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Stock Status Report 2004/001

Capelin of the Estuary and Gulf of St. Lawrence (4RST) in 2003

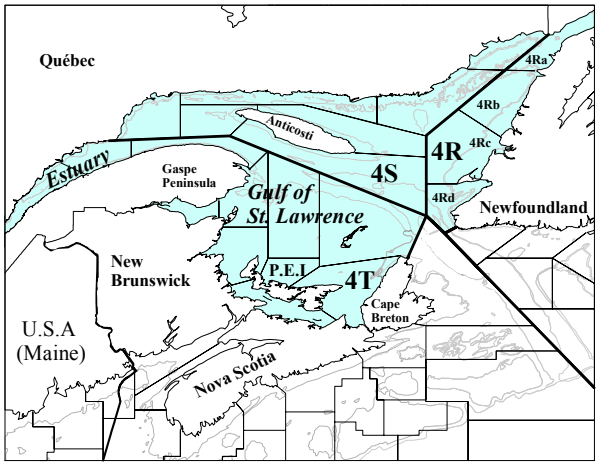

Figure 1. Map of NAFO Divisions 4RST and unit areas associated with the capelin fishery on the west coast of Newfoundland.

Background

Capelin (Mallotus villosus) is a small, marine fish species with a circumpolar distribution. In the North Atlantic, capelin occur around Russia (Barents Sea), north of Norway, in Iceland, and in Greenland. In the Pacific, the species resides along the coasts of Alaska and British Columbia, and in Asia, along the coasts of Japan, Korea, and Russia. Finally, in eastern North America, capelin occur along the coasts of Labrador and Newfoundland, on the Grand Banks and in the Estuary and Gulf of St. Lawrence. Capelin were abundant in the Bay of Fundy in the 1960s and have occurred on the eastern part of the Scotian Shelf since the mid-1980s. The presence of capelin in this area coincides with below-normal water temperatures between depths of 30 m and 100 m (cold intermediate layer). The colder water temperatures of this layer in the Gulf of St. Lawrence may have affected the species' distribution, as well as gonad growth rate and maturation, which have in turn affected spawning periods and fishing season dates. As a result of the reduction in individual fish size observed in the early 1990s, the fishing season was cut short in 1994, and the fishery was closed almost completely in 1995. However, growth in size has been noted in recent years.

Capelin plays a key role in the food chain by transferring energy from primary and secondary producers to higher trophic levels. It is an important prey for other fish species such as cod (Gadus morhua) and redfish (Sebastes sp.), as well as for certain seabirds and marine mammals. Estimates show that its main predators consume several hundred thousand tonnes of capelin annually in the Gulf of St. Lawrence. In light of those estimates, it seems clear that the commercial fishery removes only a small portion of the total biomass.

The capelin fishery in the Estuary and Gulf of St. Lawrence developed rapidly with the emergence of a Japanese market for roe-bearing females in the late 1970s. Annual landings have risen to nearly 10,000 t from a level of less than 700 t at that time. The bulk of catches are made by purse senners on the west coast of Newfoundland. In addition to recreational fishery landings made during beach spawning, capelin is a by-catch of shrimp (Pandalus borealis) harvesting. Although the structure of the species' population is relatively unknown, capelin are managed via two separate management units, i.e. the Northwest Atlantic Fisheries Organization (NAFO) divisions 4ST and 4R (Figure 1). No abundance survey is currently conducted specifically for capelin in the Estuary and Gulf of St. Lawrence. However, two indices of dispersion are derived from by-catches made in annual groundfish and shrimp surveys conducted in August and September in the northern and southern Gulf of St. Lawrence.

