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Review and Assessment of the Literature on Marine Benthic Molluscs (Amphineura, Bivalvia, Gastropoda) in Newfoundland and Labrador Waters

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Abstract

A review of the existing literature on marine benthic molluscs (Amphineura, Bivalvia, Gastropoda) in the Newfoundland-Labrador region indicated that at least 158 species, representing 69 families, have been referenced in reports of scientific investigations. Less than one-third of these reports have appeared in the primary literature, while the remainder exist as manuscript reports and university theses. Several species (e.g. *Mytilus edulis* and *Placopecten magellanicus*) have been studied intensively, but most species have received only very cursory attention. Specific inventories of molluscs are rare. Most zoobenthic surveys which include molluscs fall into one of three categories: fisheries-related investigations, resource assessment studies, and environmental impact studies. Additionally, the literature contain numerous academic (university) studies. Analysis of the geographic distribution of research effort indicated that most of the work was concentrated in southeastern Newfoundland (Avalon Peninsula) in proximity to the major institutions at St. John's, Newfoundland.

Introduction

Since the mid-1970's, there have been several literature reviews which pertain to the coastal resources of Newfoundland and Labrador as a result of offshore oil explorations (MacLaren, MS 1977; South *et al.*, MS 1979; Campbell and Sutterlin, MS 1981; Thompson and Aggett, MS 1981; LeDrew, MS 1984; Hardy, MS 1985). What is apparent from these studies are the large gaps in knowledge of the zoobenthos of coastal and offshore waters in the Newfoundland-Labrador region as well as in the Gulf of St. Lawrence (Dunbar *et al.*, MS 1980). Some molluscs have been the subject of both pure and applied scientific research, but species lists and distributional aspects have been poorly documented. A number of zoobenthic inventories have been compiled in conjunction with increased oil-exploration activity, but they have generally been concentrated in specific areas. The Offshore Labrador Biological Studies (OLABS) Program, which was initated by the Canadian Department of Energy, Mines and Resources in 1978, was quite intensive, but work was targeted at specific coastal areas. Also, the few studies of the marine fauna in Terra Nova National Park and Gros Morne National Park (east and west coasts of Newfoundland respectively) have been concentrated efforts in restricted time periods. In general, much of the coastline fauna of Newfoundland and Labrador remains to be inventoried.

Assessments of available information on the various zoobenthic groups are often useful in providing a focus for researchers to direct their interest toward geographical areas and species groups where large gaps exist. Marine molluscs of Newfoundland and Labrador waters are important not only in terms of present and future fisheries but also in terms of the trophic roles of the various organisms in the ecosystems. In a biogeographical sense, the distributional aspects contribute to further understanding of the ecotone position which the Newfoundland-Labrador region occupies between boreal and subarctic environments. This paper categorizes and assesses the existing literature on marine benthic molluscs (Amphineura, Bivalvia and Gastropoda) of the Newfoundland-Labrador region and provides a referenced list of 158 species. The various areas that are used in this study to reflect geographical distribution of research effort on molluscs are shown in Fig. 1.

Overview

In 1876, T. A. Verkruzen collected several species of molluscs at Quidi Vidi near St. John's, Newfoundland (Whiteaves, 1901). Since that time, the Newfoundland-Labrador region has attracted widespread interest in research on molluscs. This was probably due to the "frontier mystique" atmosphere which still envelopes the region. To date (1985), 158 species of benthic molluscs have been reported in the available literature. Several species (e.g. *Mytilus edulis* and *Placopecten magellanicus*) have been studied rather intensively, but most of the species have received only very cursory attention. Specific inventories of molluscs in the region are rare. In most cases, they represent parts of larger overall investigations of entire zoobenthic communities. With few exceptions, most of these surveys which include benthic molluscs fall into one of three categories: (a) fisheries-related investigations, (b) special government-sponsored resource studies such as those for the Canadian National Parks Service,

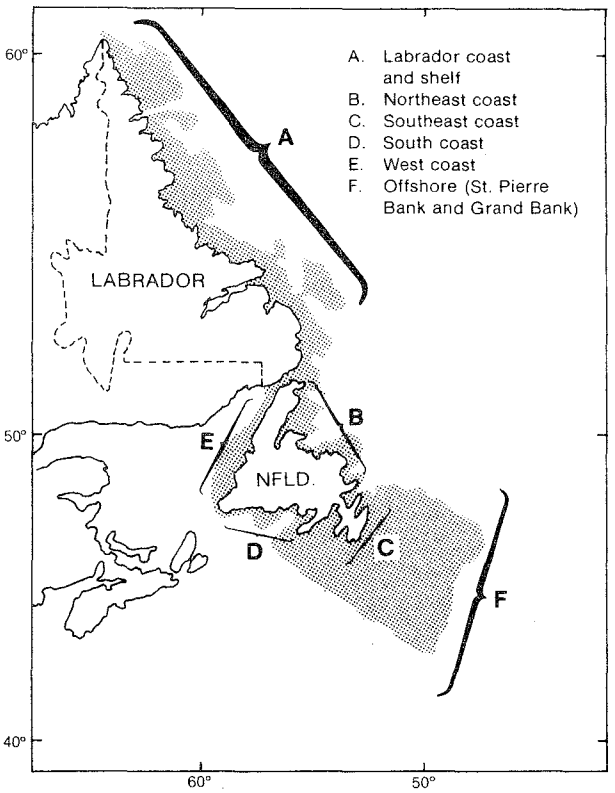

Fig. 1. Geographic areas of the Labrador-Newfoundland region used in the analysis of research effort on marine benthic molluscs.

and (c) environmental impact assessment studies (e.g. baseline and postoperational comparisons). There have also been several academic studies which by their nature (i.e. ecological studies) have provided inventories of mollusc species (Christie, MS 1066; Himmelman, MS 1970; Emerson, MS 1973; Pittman, MS 1974; Barrie, MS 1979; Keats, MS 1985).

