The Ichthyoplankton and Invertebrate Zooplankton of the Coastal Waters of Cape Breton Island: A Review

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Abstract

The western (Northumberland Strait) and eastern (Sydney Bight) coastal waters of Cape Breton Island are each occupied by a diverse and productive assemblage of zooplankton species. Different species assemblages occupy each area, but both are important nursery areas for egg and larval stages of commercially and ecologically important fish and macroinvertebrate species.

Western Cape Breton (Northumberland Strait) waters support a zooplankton community similar to other parts of the southern Gulf of St. Lawrence, dominated by small copepods, a diverse and abundant meroplankton fauna, and high abundance of jellyfish. These waters are typified by high summer zooplankton biomass relative to more northern parts of the St. Lawrence Gulf/Estuary system. At other times, biomass is comparable to other parts of the Gulf. The high summer biomass reflects the use of this area as a nursery from approximately May to September by a variety of species. The southern Gulf of St. Lawrence, including the western Cape Breton area, is the only significant nursery area for mackerel *Scomber scombrus* in eastern Canada and the northeastern United States. As well, the production of American lobster *Homarus americanus* larvae in St. Georges Bay and Northumberland Strait is among the highest recorded in North America. Although the summer period has been identified as being of primary importance in this area, very little information exists between December and April because of the problems of sampling through ice cover.

A community of large copepods (*Calanus* spp.) typical of the northern Gulf of St. Lawrence is maintained in the waters off eastern Cape Breton Island by advection from the Gulf of St. Lawrence in the Nova Scotia Current. Compared to the western Cape Breton community, this assemblage is much more “oceanic” in nature. This is an important area for early larval stages of snow crab *Chionoecetes opilio*, rock crab *Cancer irroratus*, Atlantic and Arctic lyre crabs *Hyas araneus* and *H. coarctatus*, and American lobster *Homarus americanus*, and eggs of northern cod *Gadus morhua*, witch flounder *Glyptocephalus cynoglossus*, and American plaice *Hippoglossoides platessoides*. The peak timing of the use of this area as a nursery (i.e., maximum number of species) appears to be from April to July or August, although pelagic eggs are present in these waters year-round.

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Résumé

Les eaux côtières de l'ouest (détroit de Northumberland) et de l'est (Sydney Bight) de l'île du Cap-Breton sont occupées par deux assemblages divers et productifs d'espèces zooplanctoniques. Dans chaque zone, l'assemblage d'espèces est particulier, mais les deux zones constituent des nourriceries importantes pour les œufs et les larves d'espèces commercialement et écologiquement importantes de poissons et d'invertébrés.

Les eaux de l'ouest du Cap-Breton (détroit de Northumberland) abritent une communauté zooplanctonique semblable à celle d'autres parties du sud du golfe du Saint-Laurent, dominée par des petits copépodes, par une faune méroplanctonique diverse et abondante, et par une grande abondance de méduses. Par rapport à d'autres zones plus septentrionales du système du golfe et de l'estuaire du Saint-Laurent, ces eaux se caractérisent par une forte biomasse zooplanctonique en été. Aux autres périodes, la biomasse est comparable à celle des autres zones du golfe. La forte biomasse présente en été correspond à la vocation de nourricerie de cette zone, qui est ainsi utilisée de mai à septembre environ par une gamme variée d'espèces. Le sud du golfe du Saint-Laurent, y compris l'ouest du Cap-Breton, est la seule nourricerie importante du maquereau, *Scomber scombrus*, dans l'est du Canada et le nord-est des États-Unis. De plus, la production de larves de homard américain, *Homarus americanus*, dans la baie St. Georges et le détroit de Northumberland est parmi les plus élevées qu'on ait observées en Amérique du Nord. Si la saison estivale a été signalée comme de première importance dans cette zone, on a très peu d'information pour la période de décembre à avril à cause de la difficulté de l'échantillonnage à travers la couche de glace.

Une communauté de gros copépodes (*Calanus* spp.) typique du nord du golfe du Saint-Laurent se maintient dans les eaux de l'est de l'île du Cap-Breton à cause d'un phénomène d'advection depuis le golfe du Saint-Laurent par le courant de Nouvelle-Écosse. Comparé à la communauté de l'ouest du Cap-Breton, cet assemblage est de nature beaucoup plus « océanique ». Il s'agit d'une zone importante pour les premiers stades larvaires du crabe des neiges, *Chionoecetes opilio*, du crabe commun, *Cancer irroratus,* du crabe araignée, *Hyas araneus*, du crabe violon, *H. coarctatus*, et du homard américain, *Homarus americanus*, ainsi que pour les œufs de la morue franche, *Gadus morhua*, de la plie grise, *Glyptocephalus cynoglossus*, et de la plie canadienne, *Hippoglossoides platessoides*. La période de la plus forte utilisation comme nourricerie (nombre maximal d'espèces) semble aller d'avril à juin ou août, mais des œufs pélagiques sont présents dans ces eaux toute l'année.

1. Introduction

Offshore exploration activities have been requested by the oil and gas industry for waters off Cape Breton Island in the southern Gulf of St. Lawrence (Northumberland Strait) and Scotian Shelf (Sydney Bight). In order to compile existing information on these ecosystems, a Regional Advisory Process (RAP) was held by Fisheries and Oceans Canada in Antigonish, NS, on November 21-22, 2001. The information summarized in this document was presented and discussed at the RAP. Specifically, the purpose of this document is to review the published literature on zooplankton communities in the waters adjacent to Cape Breton Island that are currently proposed for oil and gas exploration activities. The productivity and composition of both invertebrate zooplankton and ichthyoplankton are addressed. Gaps in knowledge that may preclude reasonable predictions of potential impacts of the proposed oil and gas exploration activities on zooplankton are noted. This document also identifies additional sources of information that are currently unpublished, or published in unanalysed data report form.

2. Western Cape Breton (southern Gulf of St. Lawrence)

It has been known for over 80 years that the composition of the zooplankton communities of the Magdalen Shallows or southern Gulf of St. Lawrence (sGSL) is distinct from that of other regions within the Gulf of St. Lawrence (Dannevig 1919; Huntsman 1919; Willey 1919). The same researchers also identified differences in the plankton of the sGSL when compared to that of the Scotian Shelf; i.e., the waters to the west and east of Cape Breton Island contain different zooplankton communities (and therefore will be discussed separately in the present document). More recent analyses of planktonic productivity (Steven 1974, 1975), biogeography (Dunbar *et al*. 1980) and indicators of food web structure (Grégoire and Castonguay 1989; de Lafontaine *et al*. 1991) in the Gulf of St. Lawrence confirm the distinctive nature of the plankton communities and indeed of the entire ecosystem of the sGSL.

There has been limited examination of spatial trends within the sGSL. Most publications have focussed on comparing the sGSL as a whole to other parts of the Gulf, or have examined only subregions of the sGSL within a single study period. Often, the Northumberland Strait has been omitted from studies that are otherwise fairly comprehensive in their spatial coverage. There are, however, indications in the literature that the community composition and biomass of zooplankton differ between the eastern and northwestern parts of the sGSL, and between the Northumberland Strait and the open waters of the Magdalen Shallows. An example of the former is that ichthyoplankton apparently is more dominant in Chaleur Bay and invertebrate meroplankton in St. Georges Bay (de Lafontaine *et al*. 1991). Species typical of the northern Gulf are also more commonly reported in the northwestern part of the sGSL than elsewhere, and there may be differences in the seasonal nutrient dynamics as a result of the timing of the arrival of outflow from the St. Lawrence Estuary (e.g., Steven 1975). For these reasons, this review will place little emphasis on the large body of work that exists on Chaleur Bay and adjacent waters of the northwestern sGSL. Examples of differences between the open sGSL and Northumberland Strait will be mentioned throughout this review.

Much of the existing information specific to the coastal waters of western Cape Breton Island is not easily accessible without further analysis of data or samples (see section 2.5). A series of surveys conducted in St. Georges Bay in the 1970s and 1980s provides data from an area adjacent to the proposed Northumberland Strait oil and gas lease. The zooplankton community of

St. Georges Bay seems to be reasonably representative of the eastern end of Northumberland Strait, although there are some differences which will be noted in the following sections. It is probably reasonable to assume that western Cape Breton waters share characteristics with both Northumberland Strait and the eastern part of the sGSL near the Magdalen Islands. For the most part, the discussion that follows is based on a general literature review of the zooplankton of the sGSL rather than on studies specifically focussed on the Cape Breton coastal region. Exceptions to this will be noted.

2.1 Biomass and productivity

Surveys conducted as part of Canada's contribution to the International Biological Program (IBP) in 1969 to 1972 found zooplankton biomass (per unit volume) much higher in the sGSL than elsewhere in the Gulf or Estuary of St. Lawrence from April to September. From June to September, the zooplankton dry weight biomass in the sGSL was about three times the average biomass found in most of the deeper water areas of the Gulf. Only in October-November did another area of the Gulf (the area between Anticosti and Gaspé) support a greater biomass of zooplankton expressed per unit volume (Steven 1974, 1975). de Lafontaine (1994) confirmed the presence of a sharp biomass gradient at the boundary of the Magdalen Shallows and the Laurentian Channel. On the basis of biomass/m^2 surface area, however, the biomass of zooplankton in the sGSL was lower than the average of the entire Gulf (de Lafontaine *et al*. 1991), because the sGSL is shallower than other areas of the Gulf.

The sGSL is characterised by a large seasonal change in biomass. In 1967-1971, biomass was low in May, but increased five-fold in summer to maximum values in July and August (de Lafontaine 1994). The highest monthly average of zooplankton dry weight recorded in the IBP surveys was 124 mg/m^3 in August, but many values exceeding 200 mg/m^3 were obtained in each of the summer months. This high concentration of zooplankton disappeared by October-November when the average value was ~28 mg/m^3, about the same as in the central Gulf (Steven 1974, 1975).