Summary

- Capelin is one of the most important **forage** fish species found in the Estuary and Gulf of St. Lawrence. Estimates show that its primary predators consume hundreds of thousands of tonnes of capelin annually.
- Capelin **size** has increased since 1999. In 2003, average lengths for males and females were 164 mm and 150 mm respectively. These values are nevertheless inferior to those recorded during the 1980s.
- The geographical distribution of the species in the Estuary and Gulf of St. Lawrence is now assessed using two **dispersion indices,** which have been rising since 1990. Capelin is also increasingly found in the southern Gulf of St. Lawrence.
- **Post-spawning** and **predation** mortality are generally very high among capelin. Current landing levels have little impact on the fluctuations in the abundance of the species. However, the impact that recent changes in the species' distribution, migration, and spawning have had on the production and abundance remains unknown.
- In 2003, preliminary **landing** data for capelin of NAFO divisions 4RST totalled 4,640 t, which represents an increase of 1,345 t compared to 2002. Most of these landings were made by purse senners in unit areas 4Rb and 4Rc on the west coast of Newfoundland.
- Since the late 1980s, the capelin spawning and fishing seasons have started at increasingly **later** dates. However, since 1996, the spawning and fishing periods have moved closer to historical seasonal patterns. The 2003 fishing season was premature compared to those of 2001 and 2002, and heavy spawning was monitored in certain areas.
- Although commercial fishery only harvest a small proportion of the total biomass, any TAC **increases** should be made **progressively** due to capelin's prominent role in the marine ecosystem, and the lack of knowledge regarding the species' biology.

Biology

Capelin (*Mallotus villosus*) spawn at around three years of age and live for five or six years. During the spawning period, males can be distinguished from females by their larger fins and the presence of two pairs of spawning ridges (elongated scales), one dorsally and the other ventrally. Spawning, which is preceded by a mass shoreward migration, occurs on beaches or in deeper waters. During beach spawning, the capelin literally *"roll"* on the sand or fine gravel, whereas the second type of spawning takes places in deeper waters. On the west coast of Newfoundland, as elsewhere in the Gulf of St. Lawrence, spawning may sometimes occur in specific areas or be sporadic due to

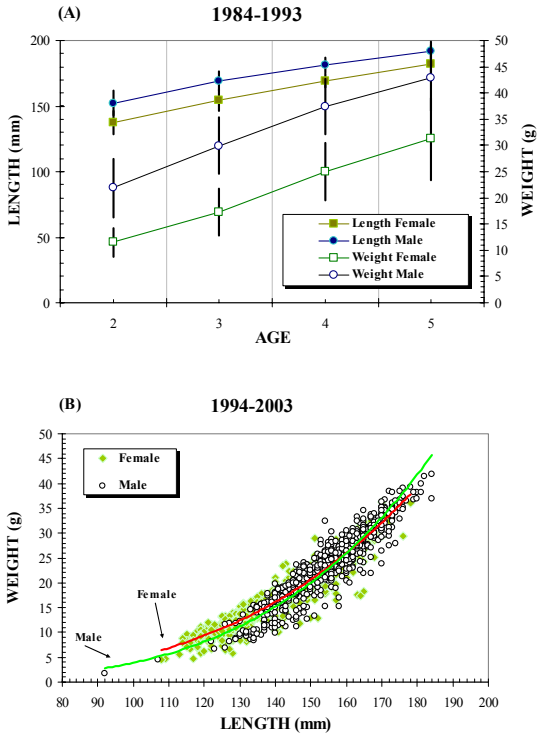

Figure 2. Mean length (mm) and weight (g) at age (A) (the vertical bars represent standard deviations) and weight-length relationships (B) for capelin in NAFO Division 4R.