For insular Newfoundland, inventories of benthic molluscs which fall into the first category include studies by Squires (1962), Templeman (1966), Aldrich and Scaplen (MS 1969b), Fukai (MS 1973); Fowler and Fletcher (1975), Sutterlin *et al.*, (1981), and several papers by K. S. Naidu and colleagues (see references). The only known inventories in this category for coastal Labrador were those by Fletcher and Haggerty (1975) and Fletcher *et al.* (1974).

Inventories which fall into the second category relate to resource studies within Gros Morne National Park of western Newfoundland (Rivard and Bowen, MS 1971; Hooper, MS 1975; Carter and McGregor, MS 1979) and in Terra Nova National Park of eastern Newfoundland (South and Steele, MS 1971; Deichmann and Bradshaw, MS 1984).

The majority of zoobenthic studies which include molluscs fall into the third category. For coastal Newfoundland waters, these include the following references: Beak (MS 1974, MS 1980, MS 1981, MS 1985), Foy *et al.* (MS 1980), Gilkinson and Boothroyd (MS 1985), MacLaren (MS 1978), Mobil (MS 1985), NECL (MS 1985), Nfld. Hydro (MS 1980); Oceans (MS 1984), Osborne (MS 1978), Osborne and Roberts (MS 1983), Osborne and Swiss (MS 1982), Shawmont (MS 1983), and Swiss and Osborne (MS 1976). Inventories of benthic molluscs on the Grand Bank include studies by Gagnon and Gilkinson (MS 1984), Hardy (MS 1984), and Hutcheson *et al.* (MS 1981). Inventories of molluscs in Labrador waters have resulted from studies which were conducted under the OLABS Program. This 3-year program which began in 1978 was a joint effort of government, communities and the petroleum industry and was designed to collect baseline biological data on fish and the fishery, zooplankton, phytoplankton, benthic organisms, and marine mammals and seabirds in Labrador coastal waters. Most of the resulting studies involved marine benthic communities and provided comprehensive species lists (Barrie, MS 1979; Barrie and Browne, MS 1980; Barrie and Steele, MS 1979; Barrie *et al.*, MS 1980; Denbeste and McCart, MS 1979; Gilbert *et al.*, MS 1982).

The remaining literature deals with specific studies which can be categorized as ecological, behavioral, developmental/morphological, and physiological. Many of these studies are in the form of students' theses at Memorial University, St. John's, Nfld., and span the 1966–85 period, but others have been published as technical reports, conference documents and primary journal articles.

Literature Categories

Fishery research inventories

Fowler and Fletcher (1976) conducted SCUBA-diving surveys of unexploited invertebrates in Bonavista Bay (east coast) and Fortune Bay (south coast). Molluscs in their inventories included the blue mussel (*Mytilus edulis*), whelks (*Buccinum undatum*, *Apporhais occidentalis*), soft-shelled clams (*Mya arenaria*, *Mya truncata*), cockles (*Clinocardium ciliatum*, *Serripes groenlandicus*), scallops (*Chlamys islandicus*, *Propeamussium groenlandicus*) and the periwinkle (*Littorina littorea*). Fletcher and Haggerty (1975) and Fletcher *et al.* (1974) conducted similar surveys of bays in southern Labrador, with observations from more than 800 locations. Because the resources in Labrador coastal waters were virtually unknown at that time, the information was valuable in highlighting areas for more detailed study. A significant conclusion was that further studies on scallops should be undertaken to determine the extent of the beds and to evaluate the commercial potential.

Sutterlin *et al.* (MS 1981) reported the results of a detailed study of blue mussel (*Mytilus edulis*) aquacul-

ture potential in Newfoundland. The work included a study of natural mussel beds along the northeast coast with an attempt to identify areas which might support commercial culture of the blue mussel.

Fukai (MS 1973) surveyed the distribution and abundance of the whelk (*Buccinum undatum*) in relation to substrate type at various locations along the northeast coast and in Conception Bay. The results indicated that a whelk fishery was not practical with existing gear and methodology.

Squires (1962) reported the results of intensive surveys for the giant scallop (*Placopecten magellanicus*) in Newfoundland waters during 1957 and 1958. Many coves and inlets with sandy and muddy bottom were surveyed. These surveys marked the beginning of intensive interest in stock assessments of sea scallops in both the coastal and offshore waters, and this interest has persisted in more recent years with respect to the potential for scallop aquaculture (e.g. Naidu and Cahill, MS 1983, MS 1986).

