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Biology of the Iceland Scallop and Some Implications for Management of an Arctic Fishery

R.E. Crawford

Central and Arctic Region
Department of Fisheries and Oceans
Winnipeg, Manitoba R3T 2N6



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BIOLOGY OF THE ICELAND SCALLOP
AND SOME IMPLICATIONS FOR MANAGEMENT
OF AN ARCTIC FISHERY

by

R.E. Crawford

Central and Arctic Region
Department of Fisheries and Oceans
Winnipeg, Manitoba R3T 2N6

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TABLE OF CONTENTS

	<u>Page</u>
ABSTRACT/RÉSUMÉ	iv
INTRODUCTION	1
DESCRIPTION	1
General	1
Feeding mechanism	2
NUTRITION AND GROWTH	2
Nutrition	2
Growth	2
REPRODUCTION AND RECRUITMENT	3
Sexual maturation	3
Early life history	3
Recruitment	4
DISTRIBUTION	4
ENVIRONMENTAL REQUIREMENTS	4
IMPLICATIONS FOR FISHERY MANAGEMENT	5
Exploratory survey design	5
Resource assessment	5
Sustainable harvest levels	5
Fishing seasons	6
Fishing strategies	6
Fishery development	6
Research needs	6
ACKNOWLEDGMENTS	6
REFERENCES	7

LIST OF FIGURES

<u>Figure</u>	<u>Page</u>
1 Drawing of an adult Iceland scallop showing its characteristic shape and the ridges of its shell	9
2 General arrangement of the internal anatomy of an adult Iceland scallop	10
3 Geographic locations in northeastern Canada mentioned in the text	11

ABSTRACT

Crawford, R.E. 1992. Biology of the Iceland scallop and some implications for management of an Arctic fishery. Can. Manuscr. Rep. Fish. Aquat. Sci. 2175: iv + 10 p.

The Iceland scallop, Chlamys islandica Müller, is a slow growing bivalve of potential commercial importance in the eastern Canadian Arctic. Its physical characteristics, nutrition and growth, reproduction and recruitment, distribution and environmental requirements are described.

The local distribution of Iceland scallops in the Canadian Arctic is very patchy. Cohorts of a few dominant year classes can be found in low numbers in many places but denser aggregations are less common. Iceland scallops are mobile and will occupy marginally favourable habitat. Natural mortality of juveniles is high and recruitment is variable. In addition, local sea ice conditions and weather generally limit fishing seasons to a brief duration. The implications of these considerations are related to current research needs, resource assessment, design of resource surveys, and fishing and fishery development strategies.

Key words: life history; Chlamys islandica; Inuit; Canada; fishing strategy; aquaculture.

RÉSUMÉ

Crawford, R.E. 1992. Biology of the Iceland scallop and some implications for management of an Arctic fishery. Can. Manuscr. Rep. Fish. Aquat. Sci. 2175: iv + 10 p.

Le pétoncle d'Islande, Chlamys islandicus Müller, est un bivalve à croissance lente de la partie est de l'Arctique canadien qui pourrait comporter un certain intérêt commercial. On décrit ici ses caractéristiques physiques, sa nutrition et sa croissance, sa reproduction et son recrutement de même que sa distribution et ses exigences environnementales.

La distribution locale du pétoncle d'Islande dans l'Arctique canadien est très inégale. On trouve des cohortes de quelques classes annuelles dominantes en faible nombre en de nombreux endroits, mais les agrégations plus denses sont moins courantes. Les pétoncles d'Islande sont mobiles et occupent un habitat marginalement favorable. La mortalité naturelle des juvéniles est élevée et le recrutement est variable. En outre, les conditions locales de glace marine et le temps limitent généralement la saison de pêche à une courte période. L'étude de ces sujets est liée aux besoins actuels de la recherche, à l'évaluation des ressources, à la conception d'enquêtes sur les ressources, aux pêcheries ainsi qu'à des stratégies de développement des pêches.

Mots-clés: cycle évolutif; Chlamys islandicus; Inuit; Canada; stratégie de pêche; aquaculture.

INTRODUCTION

Within the limited biological diversity of the Canadian Arctic, few commercially valuable species are sufficiently abundant, or adequately available, to represent promise for badly needed fishery development. One potential candidate is the Iceland scallop, *Chlamys islandica* Müller. Since the late 1970's, there has been interest in the development of a commercial fishery for the Iceland scallop in the eastern Canadian Arctic (Allard 1980). Beds of this mollusc have been found near several northern communities. Native fishermen, as well as government fishery development agencies, have worked in various projects to establish new fisheries for this species. Most of this effort has been in the form of exploratory resource surveys but during the late 1980's, an experimental commercial fishery was tested in Cumberland Sound. There has been very little investigation of the biology of this species in Canadian Arctic waters (Cosens et al. 1990). As a result, we have a poor understanding of how characteristics of its biology may relate to Arctic fishery management objectives and fishery development goals.

In contrast to the paucity of Canadian information, there has been extensive research on this species in Norway and Greenland. The closely related bay scallop, *Argopecten irradians* Lamarck, has been examined even more thoroughly. Without data specific to the Canadian situation, we can benefit from these other bodies of knowledge as a source of initial information.