Steven (1975, p. 241) stressed the significance of the sGSL as a production area for the entire Gulf system, and the interconnected nature of that system, as follows. "The importance to the overall production system of the rich summer zooplankton on the Magdalen Shallows cannot be over-emphasized, as this is the main spawning and nursery area for some of the commercially important fish and a seasonal feeding ground for others. This would hardly be so unless an abundance of food were available at the right time for the young stage, and the most important outcome of our study may be to show how this depends on the supply of nutrients from the St. Lawrence Estuary....in the estuary and plume of a great river, where large quantities of water are moved continuously seaward, the components of the plankton production system are to some extent separated as they move simultaneously through both space and time. Thus in the Gulf we can recognize successively a region of nutrient supply [the St. Lawrence Estuary], a region of maximum phytoplankton production [the Gaspé Current and, in summer, stratified lower Estuary] and a region of maximum zooplankton production [Magdalen Shallows] linking events in the St. Lawrence Estuary with those on the Magdalen Shallows".

Summer zooplankton biomass in the sGSL varied annually by a factor of 2.5. During the mackerel egg and larval surveys of June-early July of 1982, 1987 and 1991, mean zooplankton dry weight biomass (entire water column) varied from a minimum of 1.5 g/m^2 in 1987 to a maximum of 4.0 g/m^2 in 1982. Most of this variation was due to fluctuations in the >1000 µm size fraction, which was usually equivalent in biomass to the other three size fractions sampled (between 333 and 1000 µm). The range in biomass of the >1000 µm fraction was 0.8 to 3.2 g/m^2. Biomass in the <1000 µm fraction varied by less than a factor of two, from 0.5 to 0.9 g/m^2. There was a significant negative relationship between zooplankton biomass and an index of freshwater runoff from the St. Lawrence Estuary (Runge *et al*. 1999).

Maps of zooplankton biomass from the mackerel surveys indicate that high biomass of zooplankton (size fractions from 300 µm to >1000 µm) frequently occurred in late June-early July in the years between 1982 and 1991 in western Cape Breton waters (Castonguay *et al*. 1998). There was, however, a tendency for higher biomass of the larger zooplankton size fractions (>700 µm) to be distributed in the waters to the north and west of Cheticamp than in eastern Northumberland Strait in most years. More recent data from this ongoing program currently exist as unprocessed samples or raw data (F. Grégoire, Fisheries and Oceans Canada, Mont-Joli, PQ, pers. comm.).

In contrast to the seasonal cycle described above for the sGSL as a whole, in St. Georges Bay the biomass of plankton in the size range of 25 µm to 4 mm was greatest in April (167 mg dry weight/m^3). It declined to less than 60 mg/m^3 in August and September. The decline in plankton biomass in the copepod size fractions, starting in mid-July, coincided with the replacement of a cold water *Calanus-Temora-Pseudocalanus* community by a *Centropages-Tortanus-Acartia* community (see section 2.2.2). The low biomasses in August and September were reflected in all size fractions except algae and protozoans. Stations in the centre of St. Georges Bay had the greatest abundance of zooplankton averaged over the year and the least variability (Hargrave *et al*. 1985).

The eastern part of the sGSL, including the Northumberland Strait off Cape Breton, supported lower zooplankton biomass than the western sGSL in the majority of research surveys where this has been investigated (de Lafontaine 1994; Castonguay *et al*. 1998). Zooplankton biomass averaged over the sGSL (5 g/m^2, depth unspecified) was 2-3 times the mean value recorded in St. Georges Bay of 1.5 to 3 g/m^2 for water of 30 m deep (de Lafontaine *et al*. 1991). While the latter comparison may be affected by interannual variability (because the research was conducted in different years in each area), it is consistent with the survey results cited above.

St. Georges Bay is the only area of the sGSL for which secondary production estimates have been published for zooplankton. Hargrave and Phillips (1986) estimated the average macrozooplankton production to be on the order of 26-29 mg C/m^2/d, well within the range of production determined for other temperate estuaries and coastal bays (4-170 mg C/m^2/d). The secondary production of copepod-sized organisms in St. Georges Bay was estimated as 1 g C/m^2/mo (Hargrave *et al*. 1985), the equivalent of 3 mg dry weight/m^3/d during the summer (de Lafontaine *et al*. 1991). With a median copepod biomass of 40 mg/m^3 in summer, the weight specific growth rate was ~7%/d and approximated a yield of 7-13% of phytoplankton production (MEL 1980). Zooplankton biomass in the copepod size range decreased during summer, despite an increase in secondary production in late June and a high level of phytoplankton production. This was interpreted as an indication of heavy predation by planktivorous fishes such as mackerel, herring, gaspereau, or smelt (Hargrave *et al*. 1985).

2.2 Community composition

2.2.1 General description

The zooplankton community of the sGSL includes species that are found throughout all regions of the Gulf, and a number of forms that in the Gulf are restricted to the sGSL. Among the species found throughout all regions of the Gulf are the medusa *Aglantha digitale*, the copepods *Oithona similis*, *Calanus finmarchicus*, *C. hyperboreus*, *C. glacialis*, *Metridia longa*, *Paraeuchaeta* (as *Euchaeta*) *norvegica* and *Pseudocalanus* sp. (as *minutus*), and the chaetognath *Sagitta elegans* (de Lafontaine *et al*. 1991). In addition, a number of warm-temperate species that are rarely found north of the Cape Cod biogeographic boundary occur within the sGSL (Dunbar *et al*. 1980; Bernier 2001; Locke and Bernier unpub. data). For example, Locke and Bernier have recently recorded the cladoceran *Penilia avirostris* in waters adjacent to the proposed Northumberland Strait lease in October 2000, but this is normally considered to be a subtropical species which very rarely occurs as far north as Georges Bank (Colton 1985).

The zooplankton ecology of the sGSL is distinguished from that of other regions of the Gulf in summer by: the seasonal succession of the copepod community (section 2.2.2); the variety and abundance of larval invertebrates and fishes that are present from June to September (sections 2.2.3 and 3.2.5); and the predominance of gelatinous predators (section 2.2.4).

2.2.2 Copepoda

As is typical of temperate waters, copepods have been found to dominate the community in most studies of zooplankton in the sGSL. In total, copepods accounted for 81% of all zooplankters collected in Shediac Bay with a 220 µm net from May to November 1968 (Citarella 1982, 1984). Copepods represented 32-79% of the zooplankton abundance in a 405 µm net in St. Georges Bay in the months of May to December 1973 (Ware 1977). Unlike most temperate waters, and in particular unlike the deeper waters of the northern Gulf which are almost always numerically dominated by large copepods, taxa other than copepods sometimes dominate in the sGSL. For example, typically coastal taxa such as the cladoceran genera *Podon* and *Evadne* were very common and sometimes dominant in the IBP surveys (Steven 1974). Barnacle cypris larvae were among the dominant zooplankters, comprising 29% of the abundance in samples collected from a 405 µm net in St. Georges Bay in May 1973 (Ware 1977).

The composition and size characteristics of the copepod community of the sGSL are quite unlike those of other regions of the Gulf, an observation first reported by Willey (1919). The northern Gulf, in common with many North Atlantic waters, was dominated by copepods of the genus *Calanus* throughout the year. Willey referred to this as a “macrocalanoid” community. Members of this genus, particularly *Calanus finmarchicus*, are normally considered to be the mainstays of pelagic secondary production in temperate waters. By contrast, the genus was relatively unimportant in the sGSL, and furthermore a seasonal succession from larger to smaller copepods occurred throughout the growing season. Willey called the second community of copepods that he observed in the Gulf a “microcalanoid” zooplankton, consisting of species such as *Pseudocalanus elongatus, Tortanus discaudatus, Temora longicornis, Centropages hamatus, Acartia longiremis* and *Metridia longa*. In spring, the sGSL contained elements of the macrocalanoid community but microcalanoids were numerically dominant. For example, Willey collected both adult and juvenile *Calanus finmarchicus* in May 1915 between PEI and the Magdalen Islands, but 80-90% of the copepod catch was *Pseudocalanus* sp. (as *elongatus*). Sampling off the mouth of Miramichi Bay, 20% of the copepods were *Calanus*, and the community was dominated by small species of *Temora* and *Tortanus*. By summer, the copepod community was almost entirely composed of microcalanoids, although macrocalanoids were recorded - especially at the western end of the sGSL. Copepods recorded from the waters off western Cape Breton Island included *Calanus* spp., *Pseudocalanus*, *Temora*, *Tortanus*, *Metridia* and *Acartia*.

The copepod fauna of Shediac Bay was even more strongly dominated by the so-called microcalanoids from May to November 1968. The dominant copepod taxa (>10% of the zooplankton individuals) were *Acartia tonsa, Oithona similis, Acartia hudsonica* [as *clausi*] and *Centropages hamatus*. *Temora longicornis, Eurytemora herdmani, Pseudodiaptomus coronatus, Pseudocalanus* sp. (as *minutus*), *Tortanus discaudatus* and *Labidocera aestiva* each accounted for 1-10% of the individuals. *Calanus finmarchicus* and nine other species each comprised <0.1% of the abundance. *Calanus finmarchicus* was present from May through August, but was never abundant. *Temora, Oithona* and *Centropages* were abundant throughout the sampling period. Seasonal succession was observed in the dominance of copepods. *Pseudocalanus* dominated in May, *Acartia clausi* in June-July, *Acartia tonsa* in August-October, and *Temora* in November (Citarella 1982, 1984).

The copepod community in Kouchibouguac Bay off the mouth of the Kouchibouguac and Kouchibouguacis estuaries in May-November of 1997-1998 was much like that of Shediac Bay. Bernier (2001) found *Acartia hudsonica, A. longiremis, A. tonsa* and *Oithona* sp. to be abundant; *Calanus finmarchicus, Eurytemora americana, E. herdmani, Labidocera aestiva, Pseudocalanus newmani, Temora longicornis,* and *Tortanus discaudatus* to be common; and occasionally caught *Anomalocera opalus, Eurytemora affinis* and *Pseudodiaptomus coronatus*. Although *Calanus finmarchicus* was present from May through August, it was not a dominant species.