National park resource inventories

There have been several studies of the marine organisms of the two national parks in Newfoundland. These studies can be considered as true inventories because the primary objective was to record and describe, and some studies were more complete than others.

Rivard and Bowen (MS 1971) surveyed the intertidal, subtidal and deepwater (66-139 m) fauna of Bonne Bay, which is part of Gros Morne National Park in western Newfoundland. They provided a list of species (including molluscs) and typical shore-zone profiles. However, the most thorough inventory of the marine resources of the Bonne Bay region was that by Hooper (MS 1975), which contained an annotated list of species and a bibliography relevant to the invertebrates. A total of 82 species of molluscs was recorded. This inventory, based on SCUBA-diving surveys, represented a serious attempt to describe the total marine community. An important component of the study was the inclusion of marine community profiles and recommendations for future studies.

In Terra Nova National Park on the east coast, South and Steele (MS 1971) conducted an environmental study of Big Brook River Flats in Newman Sound. They described the physical characteristics and biological communities of the region and provided a qualitative assessment of the marine fauna, including a list of mollusc species.

Environmental impact studies

Many of the studies in this category have been associated with offshore exploration for oil and gas and the onshore impacts of such exploration. An analysis of benthic samples from the Hibernia oil-field region of the Grand Bank was conducted for Mobil Oil Canada Ltd. (Hardy, MS 1984). The list of invertebrates from that study included 13 species of molluscs. A recent study by Gagnon and Gilkinson (MS 1984) involved analysis of approximately 3,000 photographs (35-mm film) which were taken along five transects in the Hibernia region by the Atlantic Geosciences Center, Bedford Institute of Oceanography, Dartmouth, Nova Scotia. Identification of organisms was often limited to the genus or higher taxonomic groups. From these data, animal-substrate relationships were analyzed. Hutcheson *et al.* (MS 1981) studied the biology of benthic communities of the Grand Bank (including the Hibernia region) from benthic grab samples which were collected at several locations over a period of 1 year. Much effort was directed toward understanding the seasonal reproductive cycles of invertebrates. Their list of species included more than 20 molluscs. Their study was the benthic component of the overall environmental impact statement which was prepared by Mobil Oil Canada Ltd. for the Hibernia development project (Mobil, MS 1985).

Several benthic invertebrate surveys of Newfoundland coastal waters have been conducted in conjunction with environmental impact assessments. In Placentia Bay, these included surveys in the vicinity of the oil refinery at Come-by-Chance (Osborne and Swiss, MS 1982; Swiss and Osborne, MS 1976) and the ERCO phosphorus-reduction plant at Long Harbour (Beak, MS 1974, MS 1980, MS 1981, MS 1985; Osborne, MS 1978). More than 40 species of molluscs were identified in these studies. Other benthic surveys in Placentia Bay were carried out at Argentia, Arnold's Cove and Mortier Bay as part of an environmental impact study for the Newfoundland Government (NECL, MS 1985). Environmental impact studies at the Cat Arm hydroelectric development site (northeastern Newfoundland) provided inventories of molluscs (MacLaren, MS 1978; Nfld. Hydro, MS 1980). As part of a monitoring program for the Canadian Parks Service, two macroinvertebrate surveys were conducted at the Eastport Causeway in Terra Nova National Park (Shawmont, MS 1983; Gilkinson and Boosthroyd, MS 1985).

The OLABS program of the late 1970's resulted in the formulation of several lists of invertebrates as well as analyses of animal-substrate relationships and animal diversity and biomass in Labrador coastal waters (Denbeste and McCart, MS 1979; Barrie and Browne, MS 1980; Barrie *et al.*, MS 1980; Gilbert *et al.*, MS 1982). In the Makkovik Bay and Cartwright areas, 64 species of benthic molluscs were found (Barrie *et al.*, MS 1980). Two academic studies (Barrie, MS 1979; Barrie and Steele, MS 1979) contained analyses of benthic invertebrate communities at seven coastal sites in Labrador and one in Conception Bay. Interrela-

tionships between molluscs and various physical parameters were assessed.