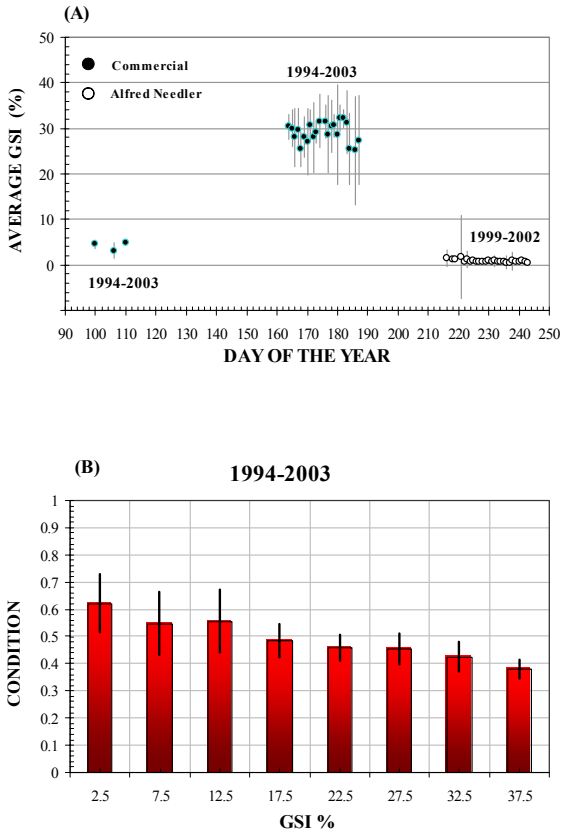

Figure 3. Relation between the mean gonadosomatic index (GSI) (the vertical bars represent standard deviations) and the day of the year (A) and condition (Fulton index) (B) for capelin (females only) of NAFO Division 4R. The condition show a downward trend with an increase of GSI values.

annual fluctuations in water temperature. The beach spawning period usually lasts from four to six weeks, beginning in the Estuary of St. Lawrence in mid-April, and then moving eastward to Quebec's Lower North Shore and Newfoundland's west coast in July. Males and females gather in separate schools at spawning grounds. Males migrate to the beaches first and wait the arrival of females, which complete their maturation offshore. A large proportion of these capelin die after spawning, particularly the males, which injure themselves while repeatedly mating on the beach. However, survivors will be able to continue spawning in future years. The amount of eggs per gram of female varies from 8,300 to 30,000 eggs. Once laid, capelin eggs adhere to the gravel substrate. The incubation period and the amount of time the larvae spend on the gravely bottom depend on water temperature and turbulence in the surrounding environment. The larvae soon become pelagic, remaining near the water surface until the arrival of winter.

Capelin do most of their growing during their first few years of life. By the age of two, males are both longer and heavier than females (Figure 2A). Males and females have similar weight-length relationships (Figure 2B), but for the lengths below 140 mm, females weigh slightly more than males. The female gonadosomatic index (GSI), which measure the ratio of ovarian

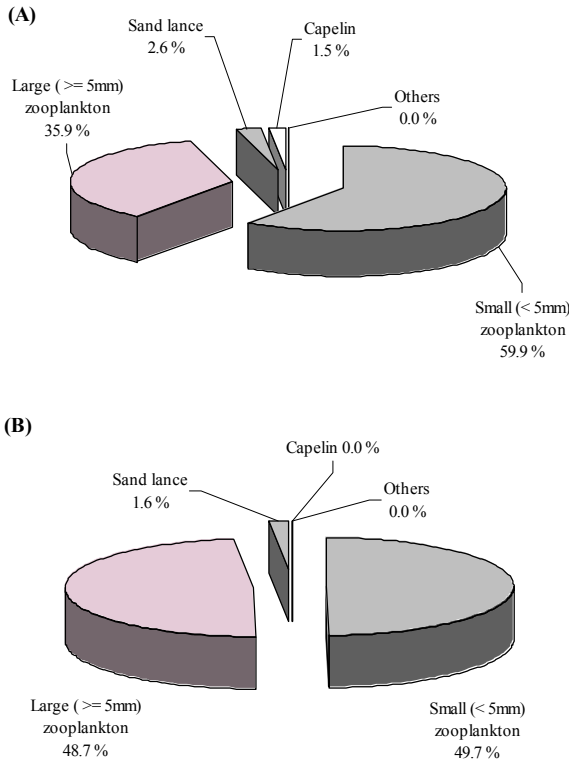

Figure 4. Diet composition (%) of capelin in the northern Gulf of St. Lawrence in the mid-1980s (A) and 1990s (B) (C. Savenkoff and M. Castonguay, DFO, MLI, pers. comm.).