This report presents a synopsis of this knowledge, as it may apply to eastern Canadian Arctic Iceland scallop populations. The scope of this report is limited to considerations of life history characteristics which may influence interpretations of studies of population dynamics. An analysis of the biological data obtained from these populations will be published separately. Although much of this description of Iceland scallop biology is a compilation of information which has been learned elsewhere, initial results from new studies (e.g. Préfontaine and Morin 1991) indicate that there are enough similarities to draw general inferences on the biology of eastern Arctic Iceland scallop populations.

DESCRIPTION

GENERAL

The Iceland scallop (Fig. 1) is a mollusc that is a member of the Class Bivalvia. As such, it is diagnosed as having the following two characteristics: a) a shell with two valves that are usually more or less symmetrical, hinged dorsally and lateral in relation to soft body parts (i.e. there is a left and a right valve); and b) a head that is not differentiated and which lacks a buccal apparatus, a radula, and cephalic sense organs (Gosner 1971). A scallop also has no siphon and its foot is reduced. The

anterior adductor muscle, present in other bivalves, is also absent (Gosner 1971). Refer to Fig. 2 for anatomical details.

The Iceland scallop is epibenthic in habit; it lives on the surface of the bottom rather than in the sediments like many other bivalves. It lies on its side, left side up. Because of its physical orientation, its valves are commonly labelled according to their appearance, as dorsal (actually left side) and ventral (right). On each valve there are approximately 50 lateral, moderately coarse ridges, radiating from the umbo (the beak in the valve hinge area) to the shell margin. The valves also have "wings" or "ears" at the hinge side and one wing is larger than the other.

The Iceland scallop attaches itself to the sea bed with byssal threads. These threads originate in the byssal gland, located in the scallop's foot. The gland secretes when the foot is extended to the substrate. Travelling along a groove in the foot, the secretions harden into a thread upon exposure to seawater. When the foot is withdrawn, the byssal thread is anchored to the substrate at one end and to the byssus opening of the foot at the other (Barnes 1974). Usually several threads are secreted in this way but an Iceland scallop is never too firmly anchored to the bottom. If the animal is threatened by a predator, which it may detect chemically (see below), the Iceland scallop can release its byssal threads at its foot and swim away.

Swimming is accomplished by 'clapping' the valves, which causes a rapid ejection of water from the mantle cavity. The centrally located posterior adductor muscle (the 'meat' harvested by a fishery) is divided into smooth and striated sections. The rapid contraction of the striated ('quick') fibres powers the swimming activity. The muscular lobe of the mantle margin, when closed against the lobe of the opposite mantle surface, controls the direction of the exiting water jet. A scallop can direct the water jet to either side of the hinge line or from the centre of the valves, opposite the hinge line. The direction of movement of the scallop is opposite the direction of water flow.

The water jet can also be used to modify the Iceland scallop's environment. If one settles onto a sand flat among dynamic water flows, attachment to the fine-grained substrate with the byssus is problematic. In this instance, the water jets can be directed downward to blow out a small depression in the sand. By settling into this depression, the scallop is less likely to be disturbed by a strong current.

The mantle sensory lobes at the margins of the valves are also highly developed (Barnes 1974). They bear numerous photoreceptive blue eyes and many small sensory tentacles, which are both tactile and chemoreceptive. The eyes are most sensitive to the blue spectrum, which is the wavelength that penetrates most

deeply into the sea. This suite of sensory organs enables the scallop to detect predators, from which it will attempt to flee by swimming away. Swimming ability may be impaired by an abundance of 'Aufwuchs', a collective term for the various epiflora and epifauna - (e.g. barnacles) that accumulate over time on their valve surfaces, particularly the dorsal one. The Aufwuchs may double the total weight of an Iceland scallop in the eastern Canadian Arctic (C. Hudon, DFO, Halifax, personal communication). If a scallop under attack does not swim away, the smooth "catch" fibres of the anterior adductor muscle will contract to keep the valves tightly closed.

FEEDING MECHANISM

Another, older name for the Class Bivalvia is Lamellibranchia. This name is derived from the characteristic gill-type known as sheet gills. These are comprised of rows of filaments that arise from the mantle walls. The filaments are arranged in sheets and are covered with fine cilia, which in an Iceland scallop beat with a frequency of 1-2 beats per second (Venvik and Vahl 1979). While this beating serves to ventilate the gills for respiration, the cilia also filter phytoplankton and particles of detritus from the water. This food is trapped in a fine sheet of mucus coating the gills. Specialized cilia transport the mucus sheet containing the food to the mouth (Barnes 1974).

This focus on the gill structure emphasizes the fact that these filter feeding animals have a very specialized feeding apparatus. The sheet gills of an Iceland scallop can filter particles as small as 0.007 mm (Vahl 1973); large particles (e.g. 0.200 mm in the scallop Pecten latiauratus; Vahl 1973) are rejected. This size selection allows the scallop to filter only desired food and avoid ingesting 'unwanted' items.

Although specialized, this feeding mechanism is not perfect. It can be clogged when phytoplankton or detritus particles become too concentrated for effective ciliary clearing of the feeding surfaces. Under such circumstances, aerobic ventilation is interfered with and suffocation is a possibility. At the other extreme, too few food particles in the near-bottom water layer may result in starvation of the animal. Where scallops are found, the conditions probably range between these two extremes. Whatever the case, local micro-environmental differences can produce very different habitats for scallops (and other filter feeding organisms) living in a relatively small area (Rhoades and Young 1970).