The copepod community of St. Georges Bay is much like that described above, although the dominance by *Calanus finmarchicus* may be somewhat stronger in spring and fall than in the western Northumberland Strait embayments. Over several years of sampling, the zooplankton community was dominated by *Tortanus discaudatus, Temora longicornis, Centropages* (identified by Ware as *typicus* but probably *hamatus*, G. Harding, Fisheries and Oceans Canada, Dartmouth, NS, pers. comm.) and *Calanus finmarchicus*. In 1973, *Calanus finmarchicus* dominated the late spring (May) copepods until the water began to warm. This species was then replaced by smaller copepods, principally *Centropages* and *Temora longicornis*. With the onset of autumn, *Tortanus* and *Calanus* increased in abundance and by December accounted for ~75% of the zooplankton community (Ware 1977). A similar pattern of seasonal succession occurred in 1974 (Lambert 1980). In 1977, a spring community of *Temora longicornis* with smaller proportions of *Calanus* and *Pseudocalanus* shifted by July-August to a late summer community dominated by *Centropages*, *Tortanus* and *Acartia* (MEL 1980).

Despite these indications that *Calanus* spp. are relatively unimportant in the sGSL in summer, there are certain years and perhaps some locations (especially, offshore stations in the northwestern sGSL) where this is clearly not the case. Runge *et al*. (1999) occasionally observed this genus in large numbers during the June-July mackerel egg/larval surveys. The numerically dominant copepod taxa captured with 333 μm mesh nets were (in descending order) *Calanus finmarchicus*, *Temora longicornis, Pseudocalanus* spp., and *Calanus hyperboreus*. This mid-summer community thus appeared to be constituted from much the same group of taxa that were described as a spring community in St. Georges Bay (MEL 1980). These taxa represented >85% of copepod abundance in the catch. *Calanus finmarchicus* tended to be the most abundant species at offshore stations. *Temora* tended to be the most abundant species at nearshore stations. Otherwise, there were no clear and consistent differences between nearshore and offshore stations. Interannual fluctuations in female abundance of the three most dominant copepod species resulted in *C. finmarchicus* abundance that was sometimes higher in the sGSL in "good" years than in some observations over the Laurentian Channel. The abundance in the sGSL in the "best" *C. finmarchicus* year studied, 1982, was 2-3 times higher than Runge and de Lafontaine (1996) had observed in the Laurentian Channel in late June of 1989. Over four years of study, the abundance of *C. finmarchicus* fluctuated by a factor of fifteen, while *T. longicornis* and *Pseudocalanus* sp. abundance fluctuated by a factor of about three. These annual fluctuations appeared to be mediated by an index of runoff from the St. Lawrence Estuary that is correlated to oceanographic conditions such as temperature and salinity. The IBP survey also found considerable numbers of *C. finmarchicus*. Most samples contained 3-4 species of calanoid copepods and 1-2 species of cyclopoids; the most abundant were usually *C. finmarchicus, O. similis* or *T. longicornis* (Steven 1974). It should be noted that neither the mackerel or IBP surveys covered the Northumberland Strait area and both were conducted mainly in offshore waters, which may account for the differences between these studies and those mentioned in the preceding paragraphs, which were mostly coastal studies except for Willey (1919).

The seasonal succession of calanoid copepods and other zooplankters in the sGSL has been attributed to a number of factors, many of which are related to the relatively shallow depth over the Magdalen Shallows. Mortality of *Calanus* may be high in the sGSL because the shallow depth prevents diel vertical migration to a light level low enough to avoid visual predators. The shallow depth may aid in recruitment of some copepods, such as *Centropages, Acartia* and *Tortanus*, which have a life cycle including resting eggs on the sea bottom. Some of these genera probably also benefit from the warmer temperatures of the sGSL (de Lafontaine *et al*. 1991).

2.2.3 Importance of the sGSL as a nursery area for invertebrates

A characteristic feature of summer (June-September) zooplankton populations in the sGSL is the great variety of larval and immature forms including many decapod zoeae, euphausiids, echinoderms, bivalves and gastropods. The adults of many of these are benthic. The richness of the summer plankton in this area is therefore thought to derive largely from the richness of the benthic invertebrate fauna (Steven 1974).

Citarella (1982) found that 18% of the zooplankton community of Shediac Bay from May to November 1968 was made up of meroplankton. Veligers of molluscs, echinoderm larvae (ophioplutei, echinoplutei, auricularia and bipinnaria), cyphonautes of bryozoans, and crustacean larvae were each found in >70% of the samples. From mid-May to early June, euphausiid calyptopis and various polychaete nectochaetes (*Pectinaria*, *Phyllodoce* and *Harmothoë*) were abundant. In early July, cyphonautes, echinoplutei and gastropod veligers (mainly *Crepidula fornicata*) were abundant. From mid-July to early September, the abundant meroplankton included brachyuran zoeae, veligers of bivalves (*Tellina agilis, Teredo navalis*), and barnacle nauplii. From mid-September to late October, there were mussel veligers (*Mytilus, Modiolus*), cyphonautes, ophioplutei, veligers of the pteropod *Limacina* (as *Spiratella*), and veligers of oyster (*Crassostrea virginica*). In November, the only dominant meroplankton were the nauplii of euphausiids.

St. Georges Bay also contains a diverse community of meroplankton. In May, barnacle cypris larvae were co-dominant with *Calanus finmarchicus* and accounted for 29% of the zooplankters (Ware 1977). Size fractionation of zooplankton collected in St. Georges Bay using various mesh sizes indicates that meroplankton abundance in the sGSL is probably underestimated because the large size of mesh used in most studies does not sample smaller taxa (de Lafontaine et al. 1991). In St. Georges Bay, cyprid and bivalve larvae were abundant in the 250-509 µm size class (MEL 1980), which is the smallest that would be routinely sampled by most investigators. However, tintinnids and bivalve larvae were abundant in 66-125 µm and 125-250 µm size-fractionated zooplankton samples taken with a 57 µm mesh net (MEL 1980). These taxa were poorly represented in larger size fractions, but may constitute a substantial proportion of the community.

The remainder of this section will discuss the significance of the sGSL as a nursery area for the planktonic larval stages of a number of invertebrate species of economic importance. Species important in commercial fisheries or aquaculture include American lobster, several crab species, mussels, oysters and sea scallops. In addition, the larval forms of many forage species that are important as prey for commercial fishes are reared in this region. Euphausiids, of special importance as prey for small to medium-sized cod and other groundfish (Hanson and Chouinard, in press), will be discussed in more detail later in this section.

Probably the aspect of invertebrate meroplankton ecology that has been studied most extensively in the sGSL is the production of lobster larvae, which is among the highest per unit of surface area of any region that has been sampled in North America (Harding *et al*. 1982). As reviewed by Stasko (1980), early studies by Templeman and Smith from 1937 to 1941 identified areas of concentration in the eastern end of Northumberland Strait between Pictou and Canso Strait (stage I larvae), and in the western end off Point du Chene (stage I) and Egmont Bay (stage IV). In 1939, Smith found larvae at all 25 stations sampled between PEI and the Magdalen Islands, but they were most abundant near both shores. These early researchers determined that larval lobsters were concentrated at the surface during the day but moved deeper in the water column at night. This behaviour may be important in the context of the present review as the depth at which a chemical were to disperse, in the event of a spill during petroleum or gas exploration, would determine the extent of exposure of larval lobsters.

The timing of lobster larval presence in the plankton of northern Northumberland Strait was well established by sampling from 1948 to 1963. In some years, larvae were already present on June 15 when sampling commenced. Below-normal temperatures in 1961 delayed the appearance of the first larvae until June 26, and first stage larvae were still present in the plankton in mid-September (Scarratt 1964). Scarratt (1973) reported substantial interannual variation in production and survival of lobster larvae. Recent data on lobster larvae in Northumberland Strait exist from the ongoing sampling programs of R. Miller and M. Lanteigne (pers. comm.). Miller's work includes a series of stations in the Pictou area (Miller, pers. comm.), including an area sampled by Scarratt (1968).

The central region of St. Georges Bay was comparable in larval lobster production to the most productive stations in Northumberland Strait off Richibucto Head, where 20-25 x 10^3 larvae (all stages)/km^2 had been recorded in the neuston by Scarratt (Harding *et al.* 1979). Lobster larvae were present in the neuston of St. Georges Bay from late June to mid-August. Mean abundances in the Bay were 0.8-9.7 x 10^3 stage I to III larvae/km^2 (Harding *et al*. 1982). This finding was in contrast to earlier work by Harding *et al*. (1979), which had estimated much lower densities in St. Georges Bay (however, in this earlier work, the estimates of abundance were stated by Harding *et al*. to be low and not comparable to Scarratt's methodology).

Compared to lobsters, relatively little has been written about the distribution or abundance of larvae of the other commercially important taxa. However, one result relevant to the present review is that a fall survey identified the west coast of Cape Breton as one of three promising collection regions of giant scallop *Placopecten magellanicus* larvae (spat) in southeastern Northumberland Strait (Davidson and Tetu 2001). The other two collection regions were St. Georges Bay and the area east of Merigomish Island. Scallop eggs are released into the water column in Northumberland Strait in mid to late August, after which the larvae are planktonic for four to five weeks until settlement in September-October (Biron *et al*., in prep.).

Larval snow crab *Chionoecetes opilio* occurred in the plankton from May to September. Early larvae were distributed throughout the sGSL with areas of concentration in the western portion and between the Magdalen Islands and Cape Breton. Eventually, these larvae moved toward the east and settled most densely in the waters west of Cape Breton in the Magdalen Shallows, and off eastern Cape Breton (Biron *et al*., in prep.).

Euphausiids, as mentioned above, are important prey to commercial fishes like cod, and the sGSL is evidently an important nursery area contributing to, and indeed probably sustaining, adult populations that mature elsewhere in the Gulf (Berkes 1976). The larvae of *Meganyctiphanes norvegica, Thysanoessa inermis* and *T. raschii* were most abundant on the Magdalen Shallows, although adults and adolescent stages were more abundant in other regions of the Gulf. These species spawned in the western part of the Gulf, and eggs and young larvae were carried in the Gaspé Current to the Magdalen Shallows, where they remained during larval development. In fall, the bulk of the larval populations were found outside of the shallows in the eastern Gulf, and the later adolescent stages were carried westward in the intermediate water layer during the winter months as a result of their diel vertical migration. All stages of *Thysanoessa longicaudata* were found mainly in the eastern Gulf (Steven 1974; Berkes 1976).

