Fecundity and Reproduction Characteristics of Beaked Redfish (*Sebastes fasciatus* and *S. mentella*) in the Gulf of St. Lawrence

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FECUNDITY AND REPRODUCTION CHARACTERISTICS OF BEAKED REDFISH (*SEBASTES FASCIATUS* AND *S. MENTELLA*) IN THE GULF OF ST. LAWRENCE.

by

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ABSTRACT

St-Pierre, J.-F., and Y. de Lafontaine. 1995. Fecundity and reproduction characteristics of beaked redfish (*Sebastes fasciatus* and *S. mentella*) in the Gulf of St. Lawrence. Can. Tech. Rep. Fish. Aquat. Sci. 2059: 32 + vii p.

In 1989 and 1990, more than 2600 females of ovoviviparous redfish (*Sebastes mentella* and *S. fasciatus*) collected in the Gulf of St. Lawrence were examined to study their reproductive cycle and fecundity. Using the number of anal fin soft rays as distinctive criteria to distinguish species, we note that *S. mentella* largely dominate (>90%) the Gulf redfish population in summer and winter. Gonad examination led to the definition of 11 different maturity stages to which calculated gonado-somatic indices (GSI) are related. Results indicate a synchronous gonadal development within the entire population. Copulation probably takes place during the fall through early winter and is followed by a short larval extrusion period extending from the end of April to the beginning of June. Both species spawn in the Gulf of St. Lawrence. Size at maturity ($L_{0.5}$ = 26 cm) did not vary significantly between species and is very close to a previous estimate obtained 30 years ago. Absolute fecundity of Gulf redfish varies between 1500 and 70000 oocytes per female and increases as a power function of fish length and weight. *Sebastes fasciatus* has slightly higher relative fecundity than *S. mentella*. We found that the characteristics of maturity and reproductive cycle of Gulf redfish are not different than those reported for populations outside the Gulf of St. Lawrence and cannot be used as criteria to distinguish redfish species. The maturity and spawning characteristics of both species are not sufficiently different to act as reproductive barriers to maintain the integrity of these two sympatric species. It is suggested that copulation processes during the fall are probably more critical than larval extrusion (spawning time) during spring to ensure species integrity.

RÉSUMÉ

St-Pierre, J.-F., and Y. de Lafontaine. 1995. Fecundity and reproduction characteristics of beaked redfish (*Sebastes fasciatus* and *S. mentella*) in the Gulf of St. Lawrence. Can. Tech. Rep. Fish. Aquat. Sci. 2059: 32 + vii p.

Entre 1989 et 1990, plus de 2600 femelles de sébaste ovovivipare (*Sebastes mentella* et *S. fasciatus*) du golfe du Saint-Laurent ont été examinées afin de décrire leur cycle reproducteur et leur taux de fécondité. En utilisant le nombre de rayons mous de la nageoire anale comme critère distinctif des deux espèces, on observe que *S. mentella* domine largement (>90%) la population de sébaste du Golfe en été et en hiver. L'examen des gonades a permis la définition de 11 stades de maturité différents auxquels sont reliées des valeurs de l'indice gonado-somatique (IGS). Les résultats indiquent un développement synchrone des gonades au sein des populations. La copulation a probablement lieu en automne et au début de l'hiver et est suivie par une courte période de libération larvaire s'étendant de la fin avril au début juin. Les deux espèces de sébaste fraient à l'intérieur des limites géographiques du golfe du Saint-Laurent. La taille à maturité ($L_{0.5}$ = 26 cm) ne varie pas de façon significative entre les deux espèces et est similaire à un estimé obtenu il y a 30 ans. La fécondité absolue du sébaste du Golfe varie entre 1,500 et 70,000 oocytes par femelle et augmente de façon exponentielle avec la taille ou le poids des individus. La fécondité relative de *S. fasciatus* est légèrement supérieure à celle de *S. mentella*. Nous avons observé que les caractéristiques du cycle de maturité et de reproduction n'apparaissent pas différentes de celles mesurées chez les populations de sébaste vivant à l'extérieur du Golfe et ne peuvent pas servir de critères distinctifs entre les 2 espèces. Les caractéristiques reproductrices des deux espèces n'apparaissent pas non plus suffisamment différentes entre elles pour agir comme des barrières assurant le maintien de l'intégrité des deux espèces sympatriques. Il est suggéré que les processus agissant au niveau de la copulation en automne plutôt que ceux liés à l'extrusion larvaire (frai) au printemps sont probablement déterminants pour maintenir l'intégrité spécifique.

INTRODUCTION

Since the late 1950s, redfish (*Sebastes* spp.) catches in the Gulf of St. Lawrence have fluctuated between 5000 and 130000 metric tons per year, with peaks in both the late 1960s and early 1980s and a major trough during the mid-1970s (Sandeman 1973; Laberge and Hurtubise 1989). These large variations were mainly due to strong but infrequent pulses in recruitment. Following the introduction of management policies in 1976, catches have reflected the total allowable catch allocated for the area increasing from 18,000 to 57,000 mt in 1991 (Morin and Bernier, 1992). Despite its commercial importance to the fishery, the reproductive ecology and life history characteristics of Gulf of St. Lawrence redfish populations are still poorly understood. This lack of information is partially due to the difficulty of studying redfish (e.g. their distribution is limited to offshore and deep (>150m) waters) and also to uncertainties concerning the taxonomic status of Atlantic redfish. In the past, research has been oriented more towards identifying and distinguishing between species than on understanding the mechanisms which underlie redfish species composition and co-existence in the area.

Three different species of redfish occur in the northwest Atlantic (Ni 1984): the Acadian beaked redfish (*Sebastes fasciatus*), the deepwater beaked redfish (*S. mentella*), and the Atlantic golden redfish (*S. marinus*). The golden redfish, the larger of the three, can be distinguished by its external morphology (Ni 1984; Scott and Scott 1988). The distinction between *S. mentella* and *S. fasciatus* has always been less obvious because their meristic and/or morphological characteristics overlap. However, the two species are considered genetically distinct based upon electrophoretic analyses (Payne and Ni 1982; McGlade *et al.* 1983). It has been proposed that anal fin ray counts (AFC) may be used to separate *S. fasciatus* from *S. mentella* with an acceptable resolution (Ni, 1981; Rubec *et al.* 1991; Barsukov *et al.* 1991; Sévigny and de Lafontaine 1992). The horizontal distribution of these three species overlaps somewhat, but distinct vertical distributions have been reported (Templeman 1976; Ni 1984; Rubec *et al* 1991; Barsukov *et al.* 1991). Both *S. fasciatus* and *S. mentella* are common in the Gulf of St. Lawrence, and it has been suggested that 70-80% of the Gulf redfish is composed of *S. mentella* (CAFSAC, 1984). *S. marinus* is only rarely (<1%) taken in the Gulf (Ni and Sandeman 1984; Rubec *et al.* 1991). Redfish migration patterns, however, are poorly known and the integrity and reproductive isolation of the Gulf stocks remain to be demonstrated.

The occurrence of mature females (Steele 1957; Ni and Sandeman 1984) and the collection of newly released redfish larvae (Dannevig 1919; Steele 1957; Jean 1955; Kohler *et al.* 1977) indicate that redfish do spawn in the Gulf, but the peak and duration of the spawning activity are not well known. Seasonal trends in maturity conditions of redfish in southwestern Newfoundland suggest that the spawning period extends from April to July (Ni and Templeman 1985). Such information is nonexistant for Gulf populations; it is generally assumed that the sexual cycle and spawning period are similar to those of populations inhabiting adjacent waters. In addition, Ni and Sandeman (1984) reported that Gulf redfish populations are characterized by a smaller size at maturity than that observed in adjacent stocks. However, species composition was not taken into account and results were based on a mixture of the two species.

Redfish are ovoviviparous, so the eggs are fertilized internally and spawning is characterized by the direct extrusion of larvae in the water column. Although the evolution of internal bearing (viviparity) in fish is often associated with reduced fecundity (Murphy 1968; Wourms 1991), relatively high fecundity rates (from 2000 to 500000 oocytes per female) have been measured in several Pacific rockfish species which are closely related to Atlantic redfish (Snytko and Borets 1973; Gunderson 1977; Bolhlert *et al.* 1982; Haldorson and Love 1991; Wourms 1991). Few fecundity studies have been conducted on north Atlantic redfish stocks and virtually all estimates pertain to the golden redfish (Nikolsky 1954; Magnusson 1955; Corlett 1964; Raitt and Hall 1967). The number of eggs per female (40-75 cm long) varied from 20000 to over 300000 depending on fish size. Kelly *et al.* (1972) reported the fecundity of average-sized redfish (30 cm in length) collected in the Gulf of Maine (probably *S. fasciatus*) to be around 50000 fertilized eggs. To our knowledge, the fecundity of *S. mentella* has not been quantified except for six individuals (45-48 cm long) caught in East Greenland with egg counts of between 2600 and 31800 (Corlett 1964). However, the large size of these six "*mentella*" type specimens casts doubt on their exact identification, and Raitt and Hall (1967) considered Corlett's specimens to be *S. marinus*. Thus, at the light of the available information, the existence of different reproductive characteristics among the three Atlantic redfish species has not been verified due to the lack of appropriate data on two species (i.e. *S. mentella* and *S. fasciatus*).