NUTRITION AND GROWTH

NUTRITION

In addition to the mechanical aspects of successful filter feeding, there is another important limiting factor which influences Iceland scallop growth. The quality of the food (food value) of the filtered particles is defined by the ratio of the particulate organic matter (POM) and particulate inorganic matter (PIM) contained therein (Wallace and Reinsnes 1985). Throughout the year, sufficient energy and nutrients for scallop growth may be present in the water column as POM (Venvik and Vahl 1979). However, measuring only the amount of POM in the water column does not necessarily provide information on growth conditions for scallops (Vahl 1980). Instead, Iceland scallops require PIM as well, and it must be available as a minimum ratio of 30 percent POM to PIM. Vahl (1980) reported that proportions exceeding this limit were available in Norwegian waters during only five months of the year, the same period when scallop growth was evident. Temperature, salinity, chlorophyll, and current speed were shown to have a negligible effect on scallop growth when compared with the ratio of POM to PIM (Wallace and Reinsnes 1985).

The characteristic that food quality rather than quantity is important for growth is a reflection of the specialized feeding apparatus in Iceland scallops. Although the feeding mechanism is size selective, it is unable to select POM in preference to PIM (Vahl 1980). In habitats with an abundance of benthic fauna, there can be considerable reworking of the bottom sediments by deposit feeders, particularly in silt-clay sediments. This biogenic activity can produce a fecal-rich surface that is easily resuspended by tidal currents, resulting in an increase in bottom turbidity (Rhoades and Young 1970). Although the POM content of this suspension may be high, sufficient PIM is also required for scallop growth. As well, total particulate concentration cannot exceed the clearing capacity of the scallop's feeding mechanism.

Wallace and Reinsnes (1985) have pointed out that the ratio of POM/PIM is generally higher in the water column than near the bottom. When Iceland scallops are placed in cages which are off the bottom, access to higher quality food increases. This also extends the length of their annual growing season, further enhancing their annual growth. This phenomenon has positive implications for the prospects for aquaculture of this species (Wallace and Reinsnes 1984).

GROWTH

Growth in scallops is most frequently measured as an increase in shell height. The Iceland scallop generally attains a shell height of about 100 mm (maximum about 120 mm). Shell height is defined here as the longest distance from the umbo to the shell margin. In an anatomical sense, this measure is actually shell length (Holden and Raitt 1974). But by convention accepted by the scallop fishing industry, height is the term used.

Growth is seasonal. In Norwegian waters, most growth occurs during April-June (Venvik and Vahl 1979). The growth pattern of Iceland scallops in the Canadian Arctic has not been examined but a similar pattern occurs in the bay scallop which is found in more southern waters (Cooper and Marshall 1963). It is likely that Iceland scallops near Baffin Island follow the same pattern.

Annual growth increments can be counted and measured by examination of the 'winter checks' or rings of ridges on the valve surface. During growth of young Iceland scallops (e.g. <12 years), the inner surface of the outer fold of the mantle generates new periostracum tissue while the outer surface deposits a calcareous-layer material, both components of the shell. When these activities of the mantle fold decrease in winter, shell deposition slows and changes in shell height are small. Shell deposition does not cease, however, and the slow continuation serves to thicken the shell slightly during this time. At the resumption of spring growth, thin new shell material is deposited at the margin. As a result, a ridge has been formed by the winter's growth cycle.

As scallops age, annual growth increments decrease and the separation between the check marks becomes unclear. Also, well-defined checks are not usually found in the first 5-7 year classes of Iceland scallops, but alternating light and dark zones can be seen on the dorsal valve surface. These zones have been shown to correspond to annual growth rings (Wiborg 1963). Finally, older scallops are often so covered with Aufwuchs that the annual rings are hard to detect. Some researchers clean the valves with a mild acid wash to facilitate age determination; others cut the valves and examine their cross section.

Johannessen (1973) determined that annual growth marks are also present under the attachment of the hinge ligament to the valve (chondrophore). Age determinations of Iceland scallops collected from Canada's Cumberland Sound and Hudson Strait have been accomplished by supplementing data obtained from the examination of dorsal valves with counts obtained from the hinge ligament scar.

During a season, the growth of the soft tissues does not follow the growth of the shell. The differences between soft tissue growth are also much more variable than for shell growth, with large variations occurring throughout the year and also between different grounds (Venvik and Vahl 1979). Much of this variation can probably be attributed to food quality and to energy partitioning by the scallops in response to the demands for development of reproductive tissue (see below). The manifestation of this variability to a fishery is presented as differences in meat yield (adductor muscle weight) by area or by season.

Scallop growth in the Canadian Arctic is consistently slower than for scallops growing in the Gulf

of St. Lawrence. A size of 5 cm is attained after 5 years in the northern Gulf waters, while 6 to 7 years are required to attain a similar size in Ungava Bay and Cumberland Sound, respectively (Cosens et al. 1990). Northern populations also appear to reach a smaller asymptotic size than those in the Gulf of St. Lawrence.