Ecological studies

Community studies of invertebrates have generally included molluscs, but, in most cases, molluscs formed only a small part of the overall studies, with observations often being ancillary. Bolton (1979) described the effects of short-term ice-scouring on intertidal benthic communities at Bay Bulls (southeast coast). He analyzed five separate shore levels and provided information on the herbivorous molluscs (*Littorina saxatilis*, *Lacuna vincta* and *Mytilus edulis*). Hooper (1981) reported the recovery of marine benthic communities from ice-scouring at Bay Bulls and in Placentia Bay (southeast coast) and in Bonne Bay (west coast), with observations on *Littorina littorea*, *L. obtusata* and *Acmaea testudinalis*. Pittman (MS 1975) carried out a detailed intertidal study of rocky-shore tidepools at Logy Bay and Portugal Cove (southeast coast), reporting on the physical and biological factors which influence the ecology of invertebrates, including five species of molluscs. Christie (MS 1966) studied the ecology of benthic invertebrates (including several molluscs) in a lagoon in Conception Bay (southeast coast). He attempted to describe, in accordance with the "Peterson concept", what positions the communities occupied in the parallel level-bottom community hypothesis. Barrie (1979) examined the relationship between species diversity and physical characteristics of the nearshore environment at sites in coastal waters of Labrador and eastern Newfoundland. The molluscs in his list of invertebrates included 37 gastropods, 15 bivalves and 3 amphineurans. The studies by Himmelman (MS 1969) and Emerson (MS 1973) were focused mainly on echinoderms in the coastal waters of eastern Newfoundland, but they provided some qualitative observations on subtidal molluscs. A recent study by Keats (MS 1985) involved quantitative observations on herbivorous molluscs at a site in Conception Bay over a 5-year period. Sergy (MS 1973) and Sergy and Evans (1975), employing direct examination and x-radiography techniques, studied the fouling of the seawater system at the Marine Sciences Research Laboratory, Logy Bay, Newfoundland. The bivalves (*Hiatella arctica* and *Mytilus edulis*) were the largest components of the total biomass of 30 species of marine foulers. Other studies, containing ancillary data on benthic molluscs, include those on fish predation (Martel, MS 1982; Goulet, MS 1985; Templeman, 1985) and seabirds (Ryan, MS 1985).

There have been several studies in which benthic molluscs were the primary subjects. Davidson (MS 1980) studied the ecology of a red chiton (*Tonicella rubra*) population and other mollusc grazers in Conception Bay. Naidu (MS 1969, 1970) studied the growth and reproduction of the giant scallop (*Placopecten magellanicus*) in Port au Port Bay, and Evans (1969) and his students (Scott, MS 1968; Barnes, MS 1974) studied the epifaunal invertebrates on the surfaces of giant scallop shells. That species was also the object of studies of endozoic algae and parasites by Naidu (1971), Naidu and South (1970), Stevenson (MS 1972), and Stevenson and South (1974, 1975). Gilkinson (MS 1984) studied growth rates in intertidal and subtidal populations of *Mytilus edulis* in the Strait of Belle Isle. Batstone (MS 1981) studied age and size-weight relationships of *Mya arenaria* in Conception Bay. Murphy (MS 1974) attempted to determine the growth performance of *Littorina littorea* as a function of diet. Black (1973) interpreted growth rates of *Littorina littorea* and *Mytilus edulis* in relation to a pollution incident in St. Mary's Bay. Bird (1968) reported the occurrence of *Littorina littorea* in a beach terrace of northern Newfoundland, predating Norse settlements. Goudie (MS 1975) studied the occurrence of trematode larvae in *Littorina saxatilis* in the vicinity of a marine bird colony. MacDougall (MS 1971) did a taxonomic survey of spirochetes in several bivalve species from Newfoundland and Prince Edward Island. Evans (1970) studied the activity of three species of marine wood borers in shallow coastal waters of Newfoundland with varying patterns of distribution. A survey of marine borers in Canadian Atlantic waters was reported by Bohn and Walden (1970). During the 1960's, research on the growth and survivorship of transplanted American oyster (*Crassostrea virginia*) in Broad Lake, Trinity Bay, resulted in reports by Aldrich (MS 1965, MS 1968), Aldrich and Scaplen (MS 1969a) and Percy and Aldrich (MS 1967). Mercer (1970) reported on the experimental transplant of American oyster in western Newfoundland.

Offshore ecological investigations of benthic invertebrates (including molluscs) on the continental shelf and slope, unrelated to oil explorations, include reports by Nesis (1966b) on *Cyrtodaria siliqua*, Houston and Haedrich (1984) on abundance and biomass of macrobenthos, Hutchings and Haedrich (1984) on two species of Nuculanidae, and Gilkinson *et al.* (1986) on *Nuculana pernula* and *Yoldia thraciaeformis*.

Physiological studies

Bivalves have been the principal subjects of physiological research on molluscs of the Labrador-Newfoundland region. Hum (MS 1976) studied oxygen consumption and growth rates of blue mussels (*Mytilus edulis*) from Conception Bay and southern Newfoundland, and Thompson (1979, 1984a, 1984b) reported on aspects of reproduction, fecundity and growth of that species from Bellevue, Trinity Bay. Research on giant scallops (*Placopecten magellanicus*) have resulted in reports on structure and electrophysiology of ciliated receptors (Moir, MS 1976), blood chemistry and reproductive physiology (Thompson, 1977), and various aspects of physiological ecology (MacDonald, MS 1984; MacDonald and Thompson,

1985a, 1985b). Percy *et al.* (1971) studied the influence of environmental factors on respiration of excised tissues of the American oyster (*Crassostrea virginica*).

Developmental and morphological studies

Although there have been several studies on development and morphology of invertebrates and their organs in the Newfoundland-Labrador region, specific studies on molluscs are rare. Snow (MS 1967) studied the radula and accessory boring organs of *Thais lapillus*, and Powell (Memorial University, St. John's, Nfld., pers. comm., 1985) is currently studying the development of mantle ocelli in *Placopecten magellanicus*.