This report compares the reproductive traits of Gulf of St. Lawrence redfish with those of populations or species in other areas. The objectives of this study are 1) to describe the maturity cycle in an attempt to delineate the spawning season of redfish in the Gulf, 2) to provide fecundity estimates for this particular population and, 3) to investigate the level of variation in the reproductive cycle and fecundity of these two sympatric redfish species in the Gulf. Such information is valuable for stock assessment purposes as spawning stock biomass can be inferred from the product of fecundity values and larval abundance based on ichthyoplankton surveys (Herra *et al.* 1987).

MATERIALS AND METHODS

Adult female Gulf of St. Lawrence redfish were collected at various stations in the Laurentian Channel and Esquiman Channel during five sampling research surveys conducted by the Department of Fisheries and Oceans (Québec) between January 1989 and February 1990 (Fig. 1). Fish was also purchased from three commercial fishing vessels during spring 1989. Although the exact site of capture is unknown, these commercial fishes were also taken in the Laurentian Channel where spring fishing operations usually take place, as indicated by the weekly positions of the Québec fishing fleet, during April and May 1989 (Fig. 2). Fish from research surveys was caught with a bottom otter trawl towed for 15 or 30 minutes, while commercial samples were captured with a mid-water otter trawl (Table 1).

A maximum of 200 female redfish were randomly selected from each set giving a total of 2,642 fish examined. Usually, fish > 25 cm were selected for analysis, except for cruise GA162 (January 1989) in which fish < 30 cm were discarded. In most cases, total weight of fish

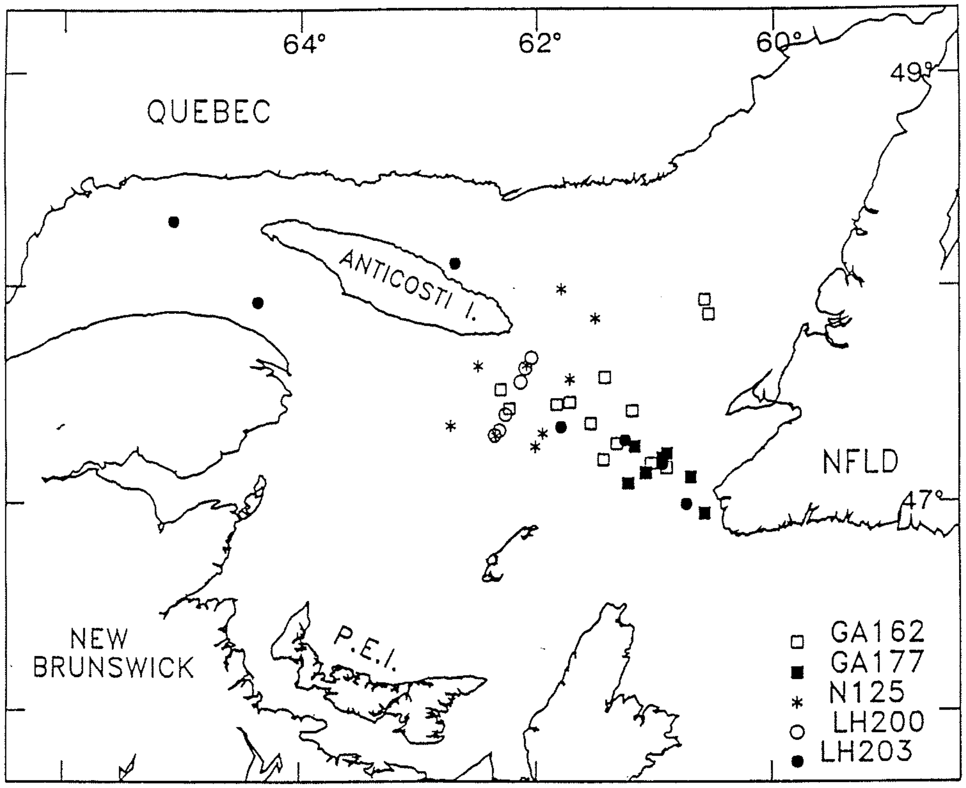

Figure 1. Sampling site locations of five research surveys.

was determined to the nearest 5 g, fork length was measured to the nearest cm, and counts of anal fin rays (AFC) were recorded. As indicated by Rubec *et al.* (1991), only anal soft rays were counted and the last 2 rays were counted as one because they are inserted on the same basal pterygiophore. Due to technical problems, weight measurements for fish collected during cruise GA162 were eliminated and replaced with estimates derived from a general weight-length relationship based on observations from other cruises (see Results). Fish gonads were extracted and frozen at -20°C. Redfish from the commercial fishery were randomly collected on arrival at port and kept frozen (-20°C) for transport to the laboratory where they were thawed for morphometric measurements and extraction of gonads as described above.

In the laboratory, all gonads were thawed and examined to determine maturity. Because no detailed maturity staging index exists for female Gulf redfish, we prepared a staging index based upon macroscopic examination of our samples and by adapting Echeverria's (1987) index for 34 Pacific *Sebastes* species, and that of Ni and Templeman (1985) for beaked redfish. Eleven stages were defined to distinguish immature, first-year spawners and mature redfish females (Table 2). Immature (stage 1) females are characterized by small gonads with very small or no apparent oocytes and showing no sign of vitellogenesis. Stages 2 to 4 describe ovary conditions for fish that will spawn for the first time. During the first year of maturity, oocytes develop by

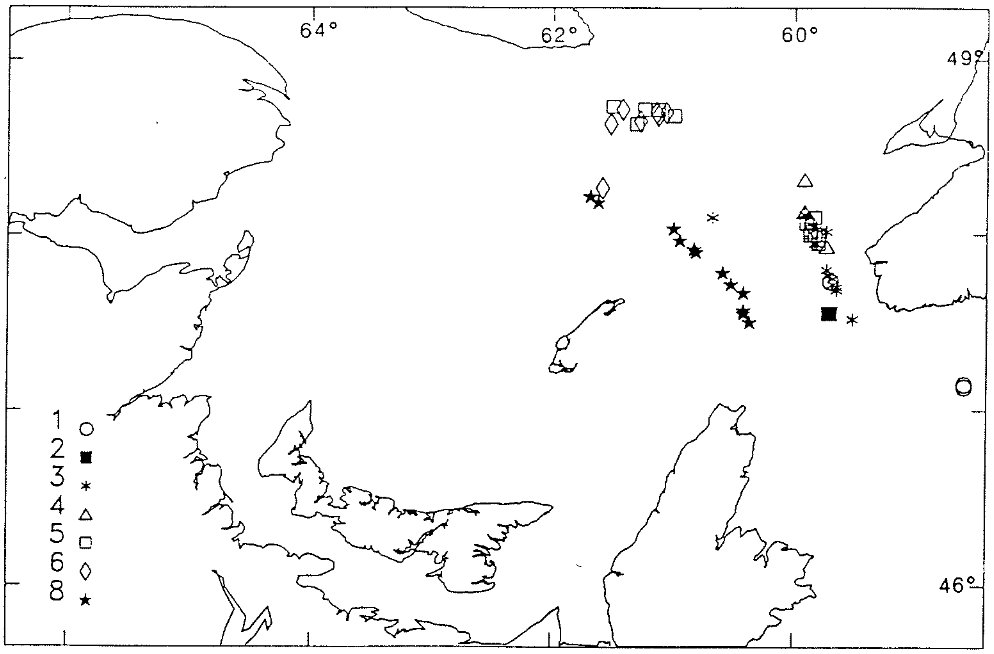

Figure 2. Weekly positions and movement of redfish fishing vessels of the Québec fleet (April -June 1989). Week 1 (open circle) is April 10-16; while week 8 (black star) is May 29-June 4. Information for week 7 is not available.

increasing in size and by incorporating yolk, but no melanin pigments are observed in the stroma of the ovary. Stages 5 to 7 are equivalent to stages 2 to 4, but they describe changes in the ovaries of fish that have spawned at least once in their lifetime. Ovaries of these fish usually contain melanin pigments from the eyes of non-extruded larvae that were re-absorbed by the peritoneum. Therefore, the presence of melanin pigments is a means to distinguish first-year and older spawners within the spawning population. Stage 5 corresponds to the resting stage after spawning, but before the beginning of vitellogenesis. Following fertilization, the distinction between first-year and repeat spawners becomes more difficult because old pigments from non-extruded larvae of the previous spawning year can be confused with developing embryos of the current spawning year. Stages 8 and 9 describe two levels of embryogenesis. Stages 10 and 11 correspond to spawning, the latter representing the very recent termination of the spawning process.