REPRODUCTION AND RECRUITMENT

SEXUAL MATURATION

Iceland scallops in Norwegian waters become sexually mature at age three to five years, although maturation is related to size rather than age (Vahl 1981a). The corresponding size range is 35-45 mm. Scallops larger than 50 mm are all sexually mature (Wiborg 1963). The gonads grow rapidly in the spring, prior to spawning. Development of other soft tissues at this time is less dramatic, indicating that the organism's energy budget is directed toward the formation of reproductive products. After spawning, the growth of muscle tissue and other soft parts is accelerated until the end of the growing season. This seasonal reallocation of energy between somatic and gonadal tissue growth declines with increasing age; however, fecundity increases with age (Vahl 1981a). Somatic growth of senescent Iceland scallops (e.g. 20+ yr) declines to almost nil, which probably limits the life of the species (Vahl 1981a).

EARLY LIFE HISTORY

Iceland scallops spawn in June and July. Those in shallower areas spawn first (Venvik and Vahl 1979). As in other bivalves, their fecundity is very high. Fertilization occurs in the surrounding water, after gametes have been shed into the suprabranchial chamber and broadcast into the surrounding waters by several clappings of the valves.

As in most other marine bivalves, the embryo first develops into a free-swimming trochophore, a primitive type of larva. The trochophore passes into a more highly developed veliger larva, in which the foot, shell and other structures make their appearance. In both larval forms, locomotion is accomplished by the synchronous movement of cilia. Movement is limited but the larvae are able to change their location in the water column (i.e. shallower/deeper). The shell and shell gland are present in the form of a single dorsal plate. This grows laterally and ventrally, eventually folding into the two halves of the adult form (Barnes 1974).

The planktonic period lasts several weeks, until the weight of the developing valves of the shell overwhelms the swimming capabilities of the veliger and the young scallop settles to the bottom. The juvenile scallop retains mobility after settling, except swimming is

then accomplished by clapping the valves. It seeks out suitable substrate and habitat, to which it temporarily anchors itself with its byssus.

RECRUITMENT

Recruitment of Iceland scallops is uneven. As is common with other species of bivalves, a population of scallops is often dominated by cohorts of relatively few year classes. Natural mortality of larvae and juveniles is high. The survival of cohorts of a new year class fluctuates according to the influence of many environmental and biological variables. This is especially so during the planktonic phase, when larvae are swept into areas unfavourable for settlement or for successful benthic development and growth.

Vahl (1981b) observed that there were few scallops which were less than two years old on a Norwegian fishing ground. Because young scallops are considerably more mobile than adults, he suggested that juvenile scallops may settle in areas not populated by adults. In Norwegian waters, adult Iceland scallops swam to a new area on an average of every 31 days (Venvik and Vahl 1979). Distance travelled varied between only several meters to considerably more. Venvik and Vahl (1979) postulated that Iceland scallops may settle to the bottom and then migrate to favourable locations where their numbers may be sufficient to support commercial fishing. These authors also found an abundance of adult scallops on grounds that were fished to depletion the previous year. This suggested that migration of adults from other areas must also have occurred (Venvik and Vahl 1979).

Smaller size classes are often poorly represented in samples of Canadian Arctic Iceland scallops obtained with dredges, even when the dredges have been modified to decrease selectivity (e.g. Allard and Gillis 1989; Morin 1991a,b). Special techniques may be required to effectively monitor the younger year classes (Cosens et al. 1990), such as by diver (Venvik and Vahl 1979) or underwater video.

DISTRIBUTION

The Iceland scallop's distribution can be described as circumpolar subarctic or northerly boreal. It has been found in the White Sea, along the Murman and Norwegian coasts, near Hopen, Spitzbergen, Jan Mayen, and Iceland, in the Bering Strait, along the coast of Alaska, and in the Bering, Okhotsk, and Kara seas (Wiborg 1963). In Canada, this scallop is known from the Gulf of St. Lawrence to Cumberland Sound, Baffin Island (Fig. 3). It is also found in Hudson Strait and Hudson Bay; for example, beds occur near the Belcher Islands, along the Keewatin Coast (Cosens et al. 1990), and in northern James Bay (Lubinsky 1980).

Recent exploratory fishing for Iceland scallops has been carried out in the following places in the eastern Arctic: off Killiniq Island (Gillis and Allard 1986; Gillis et al. 1987), in Cumberland Sound (Mackay 1986; Cosens et al. 1990; D. Pike, DFO Iqaluit, personal communication), off Akpatok and southern Baffin islands and Quaqtac (Gillis and Allard 1988), in southeastern Frobisher Bay (R. Crawford, DFO Winnipeg, unpublished data), in western Ungava Bay and off southwestern Baffin Island (Allard and Gillis 1989), off the southern coast of Hudson Strait (Albright 1990; Morin 1991a), and along the eastern Hudson Bay coast of Northern Quebec (Morin 1991b).

Concentrations of scallops sufficient to offer potential for commercial exploitation have been located in several locations in Cumberland Sound (Bodaly et al. 1992), in Ungava Bay (near Akpatok and Killiniq Islands; Gillis and Allard 1988), near Quaqtac and also in Wakeham Bay (Allard and Gillis 1989). Similar concentrations have been found near the shores of northern Quebec in the western end of Hudson Strait (Préfontaine and Morin 1991). An experimental fishery was conducted out of Pangnirtung (Cumberland Sound) between 1987-1989. There has also been a commercial fishery for this scallop operating out of Nain, Labrador since the late 1970's (Barney et al. 1982).