Behavioral studies

The most significant study in this category was that of Clarke (MS 1976) on the biology and behaviour of the chiton *Tonicella marmorea*, including observations on thigmotaxis, geotaxis, rheotaxis and phototaxis. Clarke also assessed the abundance of that species and *Ischnochiton* (*Stenosemus*) *albus* at 19 sites around Newfoundland. A study which involved molluscs was conducted by O'Neill (MS 1981) on size-selective feeding behaviour and feeding rates of starfish (*Asterias vulgaris*) on cultured *Mytilus edulis* in Placentia Bay.

Research Effort by Taxon

At least 158 species of benthic molluscs and 16 others at the genus level, representing 69 families, have been referenced in reports of scientific investigations in the Newfoundland-Labrador region (Table 1). Less than one-third of these reports have appeared in the primary literature, while the remainder exist as manuscript reports and theses which had very limited distribution.

The list of benthic molluscs contain the names of 84 gastropod species, representing 38 families. Species which have been referenced at least 10 times include *Acmaea testudinalis* (20), *Littorina littorea* (20), *Lacuna vincta* (19), *Littorina saxatilis* (19), *Buccinum undatum* (13), *Thais lapillus* (12), *Littorina obtusata* (11), and *Margarites helicinus* (11). Species which have been the subjects of specific studies are *Littorina littorea* (1), *Littorina saxatilis* (1) and *Buccinum undatum* (1).

The list of benthic molluscs contains the names of 71 bivalve species, representing 28 families. Species which have been referenced at least 10 times include *Placopecten magellanicus* (52), *Mytilus edulis* (49), *Mya arenaria* (21), *Hiatella arctica* (19), *Chamys islandica* (19), *Macoma balthica* (14), *Clinocardium ciliatum* (12), *Modiolus modiolus* (12), *Crassostrea viriginica* (11). Species which have been the subjects of specific studies are *Placopecten magellanicus* (30), *Chlamys islandica* (8), *Mytilus edulis* (8), *Crassostrea virginica* (7), *Nuculana pernula* (2), *Yoldia thraciaeformis* (2), and *Cyrtodaria siliqua* (1).

Four species of amphineurans, representing three families, were present in the list of benthic molluscs, and three species were referenced at least 10 times: *Tonicella rubra* (13), *Ischnochiton albus* (12), and *Tonicella marmorea* (10). Both *Tonicella marmorea* and *Tonicella rubra* have been the subjects of specific studies.

Most of the molluscs have been treated very cursorially and, for the most part, qualitatively in the literature. This also applies to species which have been referenced frequently (e.g. *Littorina littorea*). Consequently, information on the basic biology and ecology of most of the species in Table 1 is scarce or lacking. Two exceptions are the relatively well-studied *Mytilus edulis* and *Placopecten magellanicus*.

TABLE 1. Reference index for benthic molluscs recorded from the Newfoundland-Labrador region.

Family/Species	Literature reference
Amphineura	
Ischnochitonidae	
Ischnochiton albus	7, 10, 23, 30, 44, 50, 53, 57, 60, 106, 114, 138
Lepidochitonidae	
Tonicella marmorea	7, 10, 25, 30, 35, 44, 52, 53, 60, 98
Tonicella rubra	6, 7, 10, 15, 16, 29, 30, 53, 60, 71, 106, 114, 138
Molpaliidae	
Amicula vestita	10
Bivalvia	
Anomiidae	
Anomia aculeata	6, 15, 23, 28, 30, 53, 106, 138
Anomia ephippium[a]	106, 138
Anomia simplex	6, 106, 114, 120, 121, 138
Arcidae	
Bathyarcus glacialis	114

TABLE 1. (continued).

Family/Species	Literature reference
	Bivalvia
Arcticidae	
Arctica islandica	30, 53, 106, 132, 138
Astartidae	
Astarte borealis	7, 10, 31, 44, 50, 70
Astarte castanea	16,23
Astarte eliptica	10, 57
Astarte montagui	10, 50
Astarte striata	15
Astarte subequilatera	7, 44
Astarte undata	7, 16, 23, 30, 53, 114
Cardiidae	
Cerastoderma pinnulatum	7, 10, 15, 46, 53, 98, 106, 114, 138
Clinocardium ciliatum	7, 10, 16, 23, 30, 31, 43, 44, 51, 53, 106, 114
Serripes groenlandicus	7, 10, 23, 30, 38, 44, 53, 138
Carditidae	
Cyclocardia borealis	7, 10, 44, 53, 57
Corbulidae	
Corbula contracta	50
Hiatellidae	
Cyrtodaria siliqua	30, 43, 53, 99, 100
Hiatella arctica	6, 7, 10, 15, 23, 28, 30, 31, 35, 44, 50, 52, 53, 71, 106, 114, 120, 121, 138
Hiatella striata[a]	30, 53, 138
Limidae	
Limea subovata	57
Lyonsiidae	
Lyonsia arenosa	10, 15
Mactridae	
Spisula polynyma	10, 132
Spisula solidissima	23, 30, 53, 132
Spisula sp.	122
Mesodesmatidae	
Mesodesma arctatum	16, 53, 57, 99
Mesodesma deauratum[a]	57
Myidae	
Mya arenaria	6, 10, 11, 15, 16, 23, 24, 30, 38, 41, 46, 53, 68, 98, 106, 114, 122, 124, 132, 138, 139
Mya truncata	10, 30, 38, 43, 44, 53
Mytilidae	
Crenella decussata	10, 53, 70
Crenella faba	23, 31, 44, 53
Crenella glandula	7, 10, 15, 30, 44, 106, 138
Dacrydium vitreum	53, 114
Modiolus modiolus	16, 23, 52, 53, 68, 71, 98, 106, 114, 122, 132, 138
Musculus corrugatus	7, 138
Musculus discors	7, 10, 31
Musculus niger	10
Musculus sp.	53
Mytilus edulis	4, 5, 7, 8, 9, 10, 15, 16, 18, 20, 21, 23, 24, 28, 30, 35, 38, 39, 40, 41, 44, 45, 46, 52, 53, 56, 68, 98, 101, 102, 103, 104, 105, 106, 112, 113, 114, 116, 120, 121, 122, 124, 131, 137, 138, 139, 143, 144, 145
Nuculanidae	
Nuculana pernula	31, 47, 58
Nuculana tenuisulcata	53, 70, 114
Yoldia hyperborea	10, 44
Yoldia limatula	10, 16, 23, 53
Yoldia myalis	7, 10, 23, 50, 53
Yoldia thraciaeformis	47, 58, 99
Yoldiella fraterna	53, 114
Nuculidae	
Nucula proxima	44
Nucula tenuis	7, 44, 50, 53
Ostreidae	
Crassostrea virginica[b]	1, 2, 3, 5, 68, 73, 109, 110, 117, 128, 129
Ostrea edulis[b]	5