After determining maturity, ovaries from each female were weighed to the nearest 0.01 g and placed in modified Gilson's fluid (Simpson 1951), after incising the peritoneum longitudinally to favor rapid penetration of the fluid into the ovaries.

Table 1. Sampling date, fishing gear, number of trawl sets and total number of female redfish caught and analysed for various parameters during each survey.

SURVEY	DATE	FISHING GEAR	No. of SETS	No. of FISH	No. of FISH ANALYSED			
					Morphometrics	Maturity	GSI	Fecundity
GA162	Jan 16-28, 1989	Engel bottom trawl	13	128	126	128	126	119
FATIMA	May 03, 1989	Otter midwater trawl	-	103	103	103	---	---
BASSIN	May, 1989	Otter midwater trawl	-	237	237	237	---	---
RALI2	June 06, 1989	Otter midwater trawl	-	246	246	246	---	---
LH200	June 21-25, 1989	Western bottom trawl	6	937	937	937	828	---
N125	Aug. 1-4, 1989	Western bottom trawl	9	705	705	705	545	1
LH203	Aug. 19-30, 1989	Western bottom trawl	7	114	113	114	113	1
GA177	Jan. 16-28, 1990	Engel bottom trawl	7	179	176	179	176	163
TOTAL				2649	2643	2649	1788	284

Table 2. Description of maturity stages of female redfish in the Gulf of St. Lawrence.

Maturity Stage	Characteristics of Ovaries
1 Immature stage	Gonads firm, small, less than 2 cc. No melanin pigmentation except sometimes on the oviduct and peritoneum. Colour varies from beige to pink but sometimes from yellow to orange.
2 Internal organization; first year maturity	Gonads inflated, orange to yellow. Eggs, when present, attached to inner membrane. Small oil drops present. Some melanin pigments on the peritoneum or on the oviduct but not inside the ovary.
3 Vitellogenesis; first year maturity	Gonads inflated and yellow. Some melanin pigments on the peritoneum and the oviduct, but not inside the ovary. Eggs clear and more or less loose in the ovary with no apparent division and presence of oil droplets.
4 Fertilization; first year maturity	Gonads as in stage 3, but with eggs at a more advanced state of development and loose in the ovary. Eggs are clear and cellular divisions are visible.
5 Internal re-organization; resting mature fish	Gonads orange or yellow inside the peritoneum which is usually purple, particularly on older specimens. Eggs and small oil drops may be visible. Melanin pigments and eyes of old larvae still present inside the ovary.
6 Vitellogenesis; mature fish	Gonads inflated and yellow. Eggs are clear and more or less loose in the ovary with no apparent division. Presence of small oil drops and old melanin pigments inside the ovary. Peritoneum purplish dark on older specimens.

Table 2. (continued).

Maturity Stage	Characteristics of Ovaries
7 Fertilization; mature fish	Gonads as in stage 6 but with more developed eggs and visible cellular divisions.
8 Embryogenesis	Gonads inflated and yellow. Eggs still formed and large, embryos with yellow eyes and vitellus vesicule.
9 Pre-extrusion; embryogenesis	Gonads inflated and greyish due to developing eye larvae. Eggs still visible.
10 Larval extrusion or spawning	Gonads more inflated, dark grey. Embryos well developed, running freely out of females.
11 Post-spawning; spent	Ovary flaccid, collapsed, dark purplish and streaked with blood. No eggs visible. Melanin pigments visible and old larvae may still be present inside the ovary.

Gonadosomatic index (GSI) was calculated as in Zastrow *et al.* (1991):

$$GSI = 100\ \frac{W_g}{W - W_g} \qquad (1)$$

where W is fish total weight (g), Wg is gonad weight (g) and GSI is expressed as a percentage (%). GSI was used to validate the qualitative maturity index and to quantitatively monitor gonadal development and reproductive cycle throughout the year. No GSI was measured for the commercial samples because the gonads were in bad condition due to poor preservation.

After 12 to 14 months in fluid, the ovaries were washed on a series of three sieves with mesh size of 1000 μm, 500 μm and 180 μm. Tap water was used to rinse and disaggregate eggs onto the 1000 μm sieve. The mesh size of the sieves was chosen to separate and collect developing eggs from non-developing oocytes. This was determined by measuring the diameter of eggs from ovaries at the vitellogenesis stages (3 or 6). Measurements were made with a BIOQUANT Image Analysis System with a camera mounted on an M8 Wild stereo-microscope. Egg size ranged between 566 and 1215 μm, with a mean value of 830.9 μm (s.d.= 147.4, n= 280). Ni and Templeman (1985) reported that the size of ripe eggs immediately prior to fertilization varied between 1.0 and 1.2 mm for redfish from southern Newfoundland waters. The size of immature oocytes varies between 200 and 300 μm (Ni and Sandeman 1984; Ni and Templeman 1985). We therefore established the minimum diameter of viable or developing eggs at around 500 μm. Consequently, fecundity estimates were based on the number of eggs retained on the 500 μm sieve and on the 1000 μm. A total of 284 ovaries were found suitable for fecundity determination.

Fecundity was estimated on females with ovaries in the vitellogenesis stage (surveys GA162 and GA177). Ovaries at later stages of development are unsuitable because, during embryogenesis, eggs become loose in the ovary and may be accidentally lost or extruded during fish capture and handling (Raitt and Hall 1967; Gunderson 1977). Furthermore, in late embryogenesis, the thin egg shell and the soft body tissue of developing larvae are rapidly digested when placed in Gilson's fluid and this artifact could therefore underestimate fecundity. A more appropriate and non-destructive method is required to extract fertilized eggs and developing larvae from gonads for analysis of redfish fecundity. Fish in the early stages of reproductive development (resting stage) are not recommended because oocytes are too small (<500μm), making it difficult to separate those that will eventually mature during the year. In such a case, fecundity could potentially be overestimated. Even with these precautions, true fecundity (i.e., number of fertilized and viable eggs and larvae) is difficult to assess for redfish because the fertilization rate is not known (Raitt and Hall, 1967). Eldridge *et al.* (1991), however, found no significant difference in fecundity between pre-fertilized and fertilized yellowtail rockfish (*Sebastes flavidus*) individuals.

Absolute fecundity, expressed as the total number of eggs per female, was estimated using the dry gravimetric method described in Bagenal and Braum (1971). This method is considered to be more accurate than the volumetric method often used in the past (Wolfert 1969). From the egg mass retained on the 500 μm sieve, a subsample was removed with a spatula and placed with water on a Kolmogorov tray for eggs counting under a M3Z Wild stereo-microscope using 6X-9X magnification. The number of eggs in a single subsample ranged from 307 to 1200, with an average of 542. Usually only one subsample was counted but up to three were occasionally counted. Both the subsample and the remaining part of the sample were then drained and dried under a fume hood at ambiant temperature and relative humidity. Subsample was weighed on a Model 27 Cahn electrobalance, while the weight of the remaining sample was measured on a Mettler PE 1600 balance. During weighing, ambiant humidity was frequently recorded. After a minimum drying time of 48 h, both samples and subsamples were weighed at 24-h intervals, until the weight sequence was stable taking into account variations in ambiant humidity.

The absolute fecundity (AF: total number of eggs/female) was estimated as:

$$AF = \frac{R + \sum S_i}{\dfrac{\sum S_i}{\sum E_i}} \qquad (2)$$

where S_i is the weight (g) of subsample i, R is the weight (g) of the remaining sample, E_i is the number of eggs counted in subsample i.

Method precision was evaluated by measuring 11 subsamples taken from a single gonad. The average total number of eggs in the ovary was 5527, with a standard deviation of 246, yielding a coefficient of variation (C.V.) of 4.45%. In addition, duplicate subsamples taken from 25 different ovaries were counted to check the reliability of the counting method. The mean C.V. for the 25 pairs of subsamples was 3.44% (s.e.= ±0.57%), with a maximum of 12.15% and a minimum of 0.15%. Our method for estimating redfish fecundity was therefore considered to be sufficiently precise and highly reproducible.