ENVIRONMENTAL REQUIREMENTS

Iceland scallops are chiefly found on sea beds of sand, gravel, shells, and sometimes clay (Wiborg 1963). They are usually fastened to the substrate with a byssus (Venvik and Vahl 1979). Iceland scallops are therefore found in greatest density on relatively coarse substrates with gravel, small rocks or shell/gravel mixture. In Norwegian waters, there are moraine ridges that have been washed clean by currents. Such bottom conditions form good habitat for Iceland scallops (Venvik and Vahl 1979). Fishermen tow their drags parallel to the ridges for the best catches (Venvik and Vahl 1979). This bottom type is apparently similar to conditions extant in the eastern Canadian Arctic (e.g. Frobisher Bay; R. Crawford, unpublished data).

Gosner (1971) reported that Iceland scallops are found between depths of 18 to 327 m but the depth range for scallops in a particular area is often narrower. For example, along the Norwegian coast, the scallop beds are commonly between 15-60 m (Wiborg 1963), while at Bear Island scallops are most plentiful in 80-100 m. At Spitzbergen they are found between 40-55 m. In Cumberland Sound and Hudson Strait, Iceland scallops are typically most dense between 30-90 m.

In addition to their occurrence in a range of depths, Iceland scallops are also found in a range of salinity. For example, they are widely distributed in oceanic waters (salinity about 34 ‰) but they are also

abundant in Norwegian fjords where the salinity can be as low as 22.5 ‰, which is about at the limit of tolerance for the species.

The physical factors determining the location and size of Iceland scallop beds are not known. Off Lofoten Islands (Norway), dense populations have been found inside fjords with a sill in places with comparatively strong currents (Wiborg 1963). Concentrations in Hudson Strait are also in areas of intensive water mixing (Canadian Hydrographic Service 1989; Taggart et al. 1988). But although strong currents may be a prerequisite for good scallop habitat, there must also be a mechanism that prevents larvae from being swept away from the area (Sinclair and Iles 1989). For example, the correspondence of scallop beds with tidal fronts, persistent gyres or persistent two-layer circulation frontal areas have been reported for three species of scallops in the southern Gulf of St. Lawrence and the east Atlantic coast (Pingree and Griffiths 1980; Sinclair et al. 1985).

The incidence of concentrations of Iceland scallops might be related to high phytoplanktonic production or resuspension of detrital particulate organic matter, in association with suitable concentrations of inorganic particulate matter. It may also be a function of the size or number of favourable areas for larval retention. More likely, the driving influence is a result of a combination of these and other unknown factors.

IMPLICATIONS FOR FISHERY MANAGEMENT

From this examination of the life history of the Iceland scallop, several aspects are relevant to the development and management of fisheries for this species in the Canadian Arctic. These are summarized below.

EXPLORATORY SURVEY DESIGN

The local distribution of Iceland scallops in the Arctic is very patchy (Préfontaine and Morin 1991). Although scallops have a specialized feeding mechanism that allows them to exploit various habitats, there are rather strict limitations to their requirements for growth. However, they are somewhat mobile and can be expected to exploit even marginally favourable habitat, especially after a highly successful year class. But recruitment is variable and natural mortality of juveniles is high. Given these characteristics, it may be anticipated that the proper combination of physical and biological environmental variables necessary for highly favourable scallop habitat (e.g. high quality food during a long growing season, low abundance of predators, favourable water circulation pattern for planktonic larval retention) is not too common in the Arctic. From this, it is to be expected that cohorts of a few dominant year classes might be found in low numbers in many places. This

suggests that finding low numbers of Iceland scallops in an area does not necessarily indicate that an abundance of scallops is nearby. However, it is also unlikely that a scallop bed would exist in isolation. The implication of this for Iceland scallop exploratory fishery development in the Arctic is that large areas must be thoroughly surveyed in order to accurately assess the extent and commercial exploitation potential of an Iceland scallop resource.

Because of the great expense involved, it is important that searches for exploitable concentrations of Iceland scallops are carefully designed to maximize their results and usefulness (Préfontaine and Morin 1991). Existing data bases frequently offer limited comparability with others, in terms of data units or precision. Further exploration for scallops in Hudson Strait, Hudson Bay and Baffin Island waters should include enhanced efforts to describe the oceanographic characteristics of the study area. Accurate geo-positioning information (e.g. by Global Positioning Satellite) is also required. Survey plans should accommodate the lack of bathymetric information for the eastern Arctic and should not rely on large vessels that cannot work safely in uncharted Arctic coastal waters. Surveys should also use standardized data reporting formats to allow comparability of results. Standardization could be accomplished within DFO during the annual Quebec and Central and Arctic regions Arctic operations coordination meetings. Non-DFO agents could be included in this process through the conditions prescribed in their exploratory fishing licenses.

RESOURCE ASSESSMENT

Although it has not been rigorously examined, differences in average shell heights of Iceland scallops taken from catches obtained from different locations in a scallop bed (D. Pike, DFO, Iqaluit, NWT, personal communication; Préfontaine and Morin 1991) indicate that the growth rate of Iceland scallops in the eastern Arctic is variable. There is also variability in the meat yield (the proportion of adductor muscle weight to whole scallop weight). These differences reflect the dynamics of the responses of Iceland scallops to food quality and availability. That there is noticeable variability in these characteristics within a scallop bed indicates that fine scale environmental processes will influence the quality of a catch. This variability must be considered when evaluating the potential of a population for economic exploitation.

