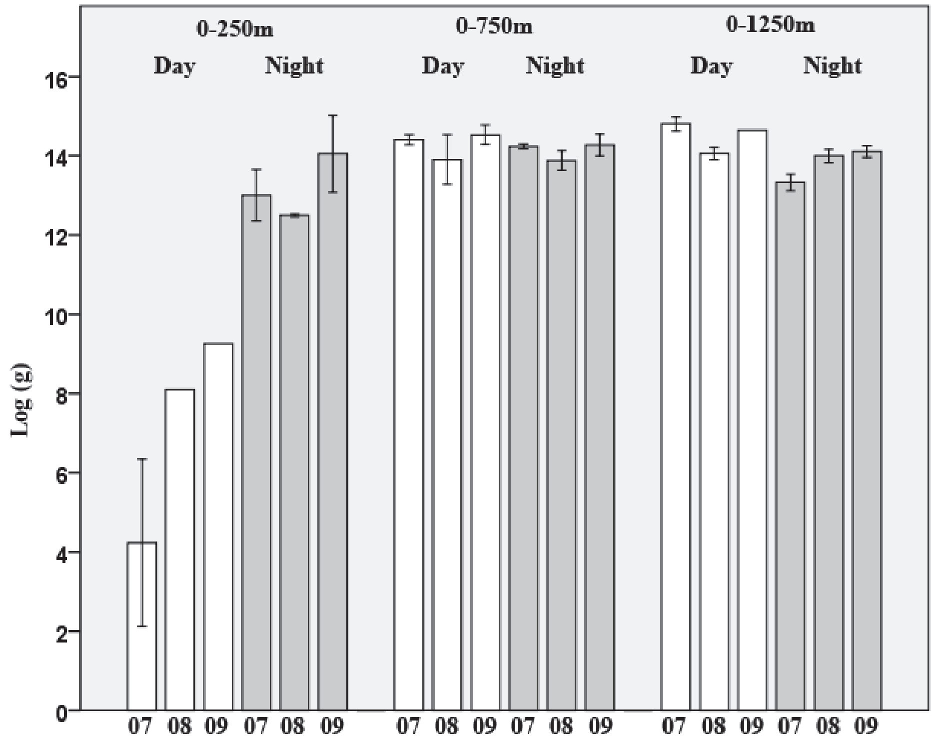
Appendix B. Catch by Year, Time of Day, and Maximum Depth Trawled for More Abundant Species

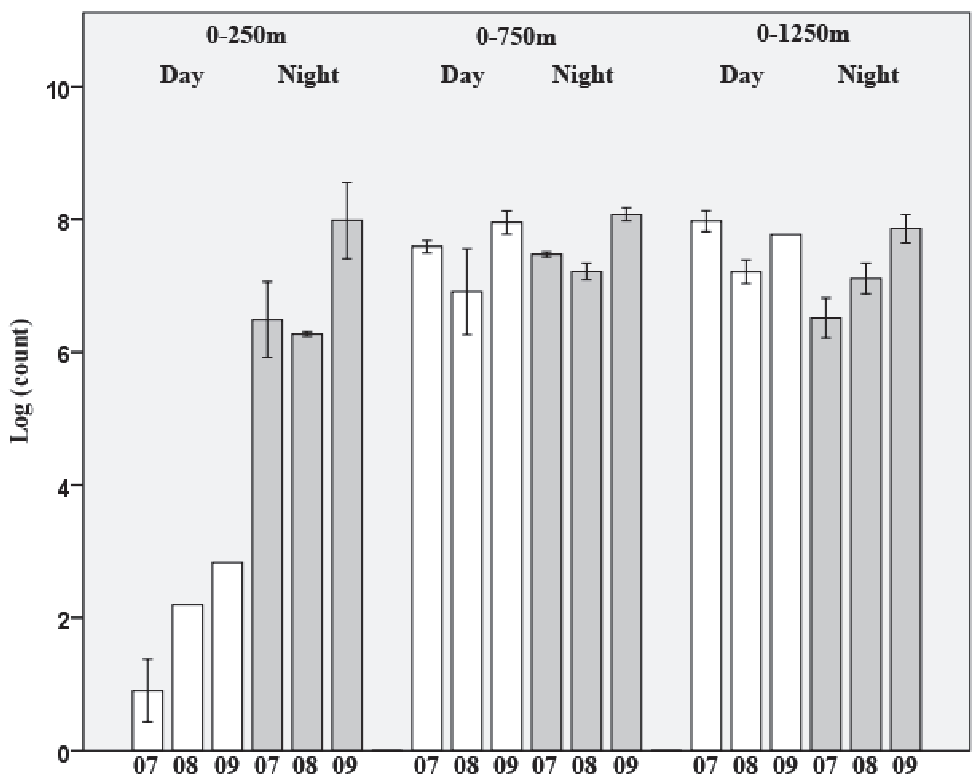
Annual variations in catch of the more abundant species at the Gully Main Station based on unadjusted (raw) data. Mean biomass (top) and abundance (bottom) ± 1 standard error, data grouped by maximum trawl depth and time of day to show differences between years 2007, 2008 and 2009 at different trawl depths and diel cycle.