RESULTS

SPECIES COMPOSITION AND DISTRIBUTION

The frequency distribution of AFC and the percentage of AFC ≥8 for each trawl set were used to separate the two redfish species possibly present in our samples (Appendix A). As suggested by Rubec *et al.* (1991), stations where than 40% of fish had AFC ≥8 were identified as *fasciatus* sets, while stations with values of AFC ≥8 greater than 70% were identified as *mentella* sets. Species allocation based on a set-by-set analysis has been previously validated by electrophoretic analyses showing that redfish sets in the Gulf usually consist of only one genetically distinct group (Rubec *et al.* 1991; Sévigny and de Lafontaine 1992). The majority of sets (37 out of 48) were dominated by *mentella* type redfish, 9 sets were represented by *fasciatus* type. The values of two sets (for a total of 24 females) were between 40 and 70% indicating a possible mixture of the two species. According to these criteria, 2354 fish belonged to *S. mentella* while *S. fasciatus* were represented by only 253 specimens (9.7% of all the fish caught). Although the total number of redfish caught during winter was less than during the summertime catch, the percentage of *S. mentella* decreased only slightly (from 91% in summer to 84.5% in winter).

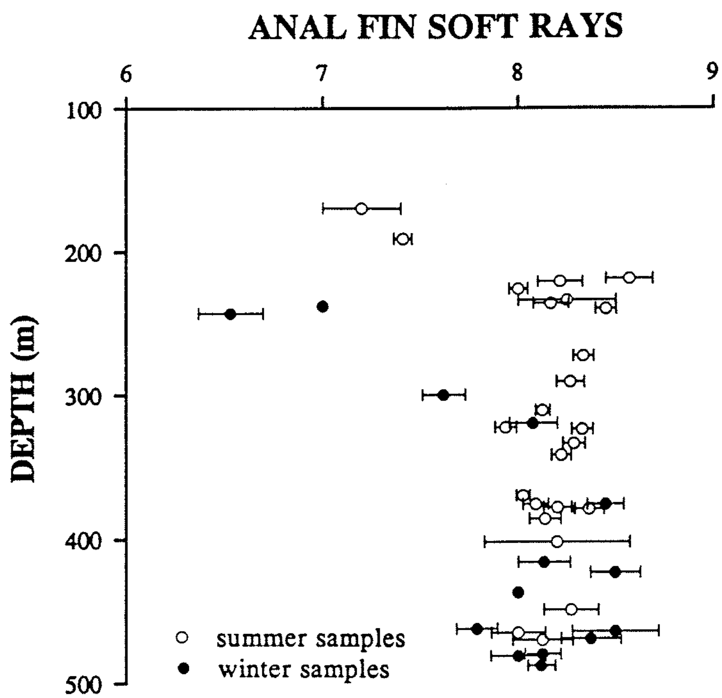

Figure 3. Mean number of anal fin soft rays (AFCs) for female redfish per trawl set, as a function of station depth in winter and summer.

A scatterplot of the mean AFC calculated for each station as a function of station depth reveals that *S. fasciatus* (mean AFC <8.0) are distributed in shallower waters than *S. mentella* (Fig. 3) and that their relative vertical distribution varies seasonally. During summer, *S. fasciatus* occurs mainly at depths <200 m but tends to be found at greater depths (down to 300 m) during winter. A similar pattern was reported by Rubec *et al.* (1991). However the decrease in redfish abundance and the lack of samples from shallow depths in the wintertime make difficult the demonstration that the relative increase of *S. fasciatus* in deeper strata results from active vertical displacement during winter and not from the absence of *S. mentella* due to horizontal seasonal migration patterns.

Weekly records of the location of redfish fishing vessels between April and June 1989 (Fig. 2) indicate a rapid northwestward displacement along the northern side of the Laurentian Channel from outside the Cabot Strait (week 1, April 10) to near the southeastern tip of Anticosti Island (weeks 5-6, May 8-15). In early June (week 8), fishing activity is essentially concentrated on the southern side of the Laurentian Channel (Fig. 2). Assuming that fishing operations are primarily dictated by fish concentrations and availability, fleet movement as depicted here probably reflects the spring migration of beaked redfish into the Gulf of St. Lawrence. This also corresponds to a spawning migration as females bearing larvae ready to be extruded were first reported in 1989 on May 13 (Observer Program, Department of Fisheries and Oceans, Québec).

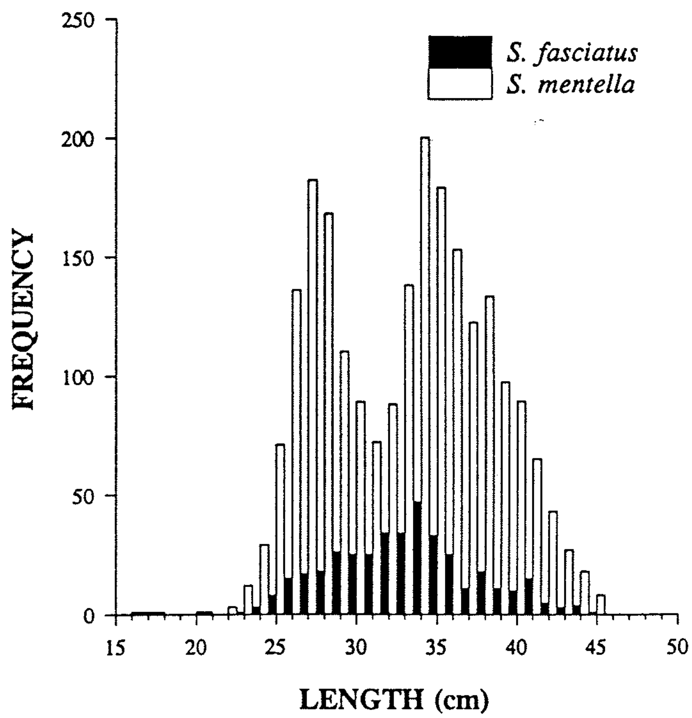

Figure 4. Size frequency distribution of female redfish in the Gulf of St. Lawrence. Open bars are for *S. mentella*; closed bars are for *S. fasciatus*.

WEIGHT-LENGTH RELATIONSHIP

The size frequency distribution of *mentella* type redfish shows two major modes at 27 and 34 cm (Fig. 4). These modes probably correspond to the two most recent strong cohorts (1979-80 and 1971-72 - Laberge 1988). Despite the small number of individuals, *S. fasciatus* also exhibits two size modes at 30 and 34 cm, respectively. The difference in the frequency distribution could be due to species-specific growth rate and/or variation in annual recruitment and the year-class strength of each species.

A simple linear regression of the log-transformed data for total wet weight (W in g) and fork length (L in cm) was used to derive the weight-length relationship for female Gulf redfish (Fig. 5). The equation parameters are very close to previous estimates of a= 0.0137 and b= 3.021 for female redfish in the Gulf of St. Lawrence (McKone *et al.* 1980). The homogeneity of samples between the various surveys was tested by comparing the slopes of weight-length relationships calculated for each survey (Table 3). No significant difference (co-variance F-test, $P= 0.657$) in slope estimates was found but intercepts differed significantly between surveys ($P< 0.0001$). This may be the result of various factors such as measurement and weighing techniques or equipment. The small number of *S. fasciatus* fish did not permit to determine the weight-length relationship for each species.

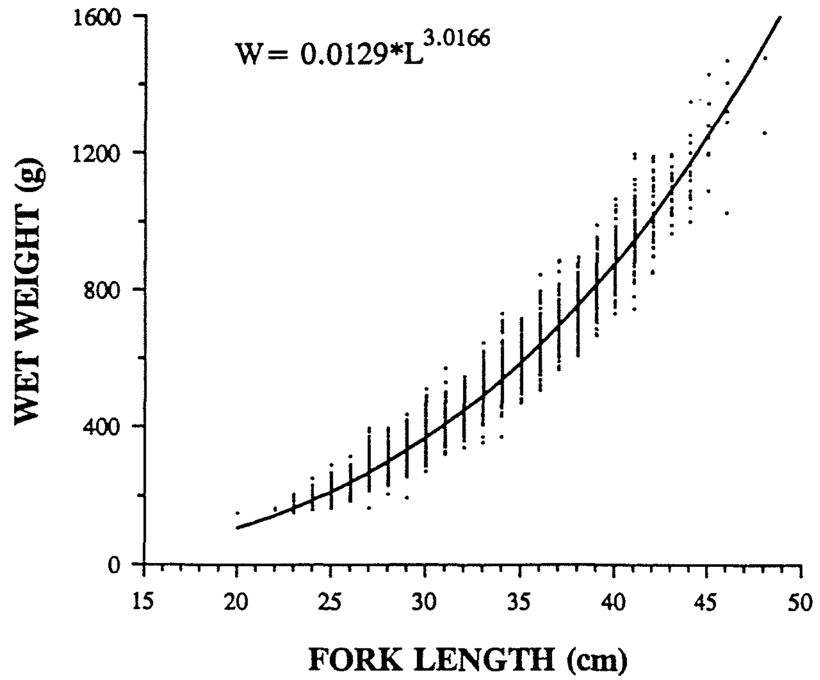

Figure 5. Relationship between total weight (g) and fork length (cm) for female redfish in the Gulf of St.Lawrence (r^2=0.96, n=2516).