2.2.4 Other invertebrate taxa

The sGSL supports a diverse community of invertebrate zooplankton, as mentioned above. In the Northumberland Strait, bottom tows in depths of 5-13 m caught numerous *Crangon septemspinosa*, mysids (identified by Scarratt as *Mysis relicta*, but this is a freshwater species – more likely *Mysis mixta*, which is common in the sGSL, see below), larvae of *Cancer irroratus*, and occasional chaetognaths, amphipods, isopods, copepods, and cumaceans (Scarratt 1973). Only a few of the planktonic groups will be further discussed here.

Jellyfish swarms are numerically, and probably ecologically, very important in the summer community of the sGSL. The numerically dominant large taxa in the Northumberland Strait in summer were *Cyanea capillata* and, to a lesser extent, *Aurelia aurita* (Locke, pers. obs.; Bernier 2001). There were also large numbers of smaller cnidarian taxa throughout the ice-free season (Bernier 2001). The ctenophore *Pleurobrachia pileus*, while not found in summer, was abundant in spring and fall at the mouth of Kouchibouguac estuary (Bernier 2001). In St. Georges Bay, large ctenophores were present in early June, but were not numerically important after mid-June (Ware 1977). The ecological importance of jellyfish in the sGSL has never been evaluated, but it is likely that they play an important role as predators in structuring the zooplankton community (de Lafontaine *et al*. 1991). Harding *et al*. (1986) speculated that the vertical migratory behaviour of certain zooplankton species in St. Georges Bay would serve to reduce their exposure to predation by jellyfish.

The pteropod *Limacina* (as *Spiratella*) *retroversa* was more abundant in the sGSL than elsewhere in the Gulf. It was relatively rare in May and June, increased in numbers as the summer progressed, and reached a peak of abundance from September to November, when both mature adults and larval stages were numerous on the Magdalen Shallows. It was concluded that reproduction of this species was concentrated over the Magdalen Shallows in late summer (Steven 1974).

Mysis mixta was the only mysid present over the major part of the sublittoral portion of the Magdalen Shallows, and was especially abundant at 45-85 m depth (Steven 1974). It was found in many areas to occur in concentrations of 10-25 mysids/m^3. There were two distinct year classes, which were separated spatially from one another. Breeding was deduced to occur during the winter or spring. There was also a deep-water mysid fauna. The Magdalen Shallows is the major area in the Gulf where the cold intermediate layer (<0 to 1.5 °C and 30-32 ‰) meets the bottom, and this resulted in a different mysid community of the deeper waters compared to elsewhere in the Gulf. The Cape Breton, Shediac and Chaleur troughs at the extremities of the shallows contained the mysids *Erythrops erythropthalma*, *Pseudomma truncatum* and *Meterythrops robusta*. Note: This was the only reference I located that mentioned a specific planktonic fauna associated with these troughs. Given the proximity of the Cape Breton trough to the area of interest of this habitat RAP, and the likelihood that the fauna over this trough differs from that of the Magdalen Shallows, this should be considered a knowledge gap for zooplankton. *Stilomysis grandis* was occasionally encountered in the cold intermediate water. Mysids were not well sampled with plankton nets due to their hyperbenthic habitat (Steven 1974).

The only chaetognath reported from the sGSL is *Sagitta elegans*. This species was present throughout the sGSL in May-August except in Northumberland Strait. Large individuals (>20 mm length) occurred only in the Laurentian Channel and outside of Cabot Strait, thus the population of the sGSL was composed of immature individuals. The absence of *Sagitta* from Northumberland Strait was attributed to the isolation of the Strait from the places where the adults were found (Huntsman 1919).

2.2.5 Importance of the sGSL as a nursery area for fishes

The sGSL has a different ichthyoplankton community from other regions of the Gulf, and the total number of larval species and the overall abundance are generally higher than in the northern Gulf (de Lafontaine *et al*. 1991). Dannevig (1919) distinguished characteristic environments of several communities of egg and larval fish within the sGSL. The northern limit of occurrence in the Gulf for southern forms (e.g., mackerel *Scomber scombrus*, fourbeard rockling *Enchelyopus cimbrius* and cunner *Tautogolabrus adspersus*) was a line drawn from Cabot Strait to Anticosti. Northern species (e.g., northern wolffish *Anarichas denticulatus*, capelin *Mallotus villosus*, and two Arctic species, twohorn sculpin *Icelus bicornis*, and Atlantic poacher *Agonus decagonus*) could be found south of this line, however, especially in the western sGSL. Within these limits, distribution varied with the depth. Cunner and fourbeard rockling larvae and eggs were found only near land and close to relatively shallow banks, but cod and plaice were typical of offshore banks. Mackerel were found over all bottom depths, south of the line mentioned above. East-west differences in taxonomic composition of the ichthyoplankton have been noted by several researchers, e.g., Steven (1974) found white hake *Urophycis tenuis* primarily in the eastern part of the sGSL.

The sGSL is probably a retention area for ichthyoplankton. Messier and Kohler (1972) speculated that herring *Clupea harengus* larvae would drift in a southwestern direction from the major concentrations of spawning areas in the northwestern sGSL and be retained over the Magdalen Shallows. Drifting of eggs and larvae from the lower St. Lawrence Estuary toward the sGSL via the Gaspé Current has been documented by de Lafontaine *et al*. (1984). Ichthyoplankton also appear to be retained in St. Georges Bay by a gyre (Lambert *et al*. 1982).

The annual cycle of ichthyoplankton begins in late April or early May. Kennedy and Powles (1964), working mainly in the western sGSL, found larvae of sand lance *Ammodytes* and snake blenny *Lumpenus lumpretaeformis* dominated the ichthyoplankton in May and June. In Northumberland Strait, Dannevig (1919) collected only a few larvae of northern wolffish and capelin close to land in May. Moving out over the banks in the northwestern sGSL, he encountered plaice and cod larvae, a few eggs of fourbeard rockling and the Arctic species. Plaice eggs were present at virtually all stations. Cod eggs were present throughout the sGSL except Northumberland Strait.

Plaice eggs continued to be widely distributed in June (Dannevig 1919). In June, the stations in the eastern sGSL contained numerous newly spawned mackerel *Scomber scombrus* eggs, plus the "banks fauna" of cod and plaice. By early June, cunner eggs appeared in the waters off eastern PEI. Faber (1976) found larvae of cold-water species (herring, rockling, lumpfish *Cyclopterus lumpus*, radiated shanny *Ulvaria subbifurcata* and sand lance *Ammodytes* sp.) to be dominant in the western Northumberland Strait (between Richibucto and Miminegash) in June. Rare occurrences of redfish *Sebastes marinus,* winter flounder *Pleuronectes americanus,* and seasnails *Liparis* spp. were noted.

Mackerel eggs appeared in late June, and this remained the dominant species throughout July. Cunner, radiated shanny and winter flounder *Pleuronectes americanus* larvae may account for a large proportion of the summer ichthyoplankton (de Lafontaine *et al*. 1991). Steven (1974) commonly found plaice, mackerel and herring larvae throughout the southern regions from midsummer onwards, and white hake mainly in the eastern region. Plaice eggs continued to be caught until mid-July and cod eggs continued to be present throughout the sGSL with the exception of Northumberland Strait (Dannevig 1919). Rockling eggs and larvae were found throughout the sGSL including Northumberland Strait in July. A few capelin larvae were found near the Magdalen Islands in July (Dannevig 1919). Sand lance, radiated shanny, lumpfish, fourbeard rockling, mackerel and herring were abundant in Northumberland Strait (Faber 1976). Winter flounder and seasnails were occasionally found in early July. At this time Faber found that the cold-water species of June were gradually being replaced by temperate species. Peak numbers of larvae were present in this month.

In August, mackerel eggs were no longer present, whereas a few larvae were caught in the eastern sGSL (Dannevig 1919). Cod eggs were found throughout the sGSL except, again, Northumberland Strait. A few cod larvae were found, in the northwestern portion of the sGSL. Rockling eggs and larvae continued to be caught. In Northumberland Strait, the abundant larvae were lumpfish, fourbeard rockling, mackerel, cunner, and white hake (Faber 1976). A few American plaice and Atlantic silverside *Menidia menidia* were recorded in early August, and seasnails and windowpane *Scophthalmus aquosus* in late August.

Faber (1976) continued to find fourbeard rockling, cunner, and white hake larvae into September, and reported the reappearance of larval herring in Northumberland Strait.

The northern component of the Northwest Atlantic stock of mackerel spawns in the sGSL (Sette 1950; Ware and Lambert 1985). Mackerel has, by far, been the best-studied member of the ichthyoplankton within the sGSL, where larval and egg surveys specifically for mackerel have been conducted annually since the 1970's. Data were also collected in the 1960's by the surveys of Kohler and colleagues (see section 2.4); egg distribution averaged over these surveys was summarized by Lett (1980). The spatial distribution of mackerel eggs in the past three decades was mapped in Castonguay *et al*. (1998) and Grégoire (in prep.). In general, the highest densities of eggs were observed in the western portion of the sGSL, and in the waters between Cape Breton Island and PEI. Most of the eggs and larvae occurred at depths of 0-3 m (de Lafontaine and Gascon 1989). The timing of mackerel spawning has been fairly constant since its initial description by Dannevig (1919). In St. Georges Bay, mackerel eggs appeared near the first week in June (temperature about 9 °C) and were seldom found after mid-August (Ware 1977). Peak spawning occurred on average ~ July 1 ± 1 wk, at a surface temperature ~ 11-15 °C. The annual surveys of the sGSL showed considerable annual variation in the abundance of mackerel eggs and larvae. There was a fivefold variation in the mean density of mackerel eggs, from 120 eggs/m^2 in 1983 to 675 eggs/m^2 in 1991 (Runge *et al*. 1999). Mean densities of larvae were lowest in 1991 (3 larvae/m^2) and highest in 1983 (105 larvae/m^2). Exceptional recruitment of mackerel in 1982 corresponded to the observation of highest zooplankton biomass, and relatively high zooplankton biomass was also observed in 1988 and 1990, two years in which mackerel year classes were stronger than average. Mackerel recruitment was statistically significantly related to changes in total zooplankton biomass, and this relationship appeared to be driven principally by variations in the >1000 µm size fraction. There was a significant negative relationship between the winter/spring index of runoff from the St. Lawrence system and both zooplankton biomass and mackerel recruitment (Runge *et al*. 1999).