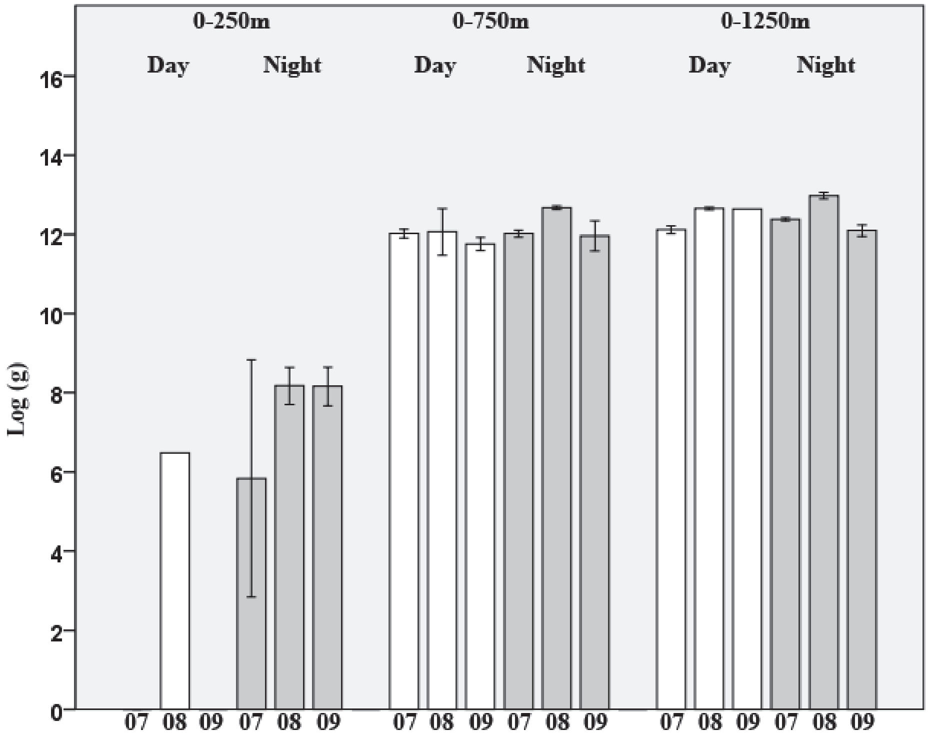


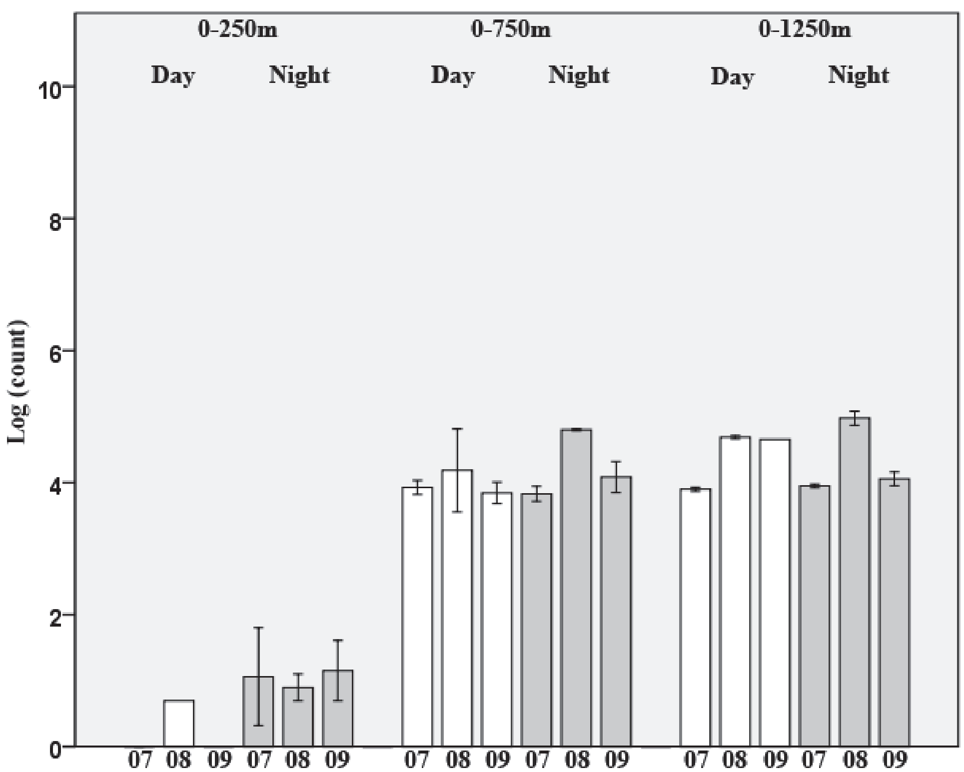
Gennadas elegans



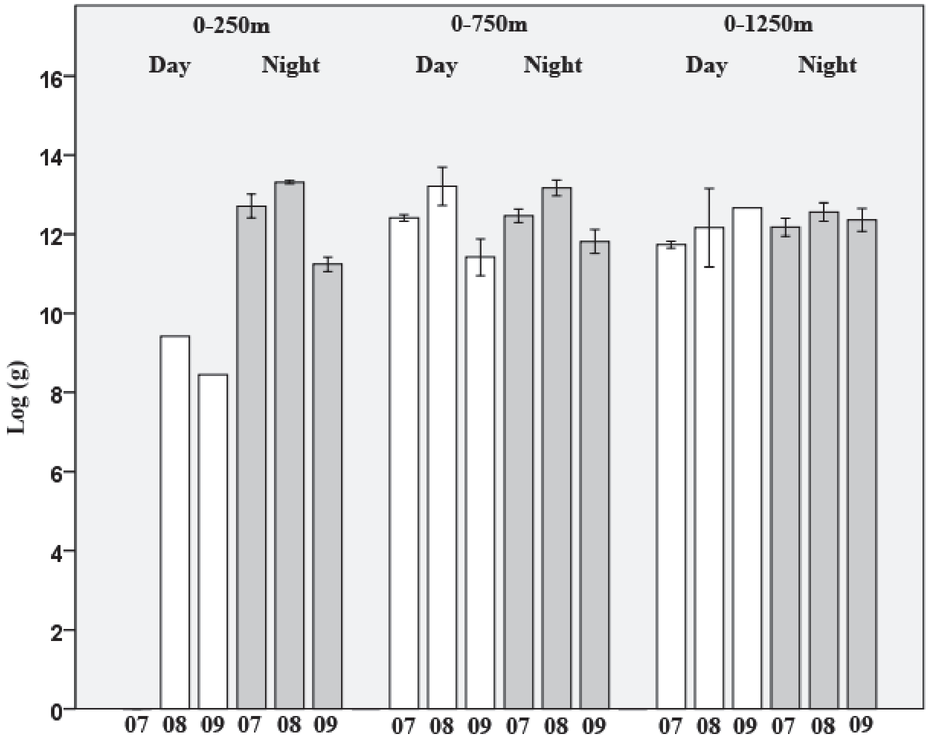