Table 3. Mean, standard error and range of values of fork length (cm) and total weight (g) of female redfish by sampling survey in 1989-90. Intercept (log a), slope (b) and regression coefficient (r^2) of the weight-length logarithmic relationship are also given.

		FORK LENGTH (cm)		WEIGHT (g)		log W = a + b log L		
SURVEY	N	Mean ± s.e.	Range	Mean ± s.e.	Range	a	b	r^2
GA162	126	37.3 ± 0.4	30 - 47					
BASSIN	237	36.3 ± 0.2	26 - 44	661.0 ± 11.6	244 - 1350	-1.838	2.980	0.923
FATIMA	103	35.4 ± 0.4	26 - 48	633.6 ± 21.3	237 - 1260	-1.885	3.014	0.946
RALI-2	246	32.1 ± 0.3	23 - 44	475.4 ± 13.6	151 - 1070	-1.807	2.956	0.970
LH200	936	32.9 ± 0.2	22 - 46	522.2 ± 7.4	160 - 1430	-1.889	3.018	0.940
N125	705	31.1 ± 0.2	16 - 46	433.5 ± 8.2	45 - 1320	-1.826	2.967	0.957
LH203	113	36.8 ± 0.4	25 - 48	752.2 ± 24.6	210 - 1480	-1.777	2.958	0.958
GA177	176	32.2 ± 0.4	22 - 43	542.8 ± 21.1	160 - 1197	-1.925	3.062	0.976
TOTAL	2642	33.1 ± 0.1	16 - 48	522.2 ± 4.8	45 - 1480	-1.889	3.017	0.958

MATURITY CYCLE

In each survey, the majority (>70%) of female redfish usually belonged to two or three adjacent maturity stages and the distribution of fish among the 11 stages was always unimodal (Table 4). Such a pattern suggests synchronous gonadal development across the entire population. The small number of *S. fasciatus* precludes any comparative analysis of the maturity cycles of the two redfish species. The absence of fish at stage 4 may be partly related to the difficulty of distinguishing between stages 4 and 7, both representing the fertilization stage for first-year and old spawners, respectively. The variability in the proportion of immature fish (stage 1) between surveys probably results from the different sampling gear used (see Table 1).

Gonadal development over the year can be more clearly visualized by eliminating immature individuals (stage 1) and combining the 10 mature stages into 6 stages: resting (stages 2 and 5), vitellogenesis (stages 3 and 6), fertilization (stages 4 and 7), embryogenesis (stages 8 and 9), spawning (stage 10) and spent (stage 11). A histogram of the percentage of fish at each one of these stages, and for each survey, ordered chronogically, shows that redfish spawning (i.e. larval extrusion) is of relatively short duration and takes place mostly in May in the Gulf of St. Lawrence (Fig. 6). The percentage of females in spawning condition increases from 52% in early May (Fatima samples) to 75.5% in late May (Bassin samples) but declines rapidly to 7.35% (mature fish only) in early June (Rali-2 samples excluding stage 1 fish). During the same period, the percentage of spent females increases to reach a maximum in late June (41.5% of mature fish in LH200), and then decreases to less than 2% in late August (cruise LH203). Although no samples were collected in February, March or April, the low proportion of spent ovaries in early May (14%) suggests that only a small proportion of females spawn before May. Interestingly, spawning females collected at the end of August (11 specimens in LH203) came from a single set in relatively shallow (150 m) waters north of Anticosti island and were classified as *fasciatus* redfish.

Resting females, which are already numerically abundant in early June (61.8% of mature fish), dominate during the summer months and are still sighted in winter (mid-January). Therefore, the resting stage appears to have the longest duration in the maturity cycle of redfish. Although no samples are available for the September-December period, there is no evidence of major changes in gonadal development, as fish collected in mid-January (GA162 and GA177) belong to a mixture of resting and vitellogenesis stages. Fertilization and embryogenesis most certainly occur between January and April.

Gonadosomatic index (GSI) values increase with qualitative indices of gonadal development (Table 4). Mean GSI for immature fish (0.22%) is significantly lower (ANOVA, $P<0.001$) than that of spent and resting mature fish (1.2% and 0.8% respectively), and increases to 6.0% at the vitellogenesis and fertilization stages with maximum values reaching 10.9%. The lack of samples for embryogenesis and pre-spawning fish precludes estimation of the expected peak in GSI. The GSI value for spawning females (4.2%) is somewhat low, probably due to the loss of larvae from gravid females during trawling operations.

Table 4. Percentage of fish in each of 11 maturity stages per survey. Mean and standard errors of fish length and GSI values at each maturity stage are also given.

	MATURITY STAGES										
		First Year Maturity									
SURVEY	1	2	3	4	5	6	7	8	9	10	11
GA162	0	3.2	46.8	0	10.5	12.9	25.8	0	0	0	0.8
FATIMA	0	0	0	0	0	0	0	23.0	11.0	52.0	14.0
BASSIN	0	0	0	0	0	0	0	0	0	75.5	24.5
RALI2	30.6	42.6	0	0	0	0	0	1.3	0	5.1	20.4
LH200	19.7	13.7	0	0	31.7	0	0	0	0	1.6	33.3
N125	15.7	45.4	0	0	30.9	0	0	0	0	0	8.1
LH203	1.8	15.9	0	0	77.9	0	0	0	0	2.7	1.8
GA177	6.4	17.5	36.8	0	24.6	14.0	0	0.6	0	0	0
TOTAL	11.9	23.6	7.5	0	21.1	2.5	2.0	1.7	0.7	15.5	13.7
Mean LENGTH	26.7	30.5	30.0	-	37.4	37.0	37.7	34.6	34.0	36.6	35.5
(±s.e.)	(0.18)	(0.20)	(0.61)	-	(0.20)	(0.76)	(0.78)	(0.86)	(1.07)	(0.22)	(0.28)
Mean GSI %	0.216	0.804	4.851	-	1.561	6.194	5.840	-	-	4.309	1.177
(±s.e.)	(0.014)	(0.074)	(0.192)	-	(0.083)	(0.252)	(0.279)	-	-	(0.866)	(0.058)
Min	0.010	0.047	0.114	-	0.382	3.183	3.587	-	-	1.642	0.334
Max	1.523	7.369	10.872	-	8.480	10.872	10.150	-	-	7.663	3.053
N	191	380	121	0	339	40	32	27	11	249	220

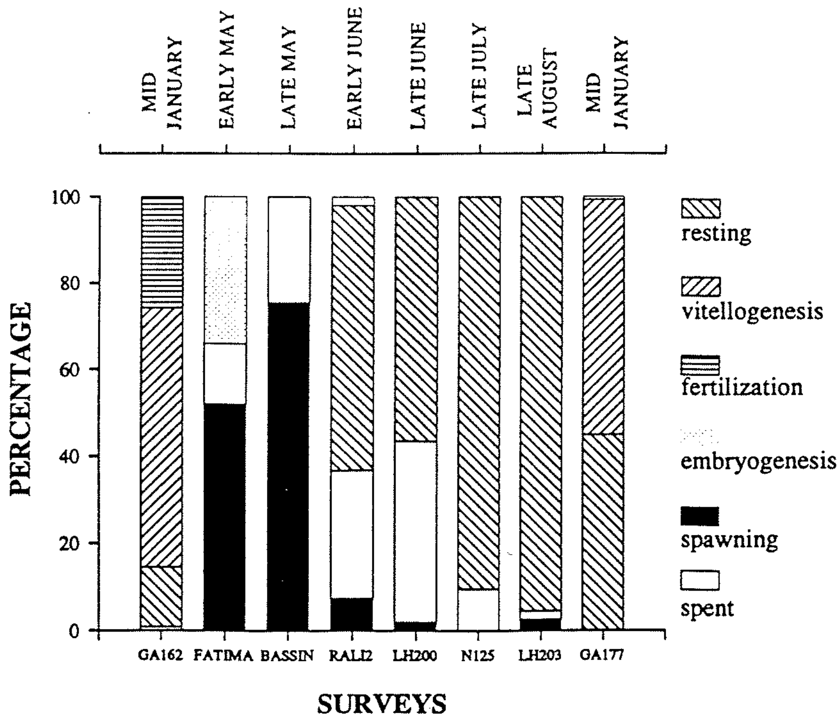

Figure 6. Percentage of fish in each maturity stage, per sampling survey ordered chronologically.