Ichthyoplankton surveys of the 1960's identified two areas of concentration of cod eggs in the sGSL: one in the Shediac Valley, and another in the waters between Cape Breton Island and the Magdalen Islands (Lett 1980). Most spawning took place from early May to mid-June. In general, larvae were distributed to the east of the area of concentration of cod eggs off Miscou Bank, following the pattern of currents (Castonguay and Swain, in prep.). There have, however, been some changes in distribution of larval cod in the past two decades. Larvae were broadly distributed in the early to mid 1980's, with higher densities in eastern and central regions. In the late 1980s and early 1990's, larval density was high between PEI and the Magdalen Islands and to the east of the Magdalen Islands, and low elsewhere in the sGSL (Castonguay and Swain, in prep.).

Although St. Georges Bay has been described as being typically dominated by invertebrate meroplankton rather than ichthyoplankton (de Lafontaine *et al*. 1991), fish eggs and larvae appear to be frequently collected. More than 20 species were identified from eggs and/or larvae (Lambert *et al*. 1982). Mackerel, herring, capelin and white hake were studied in detail over four years. Fish eggs of all species represented 24% of the number of particles caught at the surface in late May, and 60% in June and July (Ware 1977). The large numbers during June-July reflect the appearance of mackerel. In St. Georges Bay in 1974 and 1975, the length of the spawning season and particularly the date of peak egg production of mackerel coincided with the maximum concentration of the 80-µm plankton. Eggs hatch in about 5-7 days at 11-14 °C, resulting in peak production of larvae on about June 30 in 1975 and July 14 in 1974. Maximum biomass of the 80 µm size fraction of plankton, thought to be the most important food supply for the yolk-sac larvae, occurred on July 7 in 1975 and was high throughout the spawning period in 1974 (Ware 1977).

The sGSL supports spring-, autumn- and a few summer-spawning stocks of herring. Except for 1967, herring larval concentration was higher in spring than in autumn (from 1966 to 1970). The highest concentrations were found off the mouth of Chaleur Bay, to the east and southeast of Caraquet and around the Magdalen Islands. Yolk-sac larvae were found in May of 1968, 1969 and 1970, indicating that spawning had occurred shortly before these dates. The overall drift of larvae through the sGSL was southeasterly from the Chaleur area (Messieh and Kohler 1972). A summer-spawning herring stock exists in the Pictou area and Lambert *et al*. (1982) attributed the summer-spawned herring larvae they collected in St. Georges Bay to this stock. In October 1967 and August 1968, newly hatched larvae were found off the mouth of Chaleur Bay, southern Gaspe coast, south and southeast of Magdalen Islands (Messieh and Kohler 1972). Herring also spawn on Fisherman's Bank, a major spawning ground adjacent to the proposed Northumberland Strait oil and gas lease, from mid-August to mid-September (Cairns *et al.* 1993). A portion of the larval herring population overwinters in the Gulf, based on collection of autumn-spawned larvae in the spring sGSL surveys by Messieh and Kohler (1972) and in Miramichi Bay in 1992 by Locke and Courtenay (1995b).

Capelin spawned in St. Georges Bay for the first time on record from 1975 to 1977 (Lambert *et al*. 1982).

Larval white hake were collected in the neuston of the sGSL in an August-September 1979 survey. Larvae ranged in standard length from 4 to 37 mm. The greatest abundance was found in Northumberland Strait and from the Magdalen Islands to the tip of Cape Breton Island (Markle *et al*. 1982).

2.3 The role of estuaries

Estuaries may play an important role in zooplankton production in the sGSL. Essentially, estuaries serve as nodes of high production which contribute to coastal zooplankton through flushing and exchange of nutrients, phytoplankton and zooplankton. The degree to which this contributes to sustaining coastal populations has not been quantified in the sGSL. Some fish and invertebrates spawn inside the estuaries and eggs and larvae are advected out to the sGSL, or vice versa. The estuaries function as important nursery areas for a variety of species, some of which also use the coastal waters as nurseries, and others which are estuarine-dependent (Johnston and Cheverie 1988; Johnston and Morse 1988; Locke and Courtenay 1995a,b). So any environmental threat to the coastal waters also affects the estuaries. Relatively few large estuaries are found on the western Cape Breton coast compared to, for example, Northumberland Strait. The largest is probably the Margaree estuary (e.g., Rogers 1940). There are however, numerous coastal lagoons on the eastern end of PEI and on mainland Nova Scotia in Northumberland Strait.

2.4 Additional sources of data

- Kohler *et al*. (1974a,b, 1975, 1976, 1977) – Between 1965 and 1975, 35 surveys of ichthyoplankton were conducted in the sGSL. In almost all of these, samples were collected off western Cape Breton. Only the larval herring data have been analysed for distribution and abundance (Messieh and Kohler 1972). The bulk of the data from these surveys is published in a data report format which does not lend itself to easy interpretation.

- Unpublished data and unsorted samples from mackerel egg/larval and zooplankton surveys conducted by researchers from the Maurice Lamontagne Institute – Data have been collected throughout the sGSL, with the exception of the central area of Northumberland Strait, annually since the 1970’s in June-July. A subset of the data (years 1982-1991) has been published in data report format by Castonguay *et al*. (1998). The remaining samples are either sorted but not yet published, or are yet to be sorted (F. Grégoire, Fisheries and Oceans Canada, Mont-Joli, PQ, pers. comm.).

- Recent data on lobster larvae in Northumberland Strait exist from the ongoing sampling programs of R. Miller (Fisheries and Oceans Canada, Dartmouth, NS, pers. comm.) and M. Lanteigne (Fisheries and Oceans Canada, Moncton, NB, pers. comm.).

3. Eastern Cape Breton (Sydney Bight)

The Sydney Bight area comprises a portion of the northeastern Scotian Shelf which is included within the North Atlantic Fisheries Organization Division 4Vn for fisheries management purposes. DFO has conducted numerous surveys of plankton, especially ichthyoplankton, on the Scotian Shelf. However, surveys that have addressed invertebrate zooplankton and ichthyoplankton community composition throughout the entire Shelf have found the northern and southern parts of the Scotian Shelf to be quite different. Feeding studies of planktivorous fishes (e.g., Grégoire and Castonguay 1989) further confirm the differences between these two areas. This reduces considerably the numbers of available surveys from which conclusions can be drawn about the Sydney Bight area; most surveys have focussed on the southern reaches of the Scotian Shelf.

The most obvious difference between the northern and southern portions of the Scotian Shelf is that the northern part of the shelf receives direct outflow from the Gulf of St. Lawrence in the form of the Nova Scotia Current. As will be seen from the following review, this current advects populations of zooplankton from the Gulf and directly influences the community composition of the northern Scotian Shelf including the waters of Sydney Bight. As already noted in section 2, the waters to the east and west of Cape Breton contain different zooplankton communities.

One of the major sources of information on zooplankton in eastern Nova Scotian waters is the Scotian Shelf Ichthyoplankton Program (SSIP) which was conducted from 1976-1982. These surveys were designed to investigate the spatial and temporal distribution of fish eggs and larvae from Georges Bank to Cape Breton Island, and data were simultaneously obtained on selected invertebrate zooplankton, mainly copepods and the larval forms of commercially fished decapods. The grid of stations and temporal coverage of the Sydney Bight area is shown in Zwanenburg *et al*. (in prep.).

Recent (1997 to present) but unpublished information on the area exists from DFO’s Atlantic Zone Monitoring Program, with spring and fall sampling of stations on a line from Louisbourg across Banquereau Bank to the shelf break (Louisbourg Line), and a Cabot Strait line extending north from the tip of Cape Breton Island (E. Head, Fisheries and Oceans Canada, Dartmouth, NS; pers. comm.).

3.1 Production/biomass

I was not able to locate any published biomass or production estimates expressed in dry weights that would be comparable to the data summarized in section 2.1. Copepod dry weight on the Louisbourg Line in October-November 1998 was <2 g/m^2, slightly lower than the biomass observed along the more southerly Halifax Line (E. Head, pers. comm.). In 1979, biomass expressed as mL of zooplankton/m^3 was relatively high in the vicinity of Sydney Bight as compared to most other areas of the Scotian Shelf in April and November-December, while the concentration of highest biomass had shifted offshore to the area of Misaine Bank or Banquereau Bank in May and September-October (O'Boyle *et al*. 1984).

Outflow from the Gulf of St. Lawrence (Nova Scotia Current) was considered to be responsible for maintaining high zooplankton biomass concentrations on the northeastern half, relative to the southwestern half, of the Scotian Shelf in June and October (Sameoto and Herman 1992). This occurs because the Nova Scotia Current maintains the populations of several large copepod species, as outlined in section 3.2.1.

3.2 Community composition

3.2.1 Copepoda

As a result of the Gulf of St. Lawrence outflow, the northeastern Scotian Shelf has higher concentrations of the copepods *Calanus glacialis*, *C. hyperboreus*, *C. finmarchicus* and *Temora* sp. than the southwestern half, as a result of the Gulf of St. Lawrence outflow. These copepods are associated with lower-salinity (< 31 or 32, whereas adjacent waters have salinity > 35 or 36) waters and are thought to be advected from the Gulf. Advection is probably responsible for maintaining the populations of *C. glacialis* and *C. finmarchicus* on the Scotian Shelf (Sameoto and Herman 1992).

The Sydney Bight area supports a diverse copepod community, which is more "oceanic" in character than the community described for western Cape Breton. In October 1984, Lewis and Sameoto (1989a) reported high abundances of *Calanus finmarchicus*, *Pseudocalanus minutus, Centropages typicus* and *Scolecithricella minor*. Other species present at this time were *Acartia longiremis, Calanus glacialis, Calanus hyperboreus*, *Candacia pachydactyla*, *Centropages bradyi*, *Clausocalanus furcatus, Clytemnestra rostrata, Corycaeus speciosus, Paraeuchaeta* (as *Euchaeta*) *norvegica, Paraeuchaeta* (as *Euchaeta*) *tonsa, Gaetanus* sp., *Lucicutia flavicornis, Macrosetella gracilis, Metridia longa, Metridia lucens, Microcalanus pygmaeus, Oithona atlantica, Oithona similis, Oncaea media, Paracalanus parvus, Pleuromamma borealis, Pleuromamma robusta, Scolecithrix danae, Temora longicornis, Temora stylifera, Undinula vulgaris* and unidentified harpacticoids. In October 1986, the copepod community was again dominated by *Calanus finmarchicus*, *Calanus hyperboreus* and, to a lesser extent, *Pseudocalanus minutus* (Lewis and Sameoto 1989b). The diversity of species per station was lower than in 1984. *Calanus minor* was the only copepod reported in 1986 that was not found in 1984.