SUSTAINABLE HARVEST LEVELS

The economic viability of an Arctic Iceland scallop fishery is uncertain. Preliminary examination of biological data indicates that due to low productivity of the resource, sustained harvests on the order of those desired by fishing proponents (i.e. 100+ tonnes) are

unlikely (Bodaly et al. 1992). An economic analysis of the Cumberland Sound experimental fishery is in preparation (D. Topolniski, DFO, Winnipeg, personal communication) and will increase our understanding of the requirements for 'successful' Arctic exploitation. Preliminary evidence suggests that non-subsidized economic sustainability will be difficult (D. Topolniski, DFO, Winnipeg, personal communication).

FISHING SEASONS

Meat yield also increases significantly later in the growing season, after the scallop's energy budget has been shifted from gonad development to the production of soft tissues. In other scallop fisheries in southern waters, benefits in the yield-per-unit-of-effort to a fishery may be realized by fishing later in the scallop's growth season. This delay may also reduce fishing mortality during the scallop's spawning season. Although this strategy is effective in the south, the growth pattern may not be so easily exploited in the Arctic. This is due to the need to utilize the ice-free season (e.g. mid-July to mid-September) for fishing, rather than manage fishing effort toward optimizing the biological potential of the resource. Because of climatic constraints, compromises in such fishing strategies may be required in the North.

FISHING STRATEGIES

Because of these prospects, alternate fishing strategies, such as a pulsed plan may in some instances be more appropriate. A model scenario would include the situation of several suitably dense scallop beds near an Arctic community. Fishing activity could be limited to only a portion of the beds each year, on a rotating basis. Harvest levels within each bed could exceed that required for sustained harvests provided that periods of fishing inactivity were sufficient to allow the resource to recover for the next pulse of exploitation. Although profitable harvests may still exceed sustainable levels, necessitating periodic closures of the fishery, a pulsed strategy may dampen the 'boom or bust' result of open exploitation. Another plan would provide different quotas for specific areas of a fishing ground, as has been proposed for the scallop grounds near Pangnirtung (Cumberland Sound).

If alternate strategies are promoted for Iceland scallop fisheries, the increased costs of their enforcement must also be considered. However, options such as these may prove to be desirable compromises in the North where the social benefits to be derived from employment opportunities may outweigh conclusions obtained from traditional fisheries analyses.

FISHERY DEVELOPMENT

Iceland scallops in the Arctic grow more slowly than those in the Gulf of St. Lawrence (Bodaly et al. 1992). Much of this difference may be simply a response to colder temperatures rather than to differences in food, although variation in food quality may alter the duration of the growing season. Whatever the case, it is likely that scallop growth in the eastern Arctic could be enhanced with off-bottom culture techniques. However, the potential of such enterprise, in cost/benefit terms, must be thoroughly examined prior to commercial application. This examination should include the fact that aquaculture in the Arctic must contend with predation by marine mammals.

Although aquaculture of Iceland scallops may be technically feasible in the Arctic, under current conditions it is not likely to provide an economic alternative for other than labour-intensive, small scale production to local markets in which scallops may not be a traditional dietary item. Although such constraints appear to limit the regional potential for this development option, local situations may vary.

RESEARCH NEEDS

Although we have a general picture of the life history of the Iceland scallop in the eastern Arctic, we do not possess the type of knowledge required for fishery management (e.g. specifics about yield-per-recruit, growth and mortality). Basic data are also required on the abundance of this species and its distribution in Canadian Arctic waters. Because we have so little information upon which to develop a management strategy for an eastern Arctic Iceland scallop fishery, the opportunities for research on this species are numerous. Some examples are:

- a. Studies of their distribution and abundance and the biological and physical determining factors.
- b. Examination of the linkage between phytoplankton production, the maturation of Iceland scallop gonads, production of planktonic larvae, and production of the adult benthic population.
- c. Study of mechanisms for larval transport and retention, population mixing and stock fidelity.
- d. Examination of the position of the Iceland scallop in the benthic community.
- e. Determining the effect of exploitation on the population dynamics of a virgin stock and developing models for commercial fishery exploitation.