SIZE AT MATURITY

The mean length of immature females (stage 1) is significantly lower (ANOVA, $P<0.0001$) than that of newly maturing females (stages 2-3) or previous spawners (stages 5-11) (Table 4). The proportion of mature females (stage 2 and above) as a function of length (Fig. 7) was fitted to a sigmoid curve (Gunderson *et al.* 1980; Ni and Sandeman 1984) of the form:

$$P_L = \frac{1}{1 + e^{aL+b}} \qquad (3)$$

where P_L is the proportion of mature females at length L (in cm) and a and b are coefficients. Although slight differences in equation parameters (a and b values) influence the shape of the curve (Fig. 7), there is no significant difference between the two species in the size at which 50% of females are mature ($L_{0.5}$) (Table 5).

Table 5. Coefficient values (and standard errors) of the logistic equation fitted to determine the length at maturity of redfish in the Gulf of St. Lawrence and in other areas.

Species	Region	a (± s.e.)	b (± s.e.)	$L_{0.5}$ (cm)	Source
S. fasciatus	Gulf of St. Lawrence	-0.8261 (±0.0991)	21.10 (±2.540)	25.54	this study
S. mentella	Gulf of St. Lawrence	-0.5461 (±0.0360)	14.17 (±0.941)	25.95	this study
Mixed *fasciatus/mentella*	Gulf of St. Lawrence	-0.5621 (±0.0349)	14.57 (±0.910)	25.92	this study
Beaked redfish	Gulf of St. Lawrence	-	-	27.20	Ni and Sandeman 1984
Beaked redfish	Southern Newfoundland	-	-	29.60	Ni and Sandeman 1984
S. fasciatus	Gulf of Maine	-0.5950 (±0.0440)	13.24 (±1.017)	22.26	Mayo *et al.* 1990
S. marinus	Southern Newfoundland	-	-	40.30	Ni and Templeman 1985
S. marinus	Iceland and Faroe Islands	-	-	43.00	Raitt and Hall 1967

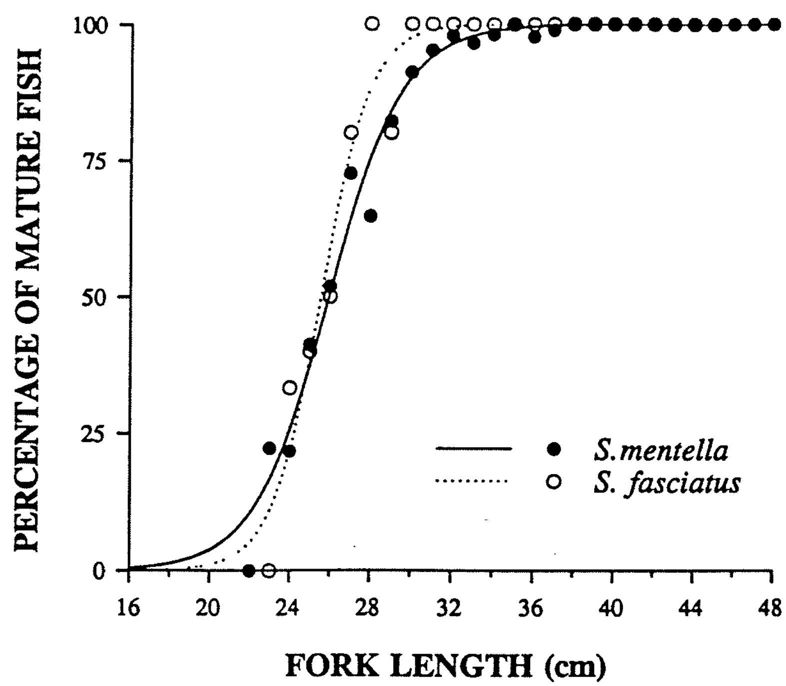

Figure 7. Size at maturity of two Gulf of St. Lawrence redfish species.

FECUNDITY

Absolute fecundity ranged from 1500 to 70000 oocytes per female and increased with fish size. The relationship between fecundity and fish size was estimated for each species using linear regression following logarithmic transformation of the variables. For *S. mentella*, absolute fecundity was significantly ($P<0.001$) related to fish length (Fig. 8; $r^2=0.65$) and fish weight ($r^2=0.67$) (Table 6). The slope coefficients of the log-log relationship were 4.165 and 1.423 for length and weight, respectively, and were both significantly ($P<0.001$) greater than 1.0. This indicates that redfish fecundity varies as a power function of length and weight. No significant relationship was found for *S. fasciatus*, probably due to the narrow size range and the small number of fish available. This precluded the inter-specific comparison of the relationship between fecundity and size, as it was originally planned. To circumvent this problem, we calculated residuals of *S. fasciatus* from the equation obtained for *S. mentella*. If fecundity does not vary between these two species, positive and negative residuals should then be equally distributed and the mean value of residuals should not differ significantly from 0. The results revealed that the number of positive and negative residuals were respectively 41 and 9 (Fig. 9), and that the mean value of residuals was significantly greater than 0 (mean=0.316, s.e.=0.037, n=50, T-test=8.58, $P<0.001$). This suggests that, within comparable size range, *S. fasciatus* redfish would be relatively more fecund than *S. mentella*.

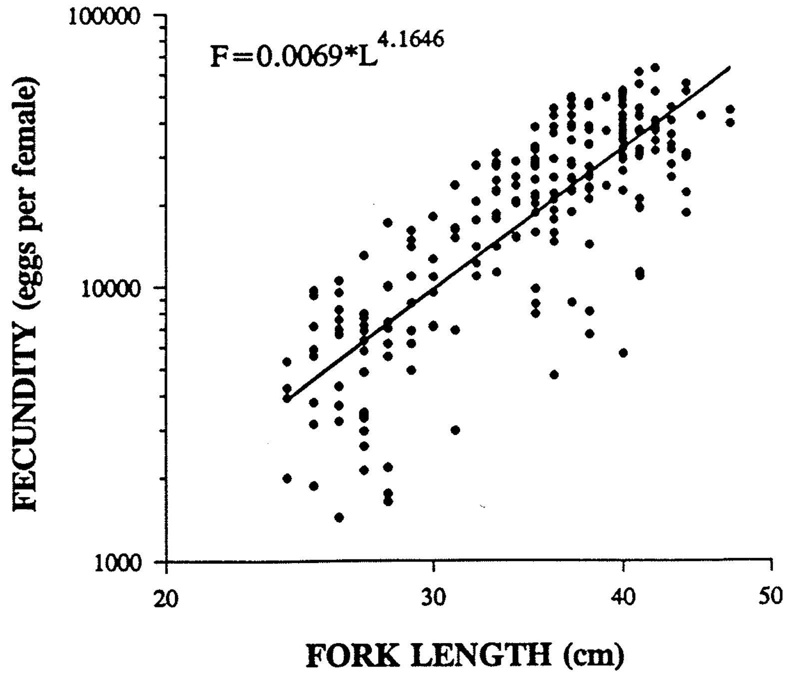

Figure 8. Logarithmic relationship between number of eggs and length for "mentella" type redfish (*S. mentella*) in the Gulf of St. Lawrence.

DISCUSSION

To our knowledge, the results of this study provide the first evidence that two species of redfish, *Sebastes mentella* and *S. fasciatus*, spawn in the Gulf of St. Lawrence. Although the evidence of redfish spawning in the Gulf had been inferred by the presence of gravid adults (Steele 1957; Ni and Sandeman 1984) and larval stages (Dannevig 1919; Jean 1955; Able 1978; de Lafontaine *et al.* 1981,1984,1991), our finding that all sexually mature females of each species were in spawning or post-spawning (spent) condition during May and June confirms that spawning stock of beaked redfish in the Gulf is multi-specific. Overall, the relative proportion of *S. fasciatus* and *S. mentella* in the 1989 spawning population was 10% and 90% respectively. These results are consistent with the general interpretation that redfish populations in the Gulf of St. Lawrence are dominated numerically by *S. mentella* (Sandeman 1969; Ni 1984; Ni and Sandeman 1984). This has probably been the prevailing situation for the last 40 years because specimens collected in the early 1950s by Steele (1957) in the western part of the Laurentian Channel had a mean AFC of 8.6, which corresponds to *mentella* type redfish. Recent genetic analysis has shown that redfish taken by the commercial fishery in the Gulf in 1991 were primarily composed of *S. mentella* (de Lafontaine and Sévigny, unpubl. data).