Willey (1919) also sampled the waters around Sydney Bight, Misaine Bank and off the Gut of Canso. Stations located on Misaine Bank in July of 1915 supported abundant *Calanus finmarchicus* from stage III to spawning females. Other copepods present included *Calanus hyperboreus*, *Pseudocalanus elongatus*, *Paraeuchaeta* (as *Euchaeta*) *norvegica*, *Centropages hamatus*, *Metridia longa*, *Anomalocera opalus* (as *patersoni*) and *Tortanus discaudatus.* In the Gut of Canso the copepod community more closely resembled that found in the sGSL; 51% *Tortanus*, 25% *Temora*, 15% *Pseudocalanus* and 9% *Centropages*. The salinity at this site was ~29 (Willey 1919).

3.2.2 Invertebrate meroplankton

The Sydney Bight region is an important area for the early life history of some economically important crabs. Based on the SSIP surveys, five species of crabs have been recorded in the area as larvae: snow crab *Chionoecetes opilio*, Jonah crab *Cancer borealis*, rock crab *Cancer irroratus*, Atlantic lyre crab *Hyas araneus* and Arctic lyre crab *Hyas coarctatus* (Roff *et al*. 1984; Roff *et al*. 1986). The importance of the waters east of Cape Breton for the planktonic stages of crabs seems to be primarily for the earliest larval stages, the zoeae; with the exception of *Cancer irroratus*, all megalopa larvae were found further south along the Scotian Shelf. Unfortunately, the reports by Roff and colleagues did not specify the timing of larval occurrence in the Cape Breton area and so it is not possible to determine whether the absence of megalopae of most species was a result of limited sampling of the northeastern Scotian Shelf during the period (usually in late summer) when megalopae are present in the water column.

The highest concentration of zoea larvae of snow crab on the Scotian Shelf occurred in waters of Cape Breton Island. Stage I zoea larvae were abundant only to the southeast of Cape Breton Island, off Louisbourg (maximum about 400 individuals/1000 m^3). Megalopa larvae were found only in coastal waters south of Halifax. The distribution was consistent with an hypothesis of spawning by one of the major stocks in the Cape Breton region or Gulf of St. Lawrence, followed by larval drift at 3-11 km/d along the length of the Scotian Shelf to waters of southwest Nova Scotia (Roff *et al*. 1984; Roff *et al*. 1986).

The zoeae of rock crab were the most abundant larval crabs in the Sydney Bight area. Numbers exceeded 1000 larvae/1000 m^3 in the neuston (Roff *et al*. 1984; Roff *et al*. 1986). This was the only crab species for which megalopa larvae were commonly reported off Cape Breton.

Zoea larvae of Jonah crab were also reported by Roff *et al.* (1984, 1986) to be relatively abundant off Cape Breton. No megalopae were reported north of Halifax (Roff *et al.* 1984; Roff *et al.* 1986). Adults have been recorded in western Sydney Bight within 30 km of shore during DFO's annual 4Vn Inshore Trawl Surveys, as well as in more offshore portions of 4Vn (Zwanenburg *et al.* 2002).

Atlantic lyre crab zoeae also reach maximum abundance to the south and east of Cape Breton Island (averaging approximately 1000 stage I and II zoeae/1000 m^3 in the neuston) (Roff *et al.* 1984; Roff *et al.* 1986). Megalopae were captured only off southwestern Nova Scotia. Roff *et al.* (1984) noted that the absence of megalopae on the northern Scotian Shelf might be an artefact of sampling seasonality.

Arctic lyre crab had two centres of distribution for the zoeal stages, one east of Cape Breton and the other off southern Nova Scotia with few animals collected in between. All megalopae were collected south of Halifax (Roff *et al.* 1984; Roff *et al.* 1986).

Larvae of the introduced European green crab *Carcinus maenas* were reported only in coastal waters of southwestern Nova Scotia by Roff *et al.* (1984, 1986) but this species has subsequently invaded waters of Cape Breton Island including the Bras d'Or Lakes (Tremblay, in press). No sampling has been conducted for the larvae but it is likely that they are present in the waters of Sydney Bight as one of the dispersal mechanisms of this species is advection of the planktonic stages in coastal currents.

In the same SSIP surveys, American lobster larvae were found to occur earlier at sampling stations near Sydney Bight than elsewhere on the Scotian Shelf. Stations from Georges Bank to eastern Cape Breton were sampled starting in May, and the first appearance of larvae occurred near the coast in Sydney Bight on July 8-9. Stage I larvae sampled at this time probably hatched no further than 88 km from the location of capture, from a calculation based on current speeds and developmental rate. The larval source was probably near shore, based on the near shore location of the three stations yielding 90 of the 97 larvae that were captured (Watson and Miller 1991). Subsequent SSIP surveys did not sample these nearshore stations, and therefore provide no information on the duration of larval occurrence in the area. Tremblay *et al.* (2001) suggested that lobster larvae could be expected in the area from late June through mid-September, based on the seasonal occurrence of ovigerous females and expected duration of planktonic larval stages.

Northern shrimp eggs hatched from February to April in Chedabucto Bay and the Scotian Shelf, and the 3-4 month duration of the larval stage resulted in larvae being expected in the Sydney Bight area from mid-February to the end of June (Tremblay *et al.*, in prep.).

Euphausiid (*Meganyctiphanes norvegica*) furcilia were present in October 1984 (Lewis and Sameoto 1989a). Eggs, nauplii and furcilia (*M. norvegica, Thysanoessa raschii)* were found in October 1986 (Lewis and Sameoto 1989b). Sampling was not conducted during other months.

Based on the timing of the life history elsewhere in Nova Scotia, sea scallop *Placopecten magellanicus* larvae were expected in the plankton from August to November (Tremblay *et al.*, in prep.).

Planktonic stages of the sea urchin *Strongylocentrotus droebachiensis* were expected from April to June, based on their occurrence elsewhere on the Scotian Shelf (Tremblay *et al.*, in prep.).

3.2.3 Other invertebrate zooplankton

In October 1984, Bioness net tows collected foraminiferans, three pteropod species (*Limacina helicoides, Limacina inflata, L. lesueurii*), Gymnosomata, the ostracod *Conchoecia pusilla,* unidentified siphonophores, chaetognaths, and stomatopods, amphipods (*Parathemisto gaudichaudi, P. abyssorum*), and euphausiids (*Meganyctiphanes norvegica*, *Thysanoessa longicauda*) (Lewis and Sameoto 1989a). In October 1986, catches included siphonophores, *Parathemisto* sp. and *P. abyssorum,* pteropods (*L. helicoides, L. lesueurii, L. trochiformis*), and *Oikopleura* sp. (Lewis and Sameoto 1989b). Macrozooplankton were not reported in the latter study.

Willey (1919) did not go into a great deal of detail on the non-copepod components of the zooplankton, but did describe the community of Misaine Bank as an "*Aglantha*" plankton in June of 1915, which had developed into a "*Euthemisto* plankton" community in July. All medusae had disappeared by the end of July. The sample he collected in the Gut of Canso, which had copepod composition similar to the sGSL, occurred in what he described as an "*Evadne* plankton" which again is consistent with the sGSL.

3.2.4 Ichthyoplankton

Larval fish diversity, measured by genus richness and abundance, was similar off eastern Cape Breton to other regions of the Scotian Shelf in the spring-summer season (Shackell and Frank 2000). Fish eggs were present in 4Vn in all months of the year (Zwanenburg *et al*., in prep.).

In April, American plaice eggs were abundant throughout the Scotian Shelf, including eastern Cape Breton waters (south of Mira Bay) (O'Boyle *et al*. 1984). Plaice eggs were abundant in Sydney Bight in May (O'Boyle *et al*. 1984). This area, and the waters south and east of Cape Breton, were the major areas of concentration of plaice eggs over the Scotian Shelf in May (Neilson *et al*. 1988). Eggs were also found in March and June (Zwanenburg *et al.*, in prep.). Eastern Cape Breton was considered to be an important area for this species (Neilson *et al*. 1988).

Haddock *Melanogrammus aeglefinus* eggs were not detected off Cape Breton but were sometimes present in April in the waters southeast of Cape Breton (Brander and Hurley 1992). Haddock eggs were found in 4Vn in May-July (Zwanenburg *et al.*, in prep.).

Redfish *Sebastes* sp. larvae were occasionally common to abundant in the waters off Cape Breton in April and May. Larvae were very widespread and abundant in Sydney Bight as well as most other parts of the Scotian Shelf except the extreme southwestern part, in July (O'Boyle *et al*. 1984).

Compared to other parts of the Scotian Shelf, the area south and east of Cape Breton was an important centre of abundance for Atlantic cod eggs in May-June (Brander and Hurley 1992). Cod eggs were present in 4Vn in January, March, and May-December, with maximum abundance in May-July (Zwanenburg *et al.*, in prep.). During the peak period of egg abundance, average densities were as high in 4Vn waters as in the two areas of highest concentration in the sGSL (Lett 1980).

Witch flounder *Glyptocephalus cynoglossus* eggs were found in the Cape Breton area in July-August (Brander and Hurley 1992) and in 4Vn in May, July-October (Zwanenburg *et al.*, in prep.).

Pollock *Pollachius virens* eggs were present in 4Vn in December-January and in May-August (Zwanenburg *et al.*, in prep.).

Silver hake *Merluccius bilinearis* eggs were present in January and from May-October (Zwanenburg *et al*., in prep.).

Hake *Urophycis* sp. eggs were present in July and August (Zwanenburg *et al*., in prep.).