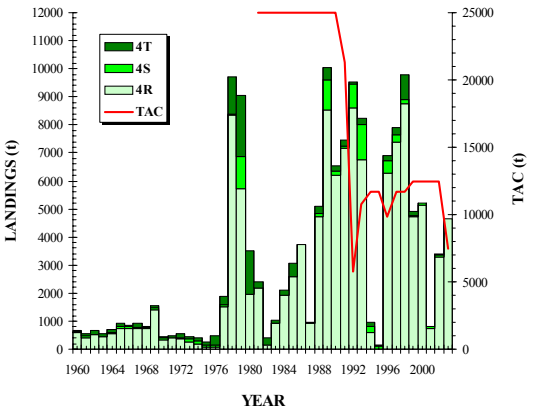

Figure 5. Capelin landings and TAC (t) for NAFO Divisions 4RST (Estuary and Gulf of St. Lawrence) between 1960 and 2003.

weight compared to the total body weight, can reach an average of 30% during spawning (Figure 3A). The GSI values are lower than 5% before and after spawning, and with an increase of this parameter, a decrease in condition (Fulton index) is observed (Figure 3B).

Little information is available on capelin's diet. Mid-1980s estimates show that capelin feed mainly on small (< 5 mm) and large (≥ 5 mm) zooplankton (Figure 4A). New estimates collected in the mid-1990s indicate that small and large zooplankton remain capelin's main feed source (Figure 4B). However, the proportion of fish in its diet is still low (< 4%). Capelin feeding patterns vary with the seasons. Thus, feeding stops completely during spawning, then gradually resumes.

Description of the fishery

Internationally, the largest capelin catches are usually made off Iceland and east of Greenland, with landings regularly exceeding more than 1 million tonnes. Very large capelin landings also occur in the Barents Sea. However, the precarious state of this stock required the fishery to be completely closed between 1987 and 1990, and again between 1994 and 1998. The main international capelin markets are tied to these European fisheries, which are in direct competition with Eastern Canadian fisheries.

Traditionally, capelin has not been a popular species with Canadian fishermen. It has been used to produce farm fertilizer, food, bait for cod, and more recently, fishmeal. The emergence of a Japanese market for roe-bearing females is responsible for the sharp increase in landings, up from 700 t/year between 1960 and 1976 to approximately 10,000 t in 1978, 1979, 1989, 1992, and 1998 (Figure 5).

In the Estuary and the Gulf of St. Lawrence, the capelin fishing season is short and

Table 1. Estuary and Gulf of St. Lawrence: Capelin landings (t) by NAFO Division and by gear from 1990 to 2003.

DIVISION AND GEAR	YEAR														AVERAGE
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003*	(1990-2002)
4R	6 205	7 166	8 605	6 739	592	15	6 265	7 399	8 764	4 735	5 129	741	3 295	4640	5 050
TAC 4R	*18 000*	*4 025*	*9 025*	*10 000*	*10 000*	*8 400*	*10 000*	*10 000*	*10 700*	*10 700*	*10 700*	*10 700*	*10 700*	*6 420*	
4S	164	59	856	1 263	208	90	461	252	141	10	69	66	77	0	286
4T	153	247	56	236	166	47	172	238	893	166	18	5	20	0	186
TAC 4ST	*5 000*	*3 300*	*1 725*	*1 725*	*1 725*	*1 725*	*1 450*	*1 725*	*1 725*	*1 725*	*1 725*	*1 725*	*1 725*	*1 035*	
Beach senne	458	149	12	0	13	15	0	0	0	0	0	0	0	0	50
Purse senne	4 215	7 014	7 517	6 827	649	0	5 479	6 511	7 232	4 791	5 129	741	3 295	4 640	4 569
Trap	1 720	181	1 921	1 283	210	103	1 306	1 203	2 509	11	1	0	7	0	804
Weir	129	127	56	128	94	34	113	175	57	0	0	0	0	0	70
Trawl	0	1	0	0	0	0	0	0	0	110	0	0	2	0	9
Other	0	0	11	0	0	0	0	0	0	0	87	0	87	0	14
TOTAL	6 522	7 472	9 517	8 238	966	152	6 898	7 889	9 799	4 911	5 217	811	3 392	4 640	5 522

* Preliminary

Table 2. West coast of Newfoundland: Capelin landings (t) by NAFO unit area from 1990 to 2003.