TABLE 1. (continued).

Family/Species	Literature reference
	Bivalvia
Pandoridae	
Pandora glacialis	33
Pandora gouldiana	23, 53
Pectinidae	
Chlamys islandica	5, 10, 23, 30, 38, 40, 43, 53, 83, 85, 88, 91, 95, 96, 97, 106, 107, 139, 140
Placopecten magellanicus	5, 6, 15, 16, 23, 30, 36, 40, 53, 65, 66, 67, 75, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 89, 90, 91, 92, 93, 94, 96, 97, 102, 106, 107, 111, 114, 118, 119, 122, 126, 127, 130, 132, 133, 134, 135, 136, 138, 139, 140, 142
Propeamussium groenlandicum	38
Petricolidae	
Petricola pholadiformes[c]	30, 46
Petricola sp.	122
Pholadidae	
Xylophaga abyssorum	33
Zirphaea crispata	53
Solenidae	
Ensis directus	16, 23, 30, 46, 68, 114, 122, 124
Tellinidae	
Macoma balthica	10, 16, 23, 24, 30, 31, 44, 46, 53, 98, 114, 122, 124, 132
Macoma calcarea	10, 31, 44, 50, 106, 138
Macoma moesta	44
Macoma sp.	15
Tellina agilis	15, 16, 46, 53, 98, 106, 132,138
Teredinidae	
Psiloteredo megotera	37, 53
Teredo navalis	19, 30, 37, 53
Thraciidae	
Thracia devexa	10
Thracia septentrionalis	53
Thyasiridae	
Thyasira gouldi	10, 15, 23, 44, 114
Turtoniidae	
Turtonia minuta	7, 30
Veneridae	
Gemma gemma	16, 30, 53, 106
Liocyma fluctuosa	7, 50
Mercenaria mercenaria	23, 53, 68
Pitar morrhuanus	70
	Gastropoda
Acmaeidae	
Acmaea testudinalis	6, 7, 10, 15, 16, 21, 23, 28, 29, 35, 44, 52, 53, 71, 98, 106, 114, 120, 121, 138
Aeolidiidae	
Aeolidia papillosa	16, 30, 53
Aporrhaidae	
Apporhais occidentalis	30, 38, 53
Atyidae	
Haminoea solitaria	7
Buccinidae	
Buccinum ciliatum	10, 31
Buccinum finmarkianum	10
Buccinum plectrum	10
Buccinum scalariforme	7, 10, 50
Buccinum totteni	57
Buccinum undatum	7, 10, 16, 30, 38, 42, 52, 53, 71, 98, 106, 113, 138
Colus sp.	44
Neptunea despecta	53
Cancellariidae	
Admete couthouyi	7, 10, 30, 31, 53, 106
Columbellidae	
Amphissa sp.	10

TABLE 1. (continued).