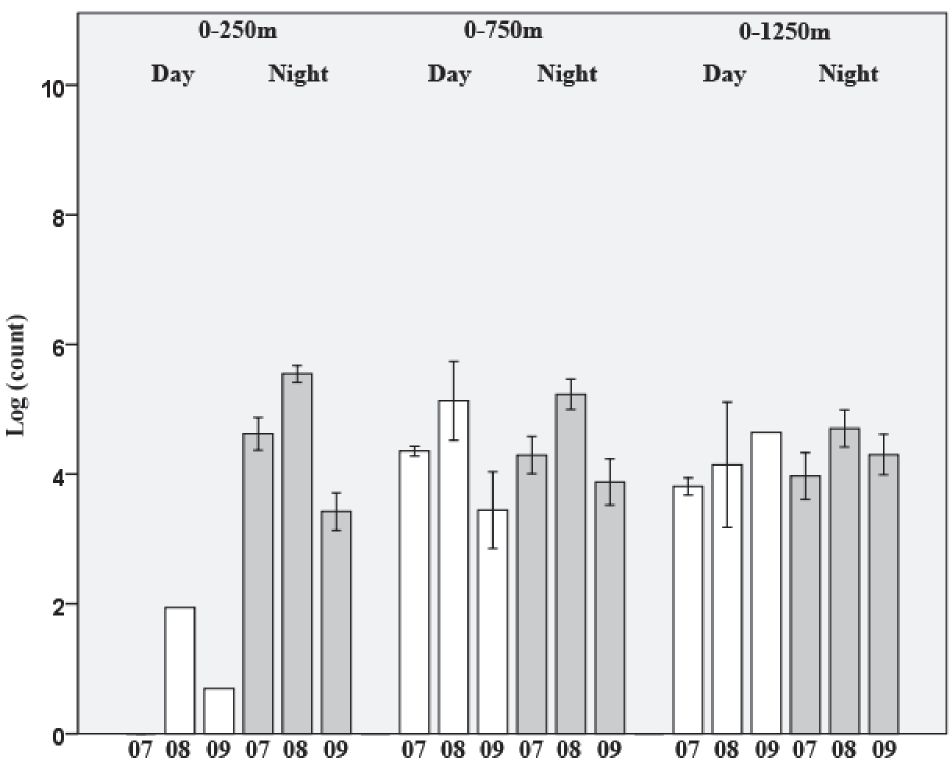
Sergestes arcticus



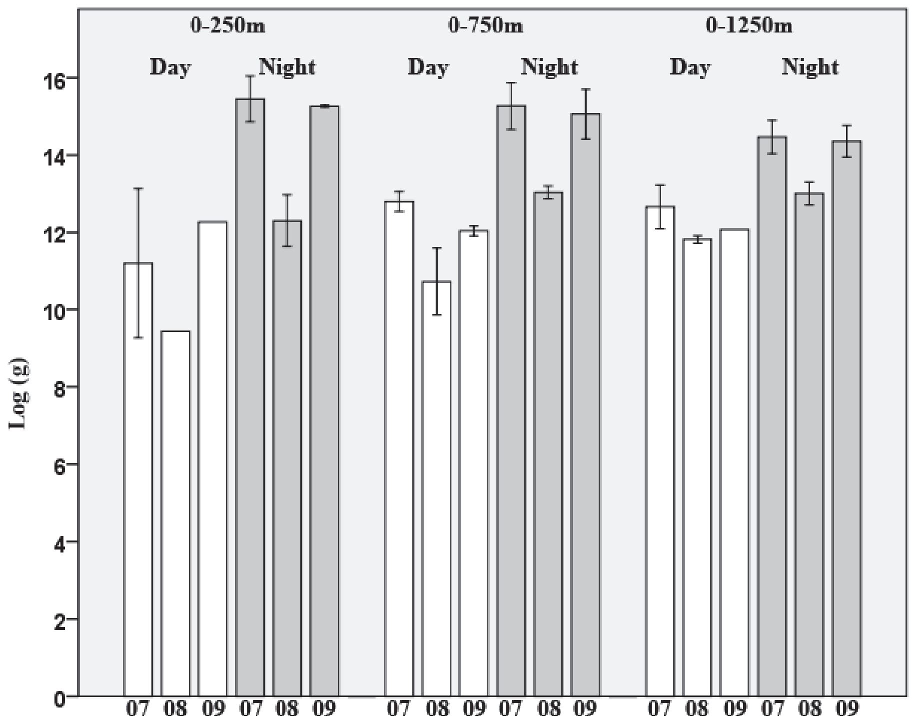


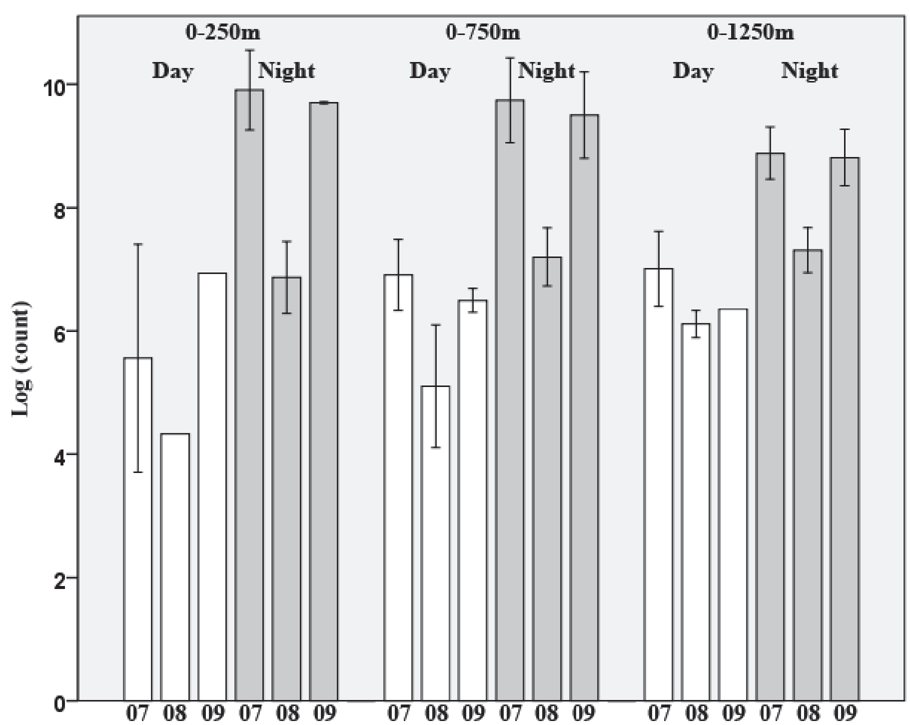
Acanthephyra pelagica