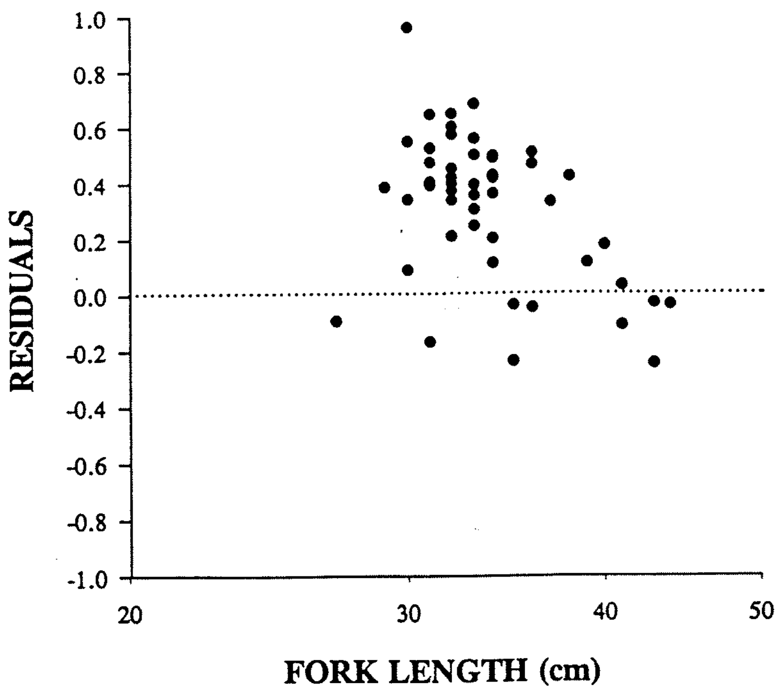

Figure 9. Residual values of fecundity estimates as a function of length for "fasciatus" type redfish (*S. fasciatus*) in the Gulf of St. Lawrence.

Our results do not support the conclusions of Barsukov *et al.* (1991) that only *Sebastes fasciatus* spawn along the North American coast (including the Gulf of St. Lawrence) whereas *S. mentella* spawning is restricted to the Irminger Sea and Flemish Cap. The analyses carried out by Barsukov *et al.* (1991) were based on maturity indices of redfish from the Grand Banks and southern Newfoundland but not from the Gulf of St. Lawrence. These authors also reported that most (94-100%) *S. mentella* females caught between April and June in southwest Grand Bank (NAFO division 3O) ranged from 24 to 47 cm with a modal size of 40 cm and were sexually immature. According to our results on size at maturity and those of Ni and Sandeman (1984) for both the Gulf and NAFO division 3O (Table 5), the *mentella* specimens captured by Barsukov *et al.* (1991) should be sexually mature. The difference between the two studies may be due to either different maturity staging or mis-identification of species. If the maturity staging systems were different, resting or recovering females may have been misreported as immature females by Barsukov *et al.* (1991). Consequently, this would imply that spawning had already terminated at the time of sampling (April 16 - May 22, 1986 for division 3O, see Barsukov *et al.* 1991). However, this is not supported by the evidence that beaked redfish normally spawn between May and July along the North American coast, from Newfoundland to the Gulf of Maine (Dannevig 1919; Kenchington 1984; Mayo *et al.* 1990; Fig. 6 in this study). On the other hand, if the difference is due to identification problems, it is possible that the large and immature *S.*

Table 6. Relationship between absolute fecundity (F) and fish size for Gulf of St. Lawrence redfish (*S. mentella*) and other redfish species. Fecundity estimates standardized for a 35 cm-long fish are calculated for comparison purposes.

Species	Location	Year	n	Relationship	r^2	Fecundity at 35 cm	Source
Sebastes mentella	Gulf of St. Lawrence	1989-1990	218	$F = 6.866x10^{-3} * L^{4.1646}$	0.65	18656	this study
			218	$F = 1.9842 * W^{1.4229}$	0.67		
Sebastes marinus	Faroe Islands	1964	21	$F = 0.458 * L^{3.2365}$	0.52	45564	Raitt and Hall 1967
		1965	24	$F = 0.041 * L^{3.8556}$	0.66	36551	"
	Iceland	1964	26	$F = 3.252x10^{-5} * L^{5.7121}$	0.72	21476	Raitt and Hall 1967
		1965	38	$F = 0.293 * L^{3.3108}$	0.45	37968	"
		1966	20	$F = 6.888x10^{-4} * L^{4.8576}$	0.75	21805	"
	East Greenland		19	$F = 0.0672 * L^{3.5118}$		17760	Corlett 1964
Sebastes alutus	Washington-Oregon	1967-1972		$F = 1.930x10^{-7} * L^{7.3251}$		39000	Gunderson 1977
	Queen Charlotte	1967-1972		$F = 1.224x10^{-4} * L^{5.5126}$		40000	"
	Vancouver Is.	1967-1968		$F = 1.130x10^{-3} * L^{4.9884}$		66000	"
Sebastes flavidus	California	1985-1988	121	$F = -1659282 + 59743.7*L$	0.74	431749	Eldridge *et al.* 1991

mentella redfish from samples taken by Barsukov *et al.* (1991) in division 3O were indeed golden redfish (*S. marinus*) specimens. Golden redfish in southwest Grand Bank (div. 3O) mature at a larger size ($L_{0.5}$=39 cm, Ni and Sandeman 1985) and spawn earlier than beaked redfish (Ni and Templeman 1985). In summary, the discrepancy between our results and those of Barsukov *et al.* (1991) may be due to the latter's difficulties in separating beaked redfish from golden redfish, in addition to possible differences in the maturity staging index.

The strong dominance (>90%) of *S. mentella* in the spawning population contrasts with the equally strong dominance (>95%) of *S. fasciatus* juveniles observed in recent years (1989-1990) in the Gulf (Sévigny and de Lafontaine 1992). The different proportion of juveniles and adult redfish may be related to differential survival and recruitment variability during the early stages of each species. This assumes that each redfish species is characterized by distinct population dynamics driven by different recruitment processes in the larval phase and by temporally and/or spatially distinct larval distribution. A second but not exclusive explanation would be that only *S. fasciatus* juveniles remain in the Gulf while *S. mentella* recruits outside the Gulf, returning as mature individuals to spawn and feed. The small abundance of redfish in the Gulf during winter and the seasonal movement of the fishing fleet from Cabot Strait towards Anticosti island in the spring (Fig. 2) support the hypothesis that beaked redfish (at least *S. mentella*) annually migrate outside the Gulf limits via the Laurentian Channel. Extensive spawning migration of redfish from offshore areas to more coastal zones has previously been reported for European populations (Sorokin 1961) and for *marinus* type redfish off Iceland (Herra *et al.* 1987). Further studies are required on larval drift and juvenile distribution inside and outside the Gulf to verify these hypotheses.

The spawning period of beaked redfish in the Gulf is rather short, peaking in May and probably extending from late April to early June. Due to the low proportion of *S. fasciatus* in spring samples, no clear delineation of peak spawning activity for the two redfish species was possible. However, the similarity in their maturity indices during summer and winter and the very strong unimodal distribution of fish among maturity stages during all sampling cruises suggest that these two species spawn less than 1 month apart. Sightings of spawning *S. fasciatus* in late August suggest that this species may spawn later than *S. mentella* in the Gulf. The short spawning activity (restricted to the month of May) for Gulf redfish is within the range of that observed (March-July) for adjacent populations outside the Gulf (Ni and Templeman 1985).

The maturity cycle of Gulf beaked redfish is characterized by long resting and vitellogenesis stages and very low GSI values during most of the year. This is typical of other *Sebastes* species and Pacific rockfish species (Sorokin 1958; Ni and Templeman 1985; Takemura *et al.* 1987; Eldridge *et al.* 1991; Nagahama *et al.* 1991; Takano *et al.* 1991; Yamada and Kusakari 1991). The resting (gonad recovery-reorganization) stage lasts about 7 months in *Sebastiscus marmoratus* (Takano *et al.* 1991) and up to 9 months in *Sebastes flavidus* (Eldridge *et al.* 1991), while spawning (or parturition) is very short for both species.