UNIT AREA	YEAR														AVERAGE
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003*	(1990-2002)
4Ra	1 959	154	1 554	73	10	15	605	734	1 827	29	0	0	115	134	544
4Rb	479	82	1 506	469	265	0	1 841	2 480	3 814	1 675	356	0	856	1 006	1 063
4Rc	925	4 907	4 675	4 264	245	0	3 364	4 171	2 541	3 031	4 773	605	2 323	3 452	2 756
4Rd	104	2 023	117	1 933	72	0	430	14	581	0	0	136	0	48	416
NK**	2 739	0	754	0	0	0	25	0	0	0	0	0	0	0	271
TOTAL	6 205	7 166	8 605	6 739	592	15	6 265	7 399	8 764	4 735	5 129	741	3 295	4 640	5 050

* Preliminary; ** Not known

corresponds to the pre-spawning period in the senne fishery and to the spawning period in the trap fishery. In both cases, the fishery mainly targets mature females for the roe-market demand. The largest landings for all the Gulf of St. Lawrence are nearly always made on the west coast of Newfoundland, i.e. in NAFO (Northwest Atlantic Fisheries Organization) Division 4R (Figure 5). In Divisions 4R and 4S, the most intensive fishing occurs in June and July. In Division 4T however, the fishing season sometimes begins as early as April, but the largest landings occur in May and June. Purse sennes, traps, and weirs are mostly used to catch capelin in the Estuary and Gulf of St. Lawrence.

The fishery in 2003

In 2003, preliminary data on capelin landings in Divisions 4RST totalled 4,640 t, an increase of 1,345 t from 2002 levels (Table 1). These catches also represent 84% of the mean annual landings between 1990 and 2002, and 62% of the TAC, which was brought back to 7,455 t in 2002. All landings in 2003 were made by the purse senne fishery in Division 4R, more specifically in unit areas 4Rb and 4Rc (Table 2). Between the late 1980s and mid-1990s, capelin fishing seasons occurred at increasingly later dates (Figure 6A). Since 1996, fishing seasons have moved closer to historical patterns, and in 2003 the fishing season began earlier than in the two previous years. A constant reduction in female and male mean size has been noted since the mid-1980s (Figure 6B). As a result, the fishery was cut short in 1994, and almost completely closed in 1995. Capelin size stabilized between 1996 and 1998, decreased in 1999, but has been increasing

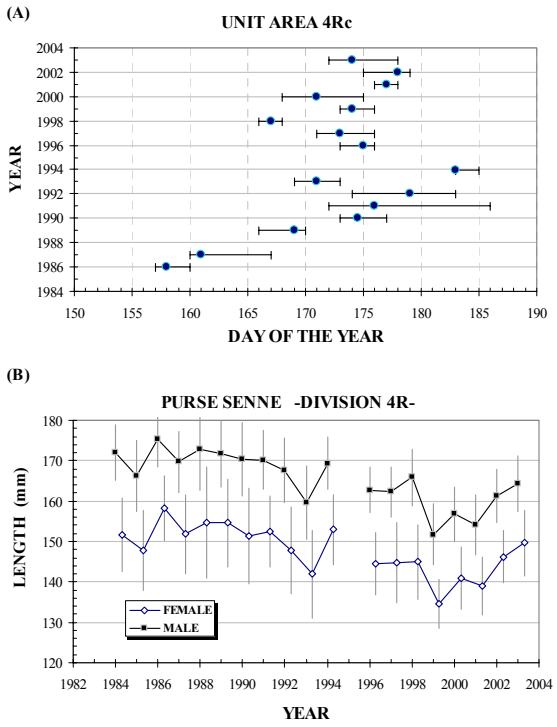

Figure 6. Temporal pattern of the capelin purse senne fishery in unit area 4Rc (A) (symbol = median landing dates; lines = dates by which 25 % and 75 % of the landings have been made) and mean length (B) of capelin caught with purse sennes in NAFO Division 4R (the vertical bars represent standard deviations).