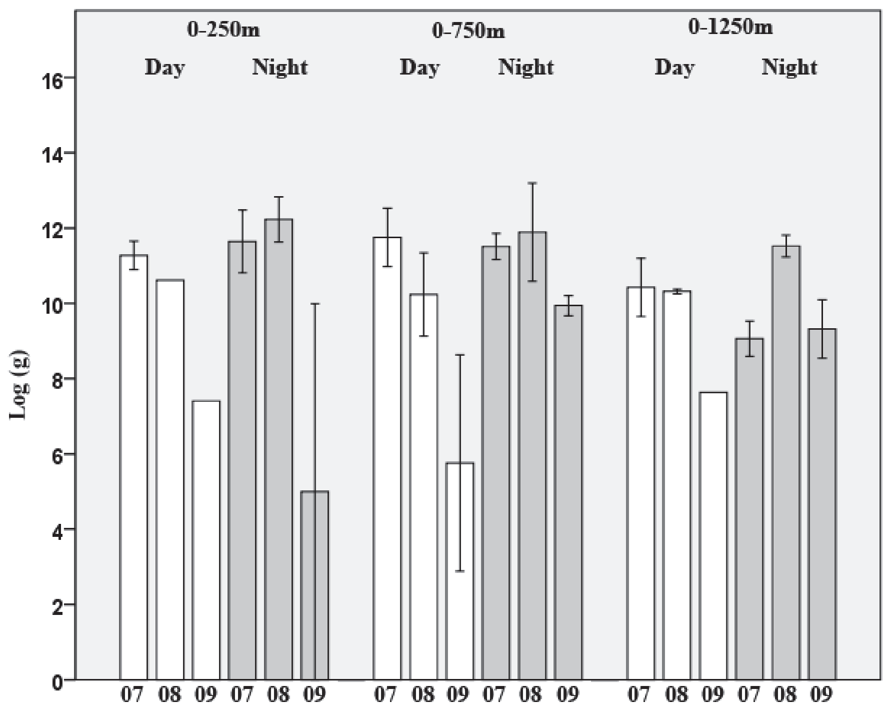


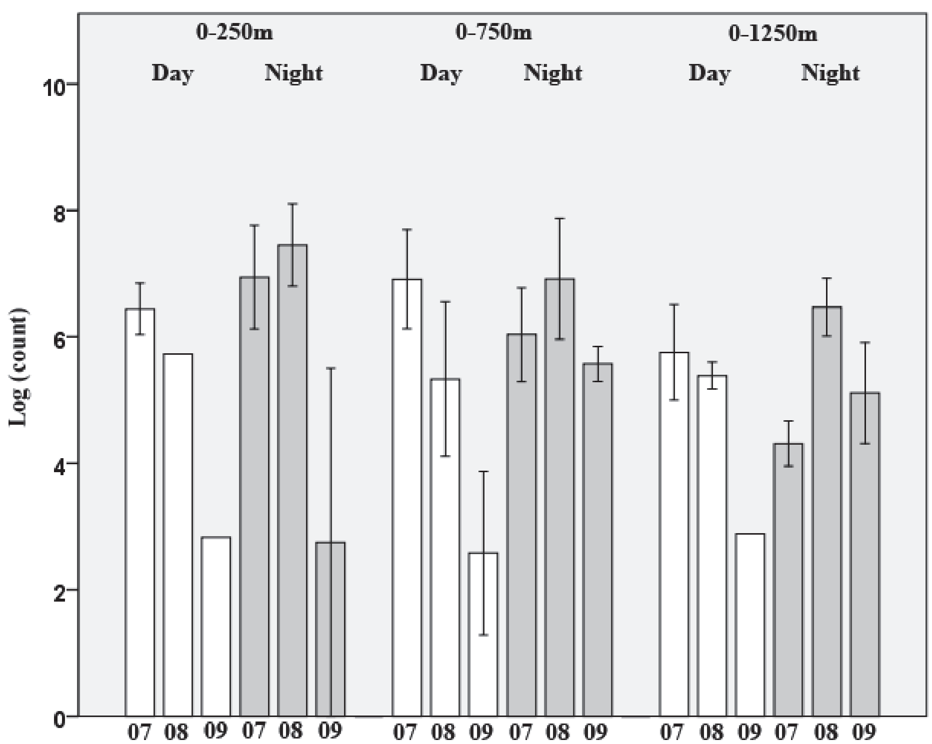
Pasiphaea multidentata





Meganyctiphanes norvegica





Themisto gaudichaudii

Appendix C. Biological Data

A representation of the three types of biological data used: raw data, epipelagic adjusted data, and estimated nominal stratum data. Vertical boxes represent the water column, numbers indicate water depth, and coloured lines the three trawl depths fished (0-250m, 0-750m, 0-1250m).

Biological Data