Family/Species	Literature reference
	Gastropoda
Coryphellidae	
Coryphella verrucosa	53
Crepidulidae	
Crepidula fornicata[c]	23, 53
Cuthonidae	
Cuthona concinna	106, 138
Trinchesia aurantia	106
Cylichnidae	
Cylichna alba	70
Cylichna sp.	70
Dendronotidae	
Dendronotus albus	53
Dendronotus frondosus	30, 53
Diaphanidae	
Diaphana minuta	7
Dotodae	
Doto coronata	30, 53
Doto formosa	53
Elysiidae	
Elysia catula	23, 53
Eubranchidae	
Eubranchus sp.	53
Facelinidae	
Facelina bostoniensis	53
Fissurellidae	
Puncturella noachina	6, 7, 30, 53, 106, 138
Hydrobiidae	
Hydrobia minuta	7, 23, 30, 106, 124, 138
Lacunidae	
Lacuna pallidula	30, 53
Lacuna vincta	7, 10, 15, 16, 20, 21, 23, 28, 29, 30, 52, 53, 70, 98, 106, 120, 121, 124, 138
Lamellariidae	
Marsenina glabra	10
Velutina undata	30, 53, 106, 138
Velutina velutina	10, 30, 53, 106
Lepetellidae	
Addisonia paradoxa	106, 138
Lepetidae	
Lepeta caeca	7, 10, 50, 57
Littorinidae	
Littorina littorea	7, 15, 16, 17, 18, 23, 24, 28, 30, 38, 51, 52, 76, 98, 101, 106, 114, 124, 129, 138
Littorina obtusata	16, 21, 23, 44, 53, 98, 106, 114, 117, 124, 138
Littorina saxatilis	7, 10, 16, 20, 21, 23, 30, 31, 44, 48, 53, 64, 98, 101, 106, 112, 122, 124, 138
Muricidae	
Boreotrophon fabricii	7
Boreotrophon clathratus	7, 10, 31
Thais lapillus	16, 23, 30, 52, 98, 106, 112, 114, 123, 124, 131, 138
Nassariidae	
Ilyanassa obsoleta[c]	30
Nassarius trivittatus	23, 53, 98, 114
Naticidae	
Amauropsis islandica	57
Lunatia heros	16, 23, 30, 53, 98, 106, 114, 122, 138
Lunatia pallida	7, 10
Natica clausa	7, 10, 31
Polinices nanus	10

TABLE 1. (continued).

Family/Species	Literature reference
Gastropoda	
Onchidoridae	
Acanthodoris pilosa	53
Issena lacera	53
Onchidoris adspersa	16, 23, 30, 53
Onchidoris fusca	16, 53
Onchidoris (*Lamellidoris*) sp.	106, 138
Philinidae	
Philine quadrata	7
Philine sp.	7
Pyramidellidae	
Odostomia trifida	114
Turbonilla interrupta	138
Turbonilla sp.	106, 138
Retusidae	
Retusa obtusa	7, 15, 23, 53
Rissoidae	
Alvania janmayeni	10
Alvania mighelsi	10
Cingula aculeus	53, 106, 120, 121
Cingula arenaria	7
Cingula castanea	46
Skeneopsidae	
Skeneopsis planorbis	30, 53, 106, 138
Tergipedidae	
Catriona (*Cratena*) *aurantia*	53
Tergipes despectus	31
Tergipes tergipes	53
Trochidae	
Calliostoma sp.	106, 138
Margarites costalis	31, 53, 70. 106, 138
Margarites groenlandicus	10, 30, 98
Margarites helicinus	7, 10, 30, 31, 53, 70, 98, 120, 121, 124, 138
Margarites olivaceus	7
Margarites umbilacalis	21, 31
Margarites sp.	15, 28
Solariella obscura	7, 10, 70
Solariella varicosa	7, 10, 70
Turridae	
Lora bicarinataa	106
Lora nobilis	30, 53, 106, 138
Oenopota arctica	31
Oenopota bicarinata	7, 10, 15
Oenopota elagans	7, 10
Oenopota harpularia	7, 10, 70
Oenopota incisula	7, 10, 53, 70, 114
Oenopota pyramidalis	7
Oenopota turriculaa	31
Propebela turricula	7, 10
Propebela sp.	15, 57
Turritellidae	
Tachyrhynchus erosus	7, 10, 15
Tachyrhynchus reticulosus	7, 10, 30, 44
Tachyrhynchus sp.	30, 57
Turretella sp.	138
Turritellopsis acicula	30

[a] Questionable taxonomic status.
[b] Intentionally introduced species.
[c] Northern range extension.

Research Effort by Area

Research effort in the Newfoundland-Labrador region has been disproportionately distributed (Table 2). More zoobenthic studies (which include mollusc-related research) have been conducted around the Avalon Peninsula of southeastern Newfoundland than in any other area. This disparity can be attributed to the location of the major research facilities in or near St. John's. These include the Biology Department and Marine Sciences Research Laboratory of Memorial University and the Northwest Atlantic Fisheries Centre of the Canadian Government.

The most under-studied area is the south coast from Fortune Bay westward to Port aux Basques. This area is characterized by a rugged coastline which is interrupted by numerous deep fjords and is accessible only by boat, helicopter or pontoon-equipped aircraft. Recently, some benthic research has been conducted in Fortune Bay and Bay D'Espoir by scientists and graduate students from the Biology Department and the Newfoundland Institute for Cold Ocean Science at Memorial University. In 1985, these studies included submersible dives to 800 m in some of the fjords. Another under-studied area is the northeast coast, many parts of which are also accessible only by boat or aircraft. An additional hindrance to research in this area is ice cover during the winter and spring months.

Accessibility to favorable research sites on the west coast has led to the establishment of zoobenthic projects in Port au Port Bay, St. George's Bay and Bonne Bay. However, benthic research in Labrador waters has been negligible since the completion of the 3-year OLABS program.