Fourbeard rockling eggs were found from June to October (Zwanenburg *et al*., in prep.).

Cusk *Brosme brosme* eggs were found in May and June (Zwanenburg *et al.*, in prep.).

Cunner eggs were found from July to August (Zwanenburg *et al.*, in prep.).

Mackerel eggs were found in June and July (Zwanenburg *et al.*, in prep.).

Windowpane *Scophthalmus aquosus* eggs were found in June and July (Zwanenburg *et al*., in prep.).

Yellowtail flounder *Pleuronectes ferrugineus* eggs were found in May and June (Zwanenburg *et al.*, in prep.).

Little is published on the composition of the larval fish community in the area. White hake larvae were found in Scotian Shelf Ichthyoplankton Program surveys from May through September of 1978 (Markle *et al.* 1982). Both the May-June and June-July surveys showed concentrations of larvae in the neuston in the vicinity of Sydney Bight. The area was not sampled in August-September, but larvae continued to be found elsewhere on the Scotian Shelf at this time. Larvae of the sibling species, red hake *Urophycis chuss*, were present in the August-September survey but their distribution barely reached the southern edge of Cape Breton Island.

3.3 Other sources of data

- Atlantic Zone Monitoring Program – Spring and fall surveys have been conducted from 1997 to present on a line from Louisbourg across Banquereau Bank to the shelf break (Louisbourg Line), and a Cabot Strait line extending north from the tip of Cape Breton Island. Most of the samples have apparently been counted and entered in a database. Limited data have been summarized at DFO's Fisheries Oceanography Committee (FOC) meetings each year. To date, the zooplankton composition data have not been worked up, but a biodiversity analysis is being proposed by E. Head to the DFO-Science Strategic Funds program.

- 4Vn Inshore Trawl Survey – Plankton samples were collected in southern Sydney Bight from 1991 to 1994, covering an area from Ingonish eastward to the shelf edge, then south to Scaterie. Fish egg and larval data exist but will require editing and quality control before analysis. No other taxa were counted from the samples, which are in storage at the Bedford Institute of Oceanography (Zwanenburg *et al.*, in prep.).

- Scotian Shelf Ichthyoplankton Program – Data collected during this program have been extensively referred to in the present review, but probably have not been used to their full potential. The full data set has been published in data report format by Kohler and Waite (1982a,b,c).

- "Gray literature" and data probably exist for the area as a result of environmental studies associated with the wreck of the tanker "Arrow" in Chedabucto Bay in 1970, the construction and impacts of the Canso Causeway, and the Point Aconi generating station. At least one report by Nova Scotia Power (1996) on plankton monitoring at Point Aconi exists.

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5. Literature cited

Berkes, F. 1976. Ecology of euphausiids in the Gulf of St. Lawrence. J. Fish. Res. Bd. Can. 33: 1894-1905.

Bernier, R.Y. 2001. Zooplankton community structure in the Kouchibouguac and Kouchibouguacis (St. Louis) estuaries, New Brunswick, Canada. M.Sc. Thesis, Mount Allison University, Sackville, NB. 215p.

Biron, M., J. Chassé, M. Comeau, L.-A. Davidson, M. Hébert, M. Lanteigne, L. Savoie, T. Surette, E. Wade and M. Moriyasu. (in prep.) Current knowledge on the commercially important invertebrate stocks (Lobster, Snow crab, Giant scallop) in the proposed oil and gas exploitation sites in the southern Gulf of St. Lawrence, Sydney Bight and adjacent area.

Brander, K. and P.C.F. Hurley. 1992. Distribution of early-stage Atlantic cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), and witch flounder (*Glyptocephalus cynoglossus*) eggs on the Scotian Shelf: A reappraisal of evidence on the coupling of cod spawning and plankton production. Can. J. Fish. Aquat. Sci. 49: 238-251.

Cairns, D.K., S.N. Messieh, E. Wade, P.A. MacPherson and G.C.J. Bourque. 1993. Timing, location and volume of herring spawn deposition at Fisherman's Bank, Prince Edward Island, 1987-1990. Can. Tech. Rep. Fish. Aquat. Sci. No. 1928.

Castonguay, M., Y. de Lafontaine and J.A. Runge. 1998. Annual and spatial variability in zooplankton biomass and species composition, and in eggs and larvae of mackerel and cod in the southern Gulf of St. Lawrence between 1982 and 1991. Can. Data Rept. Fish. Aquat. Sci. 1035.

Castonguay, M. and D.P. Swain. (in prep.) Geographic distribution of cod eggs and larvae in the southern Gulf of St. Lawrence based on the mackerel egg survey, 1982-1991.

Citarella, G. 1982. Le zooplancton de la baie de Shédiac (Nouveau-Brunswick). J. Plankton Res. 4: 791-812.

Citarella, G. 1984. Les copépodes de la baie de Shédiac (Atlantiqe canadien). Crustaceana, Suppl. 7 (Studies on Copepoda II): 137-149.

Colton, J.B., Jr. 1985. Eastward extension of the distribution of the marine cladoceran *Penilia avirostris* in the northwest Atlantic: A case of ecesis? J. Northw. Atl. Fish. Sci. 6: 141-148.

Dannevig, A. 1919. Canadian fish-eggs and larvae. Pages 1-80 in Hjort, J. Canadian Fisheries Expedition, 1914-1915, in the Gulf of St. Lawrence and Atlantic waters of Canada. Dept. Nav. Serv. Can., King's Printer, Ottawa, Ont.

Davidson, L.-A. and C. Tetu. 2001. Survey of sea scallop spat (*Placopecten magellanicus*) in southeastern Northumberland Strait – density and growth in 1998-1999. Bull. Aquacult. Assoc. Can. 2001(4): 89-92.

de Lafontaine, Y. 1994. Zooplankton biomass in the southern Gulf of St. Lawrence: Spatial patterns and the influence of freshwater runoff. Can. J. Fish. Aquat. Sci. 51: 617-635.

de Lafontaine, Y., S. Demers and J. Runge. 1991. Pelagic food web interactions and productivity in the Gulf of St. Lawrence: A perspective. Pages 99-123 in J.-C. Therriault (ed). The Gulf of St. Lawrence: small ocean or big estuary? Can. Spec. Publ. Fish. Aquat. Sci. 113.

de Lafontaine, Y., M.I. El-Sabh, M. Sinclair, S.N. Messieh and J.-D. Lambert. 1984. Structure ocèanographique et distribution spatio-temporelle d'oeufs et de larves de poissons dans l'estuaire maritime et la partie ouest du golfe Saint-Laurent. Sci. Tech. Eau. 17: 43-50.

de Lafontaine, Y. and D. Gascon. 1989. Ontogenetic variation in the vertical distribution of eggs and larvae of Atlantic mackerel (*Scomber scombrus*). Rapp. P.-v. Réun. Cons. Int. Explor. Mer 191: 137-145.

Dunbar, M.J., MacLellan, D.C., Filion, A. and Moore, D. 1980. The biogeographic structure of the Gulf of St. Lawrence. McGill University, Marine Sciences Centre Manuscript No. 32: 142 p.

Faber, D.J. 1976. Hyponeustonic fish larvae in the Northumberland Strait during summer 1962. J. Fish. Res. Bd. Can. 33: 1167-1174.

Grégoire, F. (in prep.) Oil and gas exploration off Cape Breton: Information concerning the biology and fishery of the Atlantic mackerel (*Scomber scombrus* L.) present in this area.

Grégoire, F. and M. Castonguay. 1989. L'alimentation du macquereau bleu (*Scomber scombrus*) dans le golfe du Saint-Laurent et sur le plateau néo-écossais, avec une application du test de Mantel. Can. Tech. Rept. Fish. Aquat. Sci. 1673.

Hanson, M.J. and G.A. Chouinard. (in press) Diet of Atlantic cod in the southern Gulf of St. Lawrence as an index of ecosystem change, 1959-2000. J. Fish. Biol.

Harding, G.Cd., W.P. Vass and K.F. Drinkwater. 1982. Aspects of larval American lobster (*Homarus americanus*) ecology in St. Georges Bay, Nova Scotia. Can. J. Fish. Aquat. Sci. 39: 1117-1129.

Harding, G.C., W.P. Vass, B.T. Hargrave and S. Pearre. 1986. Diel vertical movements and feeding activity of zooplankton in St. Georges Bay, N.S., using net tows and a newly developed passive trap. Can. J. Fish. Aquat. Sci. 43: 952-967.

Harding, G.C.H., P.G. Wells and K.F. Drinkwater. 1979. The distribution and abundance of lobster larvae (*Homarus americanus*) in St. Georges Bay, Nova Scotia, in 1975 and 1976 and the possible effect that the Canso Causeway has had on the Chedabucto Bay lobster fishery. Fish. Mar. Serv. Tech. Rept. 834.

Hargrave, B.T., G.C. Harding, K.F. Drinkwater, T.C. Lambert and W.G. Harrison. 1985. Dynamics of the pelagic food web in St. Georges Bay, southern Gulf of St. Lawrence. Mar. Ecol. Prog. Ser. 20: 221-240.

Hargrave, B.T. and G.A. Phillips. 1986. Dynamics of the benthic food web in St. Georges Bay, southern Gulf of St. Lawrence. Mar. Ecol. Prog. Ser. 31: 277-294.

Huntsman, A.G. 1919. Some qualitative and quantitative plankton studies of the eastern Canadian plankton. Pages 405-485 in Hjort, J. Canadian Fisheries Expedition, 1914-1915, in the Gulf of St. Lawrence and Atlantic waters of Canada. Dept. Nav. Serv. Can., King's Printer, Ottawa, ON.

Johnston, C.E. and J.C. Cheverie. 1988. Observations on the diel and seasonal drift of eggs and larvae of anadromous rainbow smelt, *Osmerus mordax*, and blueback herring, *Alosa aestivalis*, in a coastal stream on Prince Edward Island. Can. Field-Nat. 102: 508-514.

Johnston, C.E. and M. Morse. 1988. Summer ichthyoplankton communities of two estuarine systems of Prince Edward Island. Can. J. Zool. 66: 737-745.