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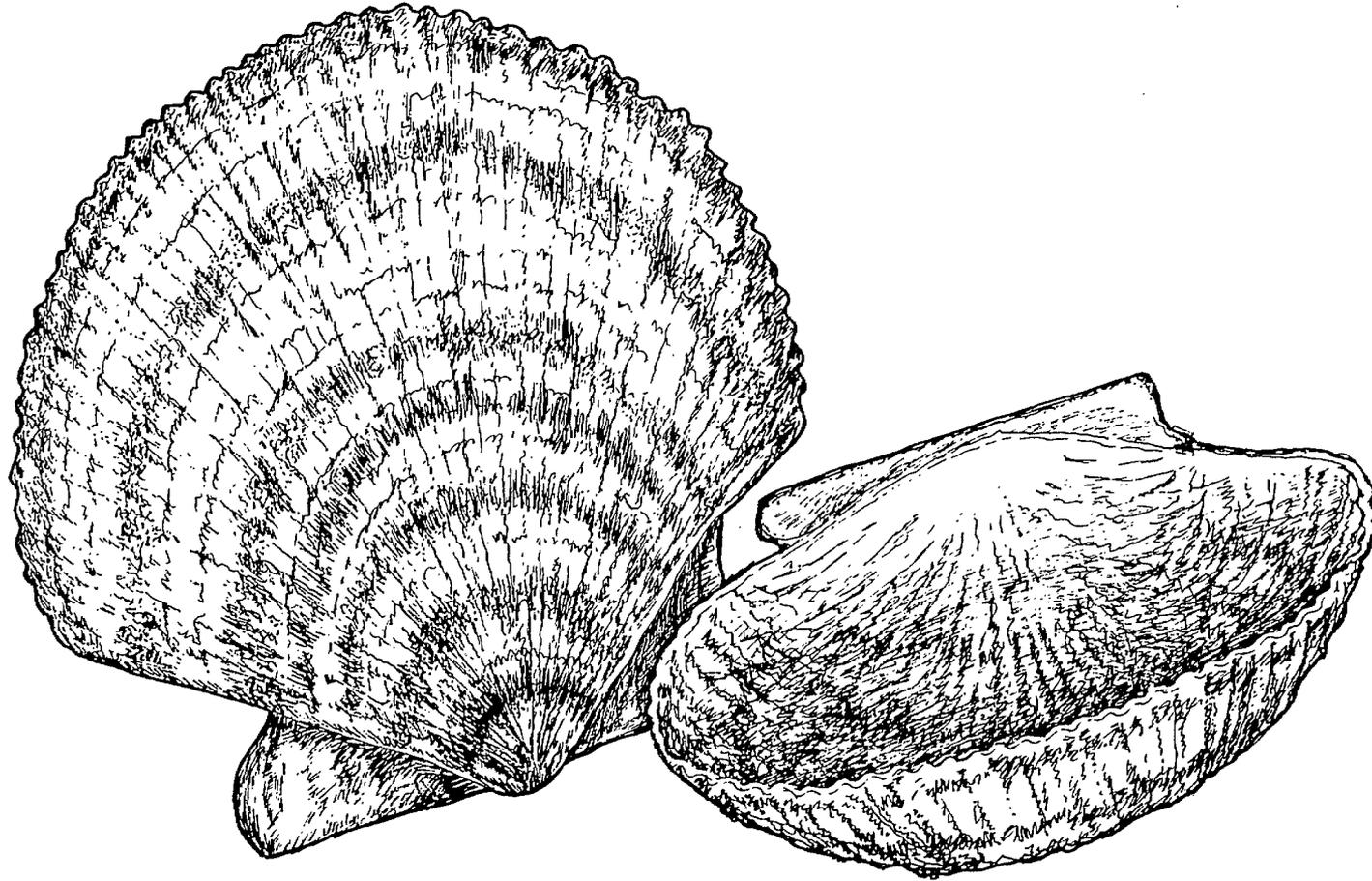


Fig. 1. Drawing of an adult Iceland scallop showing its characteristic shape and the ridges of its shell.