Female redfish can store sperm for some time between copulation and fertilization (Magnusson 1955; Gunderson 1977). The fact that fertilization and embryogenesis occur in winter implies that copulation activity for the Gulf of St. Lawrence beaked redfish precedes spawning by a long time and probably takes place some time in autumn and early winter. Such reproductive behaviour has previously been reported in other viviparous rockfish species (Magnusson 1955; Takano *et al.* 1991; Eldridge *et al.* 1991). Spawning time is usually a distinct, species-specific characteristic, and it has been inferred that this acts as an effective reproductive barrier to isolate and maintain different fish populations (Sinclair 1988). In fisheries management, spawning time is considered critical to protect the resource and management strategy is often oriented toward ensuring sufficient production of offsprings. In the case of ovoviviparous redfish, copulation time may also be an important reproductive barrier contributing to the existence of these sympatric species in the Gulf. Therefore, management strategies should consider both copulation time and spawning time as equally important to redfish reproduction and long-term population persistence. However, more detailed information on redfish copulation processes and a better definition of the maturity cycle (including the male redfish), based upon a higher sampling frequency, are necessary to evaluate completely the hypothesis that the two species of beaked redfish in the Gulf have different reproductive cycle and spawning times, based on maturity indices.

There were no significant differences in length at maturity for both species of beaked redfish in the Gulf. Pooled data from the two species yield a value of $L_{0.5}$ of 26 cm (Table 5), which is very close to that calculated (27.2 cm) from samples collected some 30 years ago (1957-1969; Ni and Sandeman 1984). Ni and Sandeman (1984) previously documented that the size at maturity of Northwest Atlantic redfish decreases from north to south and attributed this latitudinal cline to both species composition changes and geographic distribution. Our results showed that, within a restricted geographical area, both beaked redfish species have similar size at maturity. We therefore suggest that geographic distribution and latitudinal variation in environmental conditions are more important than species composition in causing variations in size at maturity of beaked redfish along the northwest Atlantic. This hypothesis may be verified by looking at the difference in size at maturity for beaked redfish from other areas.

Overall, GSI values from our samples are generally lower (1-2%) than those reported by Ni and Templeman (1985) for beaked redfish at comparable stages in southern Newfoundland waters. Presumably, this is due to differences in the GSI computation methods of both studies. Ni and Templeman (1985) used gutted and gilled weight of fish as opposed to total weight (our study), and they estimated gonad weights from gonad volumes by using a factor of 1.1. Sorokin (1961) reported that mean GSI for female golden redfish (*Sebastes marinus*) increased from 1.2% during the resting stage to 7.0% (with values up to 12%) at fertilization, and reached a peak of 11.3% during late embryogenesis. These data therefore indicate no major difference in GSI at a given stage between various redfish species in north Atlantic waters.

Contrary to other reproductive aspects, fecundity did vary significantly between these species. Differences are small however, and the large degree of variation in fecundity estimates, coupled with the high cost and lengthy procedures of the technique preclude the use of this criteria to distinguish between the two species. Fecundity is a plastic parameter and environmental factors may induce variation between populations of a single species.

Standardized fecundity estimates indicate that *S. mentella* from the Gulf of St. Lawrence have lower potential fecundity than Atlantic golden redfish (*S. marinus*) or other Pacific rockfish. This indicates also that ovoviviparous beaked redfish and other rockfish species have lower fecundity than egg-laying teleosts (Wourms 1991).

The slope of the logarithmic relationship between fecundity and length of beaked redfish is greater than the value of 3 currently reported for most teleosts (Simpson 1951; May 1967). This appears to be a general characteristic of the Scorpaenidae, as indicated by the calculated relationships between fecundity and length for other species of redfish or rockfish (genus *Sebastes*) which have slope values around or greater than 4.0 (Table 6; and see also Haldorson and Love 1991). As a corollary, fecundity is exponentially related to fish weight. Consequently, this implies that, at equal spawning stock biomass, the total number of offsprings produced annually increases with the proportion of larger fish comprising that stock. Such a relationship should be considered in a population dynamics model, which usually assumes a direct and linear relationship between stock size and the number of eggs produced (Beverton 1962; Koslow 1992), based on the observation that individual fecundity is closely proportional to body weight. Attempts to estimate redfish spawning stock biomass based on larval abundance may also be problematic without adequate information on the size distribution of spawners.

Although our scale of observation was relatively large, the fact that both redfish species spawn at approximately the same time and location in the Gulf of St. Lawrence tends to suggest that the maturity cycle and the spawning characterics are probably not important or that effective reproductive barriers exist to maintain the integrity of these two sympatric species. In the case of redfish, the genetic integrity of each species is determined more by the copulation period in autumn than by the "spawning" (larval extrusion) time in spring. If, at the time of copulation, both species are aggregating in distinct geographic areas or depth strata, genetic integrity could be achieved. This point strongly reinforces the necessity of acquiring more detailed information on redfish distribution in relation to the various stages of the maturity cycle.

It is possible, however, that isolating processes may also be acting at a much more subtle temporal and spatial scale during and after spawning. On going research on species composition and distribution of larval redfish in the Gulf (P. Gagné et coll., Université Laval, Québec, in prep.) indicates that the spatial distribution of larval stages differs between redfish species. This probably results from different spawning locations and subsequent drift patterns, where *S. fasciatus* is preferentially associated with shelf edges along the Laurentian and Esquiman channels, and *S. mentella* occupies the more central locations along these channels.

In conclusion, our results show that the two species of beaked redfish in the Gulf of St. Lawrence have very similar reproductive characteristics and that these characteristics are not very useful criteria for species discrimination and identification. In many cases, the measured values are very close and probably not significantly different from those reported for redfish captured in areas outside the Gulf. Although both species were shown to spawn in the Gulf of St. Lawrence, the extent to which these spawning populations are distinct from those found in adjacent waters remains to be verified.

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Appendix A. Number of fish (N) within each class of anal fin ray counts (AFC) and percentage of fish with AFC ≥8 for each trawl, per survey. Sampling station depth (Z) is also indicated.

			AFC					
CRUISE/ SET	Z (m)	N	6	7	8	9	10	% ≥8
GA162								
23	462	33	-	10	20	3	-	69.7
34	481	18	-	3	12	3	-	83.4
35	437	7	-	-	7	-	-	100.0
36	464	6	-	-	3	3	-	100.0
37	423	16	-	-	8	8	-	100.0
39	383	2	-	2	-	-	-	0.0
43	241	1	1	-	-	-	-	0.0
62	238	22	-	22	-	-	-	0.0
63	243	15	8	6	1	-	-	6.67
119	291	1	-	1	-	-	-	0.0
120	412	1	-	1	-	-	-	0.0
121	431	1	1	-	-	-	-	0.0
123	409	3	1	-	2	-	-	66.7
GA177								
17	300	21	-	8	13	-	-	61.9
21	320	26	-	4	16	6	-	84.6
23	376	40	-	2	18	20	-	95.0
24	480	24	-	1	19	4	-	95.9
25	469	16	-	1	8	7	-	93.8
111	488	34	-	1	28	5	-	97.1
112	416	15	-	1	11	3	-	93.3
RALI II								
1	-	244	-	20	180	44	-	91.8
FATIMA								
1	-	103	-	7	74	22	-	93.2
BASSIN								
1	-	233	-	22	155	55	1	90.5

Appendix A. (continued).

CRUISE/ SET	Z (m)	AFC N	6	7	8	9	10	%≥8
LH200								
1	323	157	2	35	92	27	1	76.4
2	379	71	-	5	36	29	1	92.9
3	236	18	-	-	15	3	-	100.0
4	191	200	1	132	51	16	-	33.5
5	311	200	-	17	141	42	-	91.5
6	370	200	-	21	153	26	-	89.5
7	376	90	1	9	61	17	1	88.7
LH203								
10	402	5	-	1	2	2	-	80.0
23	465	15	-	2	11	2	-	86.6
26	470	16	-	2	1	4	-	87.5
28	449	11	-	-	8	3	-	100.0
64	162	1	-	-	1	-	-	100.0
92	170	10	1	6	3	-	-	30.0
110	221	14	-	-	11	3	-	100.0
122	234	8	-	1	4	3	-	87.5
137	386	29	-	1	23	5	-	96.5
N125								
1	378	64	-	5	41	18	-	92.2
2	219	28	-	1	11	15	1	96.5
3	324	91	-	2	57	32	-	97.8
4	226	84	-	8	68	8	-	90.5
5	240	100	-	2	51	47	-	98.0
6	273	99	-	2	62	35	-	98.0
7	342	95	-	3	68	24	-	96.9
8	334	84	-	3	54	27	-	96.4
9	291	60	-	3	38	19	-	95.0