Kennedy, V.S. and P.M. Powles. 1964. Plankton collections from the western Gulf of St. Lawrence and central Nova Scotian Banks, 1958 to 1962. Fish. Res. Bd. Can. Manus. Rept. Ser. (Biol.) 799.

Kohler, A.C., D.J. Faber and N.J. McFarlane. 1974a. Eggs, larvae and juveniles of fishes from plankton collections in the Gulf of St. Lawrence during 1965, 1966 and 1967. Fish. Res. Bd. Can. Tech. Rept. 285.

Kohler, A.C., D.J. Faber and N.J. McFarlane. 1974b. Eggs, larvae and juveniles of fishes from plankton collections in the Gulf of St. Lawrence during 1968. Environ. Canada, Fisheries and Marine Service Tech. Rept. 490.

Kohler, A.C., D.J. Faber and N.J. McFarlane. 1975. Eggs, larvae and juveniles of fishes from plankton collections in the Gulf of St. Lawrence during 1969. Environ. Canada, Fisheries and Marine Service Tech. Rept. 521.

Kohler, A.C., D.J. Faber and N.J. McFarlane. 1976. Eggs, larvae and juveniles of fishes from plankton collections in the Gulf of St. Lawrence during 1970-1971. Environ. Canada, Fisheries and Marine Service Tech. Rept. 645.

Kohler, A.C., D.J. Faber and N.J. McFarlane. 1977. Eggs, larvae and juveniles of fishes from plankton collections in the Gulf of St. Lawrence during 1972 to 1975. Fish. & Environ. Canada, Fisheries and Marine Service Tech. Rept. 747.

Kohler, A.C. and L.E. Waite. 1982a. Collections of ichthyoplankton identified and enumerated for the year 1978 from the Scotian Shelf Ichthyoplankton Program (SSIP). Can. Data Rept. Fish. Aquat. Sci. 358.

Kohler, A.C. and L.E. Waite. 1982b. Collections of ichthyoplankton identified and enumerated for the year 1979 from the Scotian Shelf Ichthyoplankton Program (SSIP). Can. Data Rept. Fish. Aquat. Sci. 370.

Kohler, A.C. and L.E. Waite. 1982c. Collections of ichthyoplankton identified and enumerated for the year 1980 from the Scotian Shelf Ichthyoplankton Program (SSIP). Can. Data Rept. Fish. Aquat. Sci. 380.

Lambert, T. 1980. Daily and seasonal variation in the size and distribution of zooplankton in St. Georges Bay, Nova Scotia. Can. Tech. Rept. Fish. Aquat. Sci. 980.

Lambert, T.C., D.M. Ware, J.K. McRuer and A.D. MacDonald. 1982. Water temperature, zooplankton biomass and size composition in St. Georges Bay, N.S. 1973-1976. Can. Tech. Rept. Fish. Aquat. Sci. 1073.

Lett, P.F. 1980. A comparative study of the recruitment mechanisms of cod and mackerel, their interaction and its implication for dual stock assessment. Can. Tech. Rept. Fish. Aquat. Sci. 988.

Lewis, M.K. and D.D. Sameoto. 1989a. The vertical distribution of zooplankton and ichthyoplankton on the Nova Scotia Shelf October 1984. Can. Data Rept. Fish. Aquat. Sci. 731.

Lewis, M.K. and D.D. Sameoto. 1989b. The vertical distribution of zooplankton and ichthyoplankton on the Nova Scotia Shelf September-October 1986. Can. Data Rept. Fish. Aquat. Sci. 763.

Locke, A. and S.C. Courtenay. 1995a. Ichthyoplankton and invertebrate zooplankton of the Miramichi Estuary: 1918-1993. Pages 97-120 in E.M.P. Chadwick (ed.). Water, science and the public: the Miramichi ecosystem. Can. Spec. Publ. Fish. Aquat. Sci. 123.

Locke, A. and S.C. Courtenay. 1995b. Effects of environmental factors on ichthyoplankton communities in the Miramichi estuary, Gulf of St. Lawrence. J. Plankton Res. 17: 333-349.

Markle, D.F., D.A. Methven and L.J. Coates-Markle. 1982. Aspects of spatial and temporal cooccurrence in the life history stages of the sibling hakes, *Urophycis chuss* (Walbaum 1792) and *Urophycis tenuis* (Mitchill 1815) (Pisces: Gadidae). Can. J. Zool. 60: 2057-2078.

MEL (Marine Ecology Laboratory). 1980. Physical oceanography, dissolved nutrients, phytoplankton production, plankton biomass and sedimentation in St. Georges Bay, N.S., 1977. Can. Tech. Rept. Fish. Aquat. Sci. 934.

Messieh, S.N. and A.C. Kohler. 1972. Distribution, relative abundance and growth of larval herring (*Clupea harengus* L.) in the southern Gulf of St. Lawrence. Fish. Res. Bd. Can. Tech. Rept. 318.

Neilson, J.D., E.M. DeBlois and P.C.F. Hurley. 1988. Stock structure of Scotian Shelf flatfish as inferred from ichthyoplankton survey data and the geographic distribution of mature females. Can. J. Fish. Aquat. Sci. 45: 1674-1685.

Nova Scotia Power Inc. 1996. 1995 aquatic effects monitoring at the Point Aconi generating station: Plankton report. Nova Scotia Power Inc., Halifax. 57 p.

O’Boyle, R.N., M. Sinclair, R.J. Conover, K.H. Mann and A.C. Kohler. 1984. Temporal and spatial distribution of ichthyoplankton communities of the Scotian Shelf in relation to biological, hydrological and physiographical features. Rapp. P.-V. Reun. Cons. Int. Explor. Mer 183: 27-40.

Rogers, H.M. 1940. Occurrence and retention of plankton within the estuary. J. Fish. Res. Bd. Can. 5: 164-171.

Roff, J.C., L.P. Fanning and A.B. Stasko. 1984. Larval crab (Decapoda: Brachyura) zoeas and megalopas of the Scotian Shelf. Can. Tech. Rept. Fish. Aquat. Sci. 1264.

Roff, J.C., L.P. Fanning and A.B. Stasko. 1986. Distribution and association of larval crabs (Decapoda: Brachyura) on the Scotian Shelf. Can. J. Fish. Aquat. Sci. 43: 587-599.

Runge, J.A., M. Castonguay, Y. de Lafontaine, M. Ringuette and J.-L. Beaulieu. 1999. Covariation in climate, zooplankton biomass and mackerel recruitment in the southern Gulf of St. Lawrence. Fish. Oceanogr. 8: 138-149.

Runge, J.A. and Y. de Lafontaine. 1996. Characterization of the pelagic system in surface waters of the northern Gulf of St. Lawrence in early summer: The larval redfish-*Calanus*-microplankton interaction. Fish. Oceanogr. 5: 21-37.

Sameoto, D.D. and A.W. Herman. 1992. Effect of the outflow from the Gulf of St. Lawrence on Nova Scotia Shelf zooplankton. Can. J. Fish. Aquat. Sci. 49: 857-869.

Scarratt, D.J. 1964. Abundance and distribution of lobster larvae (*Homarus americanus*) in Northumberland Strait. J. Fish. Res. Bd. Can. 21: 661-680.

Scarratt, D.J. 1968. Distribution of lobster larvae (*Homarus americanus*) off Pictou, Nova Scotia. J. Fish. Res. Bd. Can. 25: 427-430.

Scarratt, D.J. 1973. Abundance, survival, and vertical and diurnal distribution of lobster larvae in Northumberland Strait, 1962-63, and their relationships with commercial stocks. J. Fish. Res. Bd. Can. 30: 1819-1824.

Sette, O.E. 1950. Biology of the Atlantic mackerel (*Scomber scombrus*) of North America. Part I. Migrations and habits. Fish. Bull. U.S. 51(49): 251-358.

Shackell, N.L. and K.T. Frank. 2000. Larval fish diversity on the Scotian Shelf. Can. J. Fish. Aquat. Sci. 57: 1747-1760.

Stasko, A.B. 1980. Lobster larval surveys in Canada. Pages 157-165 in Anthony, V.C. and J.F. Caddy (eds.) Proceedings of the Canada-U.S. workshop on status of assessment science for N.W. Atlantic lobster (*Homarus americanus*) stocks (St. Andrews, N.B., Oct. 24-26, 1978). Can. Tech. Rept. Fish. Aquat. Sci. 932.

Steven, D.M. 1974. Primary and secondary production in the Gulf of St. Lawrence. McGill University Marine Sciences Centre Manuscript Rept. No. 26.

Steven, D.M. 1975. Biological production in the Gulf of St. Lawrence. Pages 229-248 in Cameron, T.W.M. and L.W. Billingsley (eds.) Energy flow – its biological dimensions. A summary of the IBP in Canada, 1964-1974. Royal Society of Canada, Ottawa.

Tremblay, M.J. (in press). Large epibenthic invertebrates in the Bras d'Or lakes. Proc. N.S. Inst. Sci.

Tremblay, M.J., A. Reeves and T. Worcester. (in prep.). Major features of the distribution and life history of some commercially fished benthic invertebrates in the Sydney Bight area.

Ware, D.M. 1977. Spawning time and egg size of Atlantic mackerel, *Scomber scombrus*, in relation to the plankton. J. Fish. Res. Bd. Can. 34: 2308-2315.

Ware, D.M. and T.C. Lambert. 1985. Early life history of Atlantic mackerel (*Scomber scombrus*) in the southern Gulf of St. Lawrence. Can. J. Fish. Aquat. Sci. 42: 577-592.

Watson, F.L. and R.J. Miller. 1991. Distribution of lobster larvae on the Scotian Shelf: 1978-1981. Can. Tech. Rept. Fish. Aquat. Sci. 1801.

Willey, A. 1919. Report on the Copepoda obtained in the Gulf of St. Lawrence and adjacent waters, 1915. Pages 173-220 in Hjort, J. Canadian Fisheries Expedition, 1914-1915, in the Gulf of St. Lawrence and Atlantic waters of Canada. Dept. Nav. Serv. Can., King's Printer, Ottawa, ON.

Zwanenburg, K., P. Gonzalez, S. Wilson, D. Beanlands and P. Hurley. (in prep.). Information on fish and fisheries data available for NAFO Subdivision 4Vn.