In the offshore area, apart from several reports on St. Pierre Bank scallops, zoobenthic research has been largely associated with oil explorations on the Grand Bank (Hibernia region) and the Northeast Newfoundland Shelf. Much remains to be learned about the zoobenthos of these offshore regions. Mollusc species lists seem to be incomplete and information on the spatial distribution of assemblages or communities is scarce. The trophic relationships of various fish species have been studied and data have been collected on the prevalence of benthic molluscs in the stomachs of demersal fishes (especially Atlantic cod and flatfishes) on the Grand Bank and other parts of the continental shelf off Newfoundland by scientists of the Northwest Atlantic Fisheries Centre, St. John's, but much of this material is unpublished at this time.

Discussion and Conclusions

This literature review confirms the opinion of Coady and Maidment (1984) that information on marine benthic molluscs in Newfoundland and Labrador waters is generally quite scarse, the exceptions being the commercially-important species (*Placopecten magellanicus* and *Mytilus edulis*). Many of the studies cited in this review include molluscs but they have been dealt with only in a cursory manner and often only qualitatively. A result of this, in the applied sense, is that most taxonomic guides and keys are from studies outside the region, and it is not known how appropriate such descriptions and definitive characteristics are for many of the species in the Newfoundland-Labrador region. Also, the inadequate and sporadic coverage of many parts of the region tends to emphasize the incompleteness of the list of mollusc species and their distributions. However, there exists in the files of researchers at Memorial University and the Fisheries Research Branches of the Provincial and Federal Governments a considerable volume of unpublished data. An example of this is the intertidal clam resource inventory of 1971-73, which was noted by Coady and Maidment (1984). There is an urgent need for the initiation of a systematic inventory of molluscs (and other invertebrates) in the Newfoundland-Labrador region, similar to what has been achieved for the phytobenthos by phycologists of Memorial University.

In recent years, littoral benthic survey programs have been implemented in Great Britain with use of the

TABLE 2. Geographic reference index to the literature on benthic molluscs of the Newfoundland-Labrador region.

Area (Fig. 1)		Literature reference
A.	Labrador coast and shelf	7, 8, 9, 10, 31, 38, 39, 44, 45, 69, 125, 146
B.	Northeast coast	4, 19, 30, 37, 42, 46, 70, 101, 105, 115, 122, 124, 137
C.	Southeast coast (Avalon Peninsula)	1, 2, 3, 5, 6, 7, 9, 11, 12, 13, 14, 15, 18, 19, 20, 21, 24, 25, 27, 28, 29, 32, 35, 36, 37, 40, 48, 49, 51, 52, 53, 54, 56, 60, 62, 65, 66, 67, 68, 71, 72, 75, 80, 87, 98, 102, 103, 104, 105, 106, 109, 110, 112, 113, 116, 117, 119, 120, 121, 123, 131, 136, 137, 138, 143, 144, 145
D.	South coast	19, 37, 40, 51, 105, 126, 127, 132
E.	West coast	17, 19, 23, 28, 37, 45, 51, 53, 73, 76, 77, 78, 79, 88, 89, 95, 105, 113, 114, 126, 127, 133, 134, 135, 142
F.	Offshore (St. Pierre Bank and Grand Bank	22, 43, 47, 50, 55, 57, 58, 63, 74, 83, 85, 91, 96, 97, 99, 100, 118, 136, 141

skills of amateur and professional biologists. Earll (1980) outlined the development and use of a computer-based system for handling habitat and species information from the sublittoral environment. The data file was constructed to allow key items to be extracted (e.g. species, areas). Earll (1980) suggested that the involvement of amateur biologists may be an effective means of obtaining distributional records of new species.

Knight and Mitchell (1980) reported on progress that has been achieved in littoral zone surveys in Great Britain. The project, with support from the Nature Conservatory Council and the Environmental Research Council, was undertaken jointly by the Scottish Marine Biological Association and the Marine Biological Association of the United Kingdom. The objectives of that program are those which would be desirable for a similar program in the Newfoundland-Labrador region. These are (a) to assemble and record existing knowledge on the distribution of habitats and associated nearshore organisms, (b) to carry out survey work in selected sectors of the coastline in order to verify existing information and to fill gaps in our knowledge, (c) to make photographic records of main types of habitats and the associated plant and animal communities, (d) to devise methods for computer storage and retrieval of information, and (c) to develop suitable criteria for the assessment of and selection of key areas in terms of their scientific and conservation value.

The foregoing discussion is not meant to imply that information of molluscs is not already being collected in the Newfoundland-Labrador region. However, the existing data are sparse and widely disseminated and take on a variety of forms (university theses, government data files, and personal notes of biologists), and there is no means at present for retrieving all sources of information from a common database. Such a database would aid biologists in directing their own research and would eliminate redundancy in research and inventory programs. The problem at present (and hence the purpose of this review) is identification of the work that has been done on molluscs in the Newfoundland-Labrador region and the form in which such data exist. A data-storage center should be established for existing information, and future field records should involve the completion of a standard data sheet, with the name of the recorder for potential verification purposes. The invertebrate species codes, which have been used by the Northwest Atlantic Fisheries Centre, St. John's (Lilly, MS 1982), could be used and additional codes added as the species lists are improved.

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