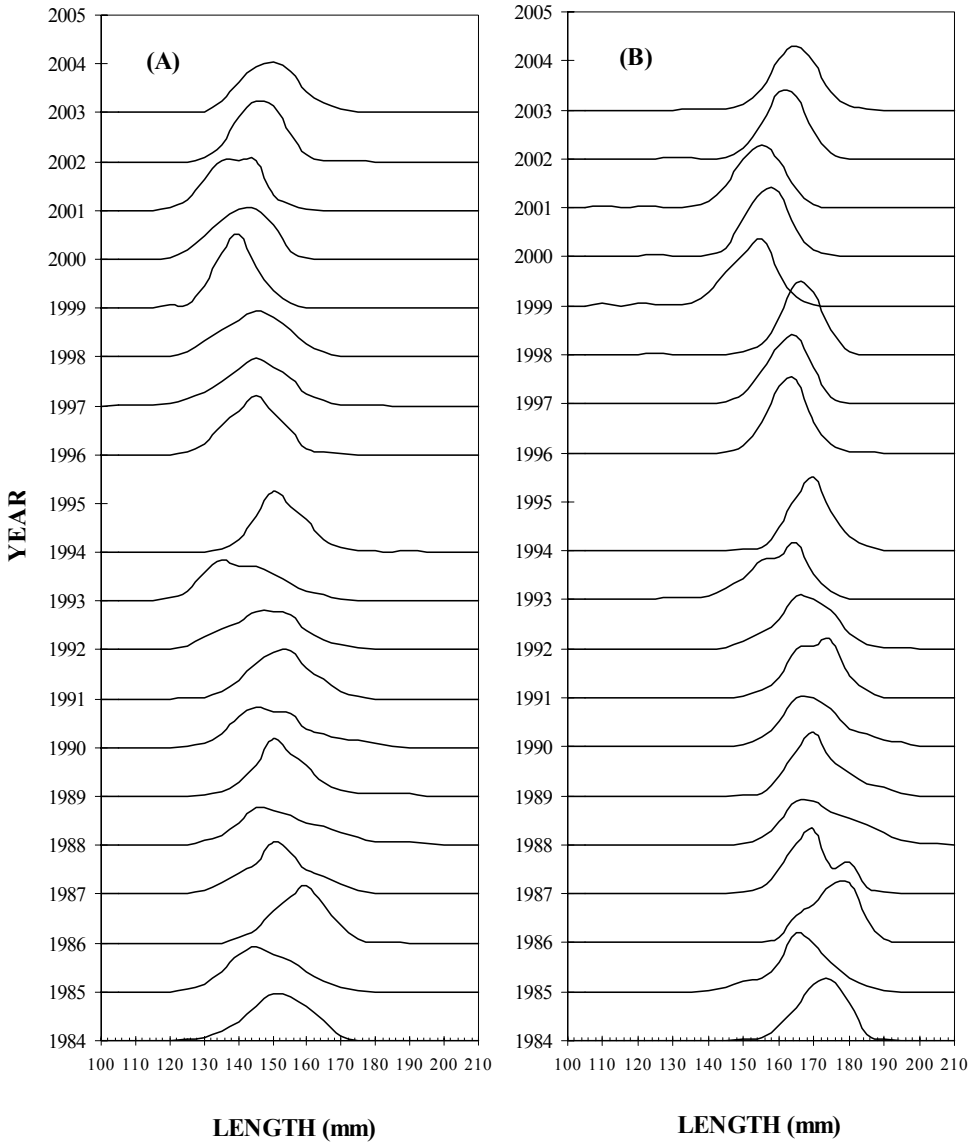

Figure 7. Size composition (%) of females (A) and males (B) caught with purse sennes in NAFO Division 4R between 1984 and 2003 (except 1995).

ever since. Nevertheless, 2003 figures are still below those recorded in the 1980s. These fluctuations in capelin size were also noted in the assessment of annual length frequencies (Figures 7A and 7B), which in most cases consist of a single modal value as a result of lengths overlapping among the various age groups.