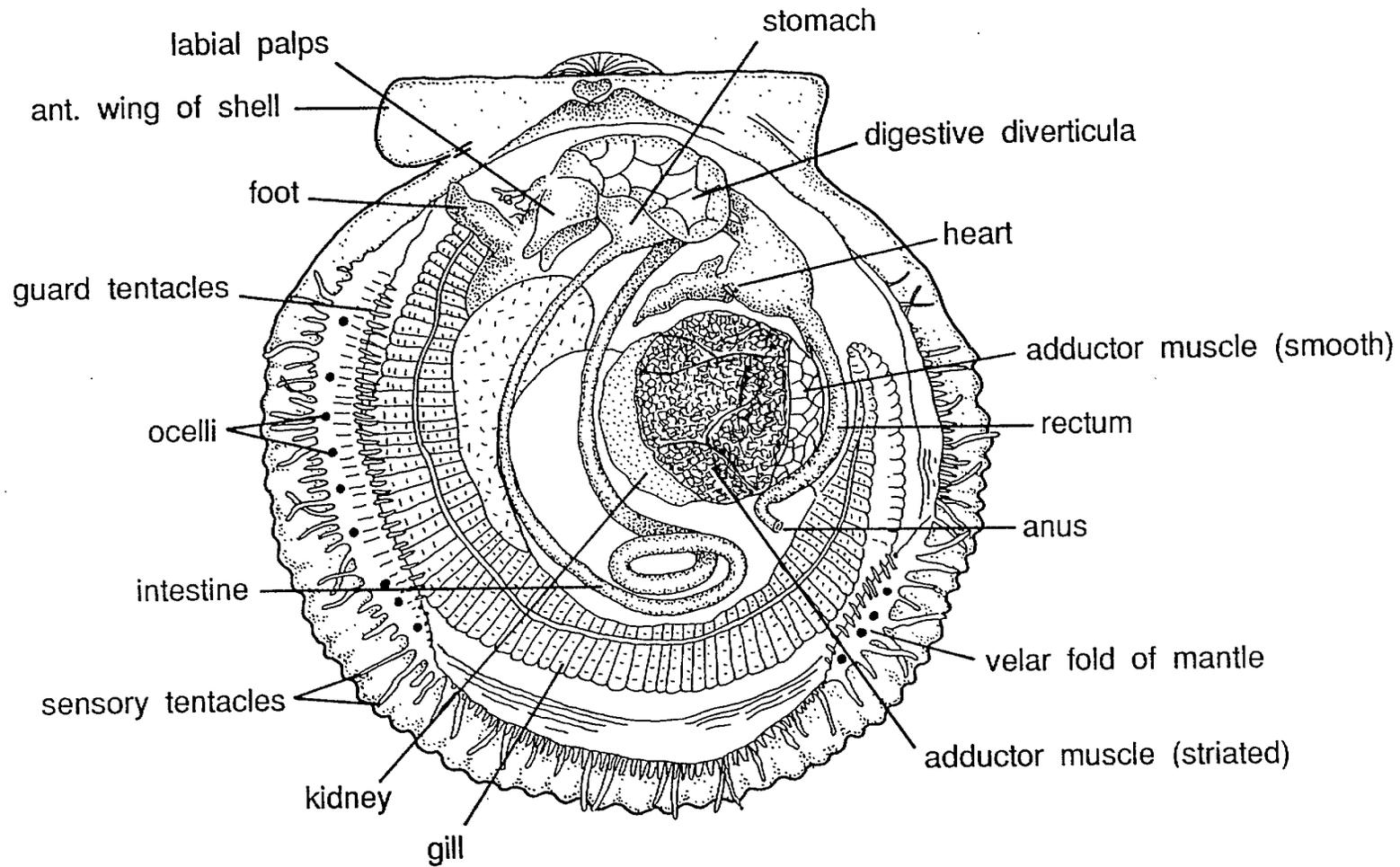


Fig. 2. General arrangement of the internal anatomy of an Iceland scallop.

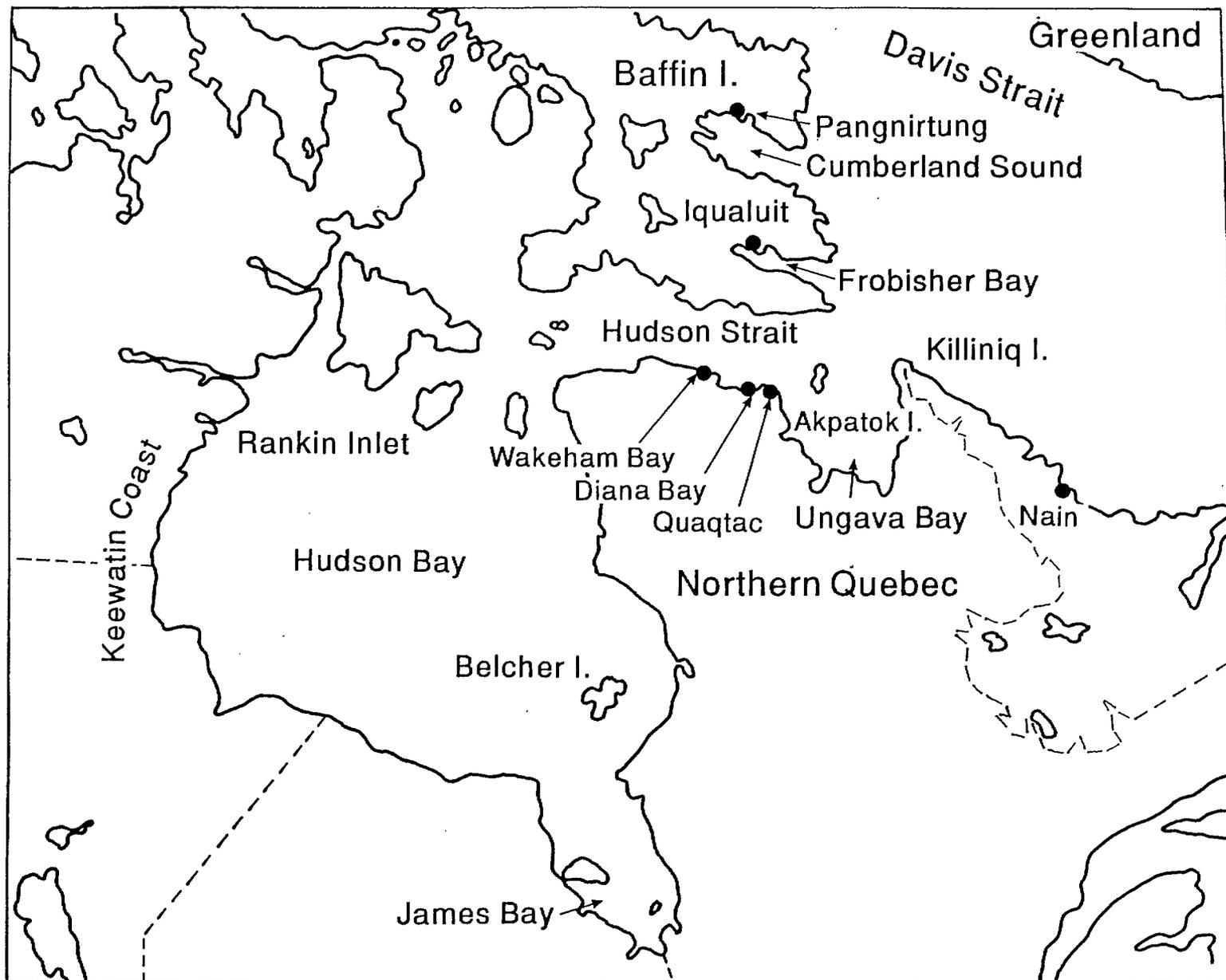


Fig. 3. Geographic locations in northeastern Canada mentioned in the text.