The average number of capelin per kilogram is used as a management measure to monitor catch sizes during a fishing season. A total of 50 capelin per kilogram has been established as a maximum level not to be exceeded. Prior to 1993, numbers per kilogram have generally been below this level within the 3 NAFO divisions (Figure 8). Subsequently, they exceeded this level but remained higher in Division 4T. In Division 4R, numbers per kilogram have been in constant decline since 1999. In 2002 and

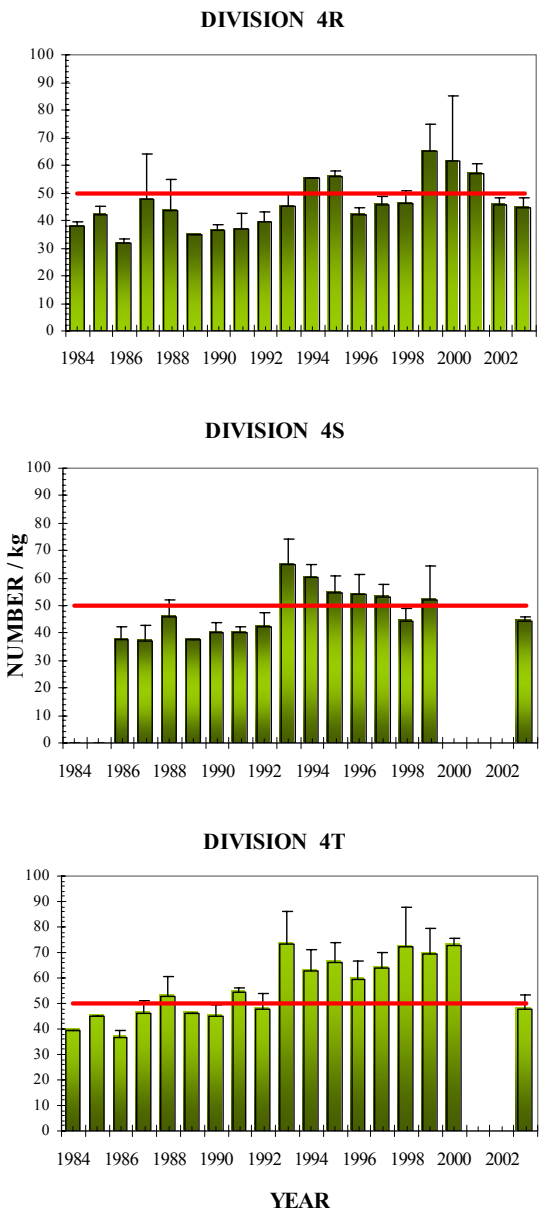

Figure 8. Mean number of capelin per kilogram (the vertical lines above the bars represent the standard deviations) for samples collected in NAFO Divisions 4RST (the horizontal line indicates the threshold of 50 capelin per kg used as a management measure).

2003, they were below the level of 50 capelin per kilogram (Figure 8).

Status of the resource

A bottom trawl survey is conducted annually to assess the abundance of groundfish and shrimp (*Pandalus borealis*) in the northern Gulf of St. Lawrence. Given the regular capelin catches, data provided by this survey had been used, until recently, to calculate an abundance index expressed as the mean weight of the catch per tow. A second groundfish abundance survey is also conducted in the southern Gulf of St. Lawrence under the supervision of the Department of Fisheries and Oceans Canada, Gulf Region. Capelin catches that have been made in these two surveys since 1990 clearly show a significant expansion of the geographical distribution of this species in the Gulf of St. Lawrence. However, as bottom trawl surveys are not well adapted for the catch of a pelagic fish such as capelin (the mean weights per tow have very large confidence intervals), it was agreed to use this information only to assess the distribution and dispersal of the species.

Distribution

During the last four surveys, the greatest concentrations of capelin have been found around Anticosti Island, in the Northern Esquiman Channel off the west coast of Newfoundland (Division 4R), and in the area located between the Gaspe Peninsula and the west coast of Cape Breton (Figure 9), where capelin has occurred only since the mid-1990s.

Indices of dispersion

Two indices of dispersion are now calculated (by kriging) using data on the presence and absence of capelin per tow for the bottom trawl surveys conducted during August and September. The first of these indices concerns the total area (km^2) associated to a 50% and more probability of finding capelin. The areas showed a clear upward trend between 1990 and 2003 (Figure 10A). This trend is more evident in the case of areas associated to the entire Gulf of St. Lawrence rather than its northern part (including the Estuary). Maps indicating areas with different probabilities of capelin presence come also with this index. Three

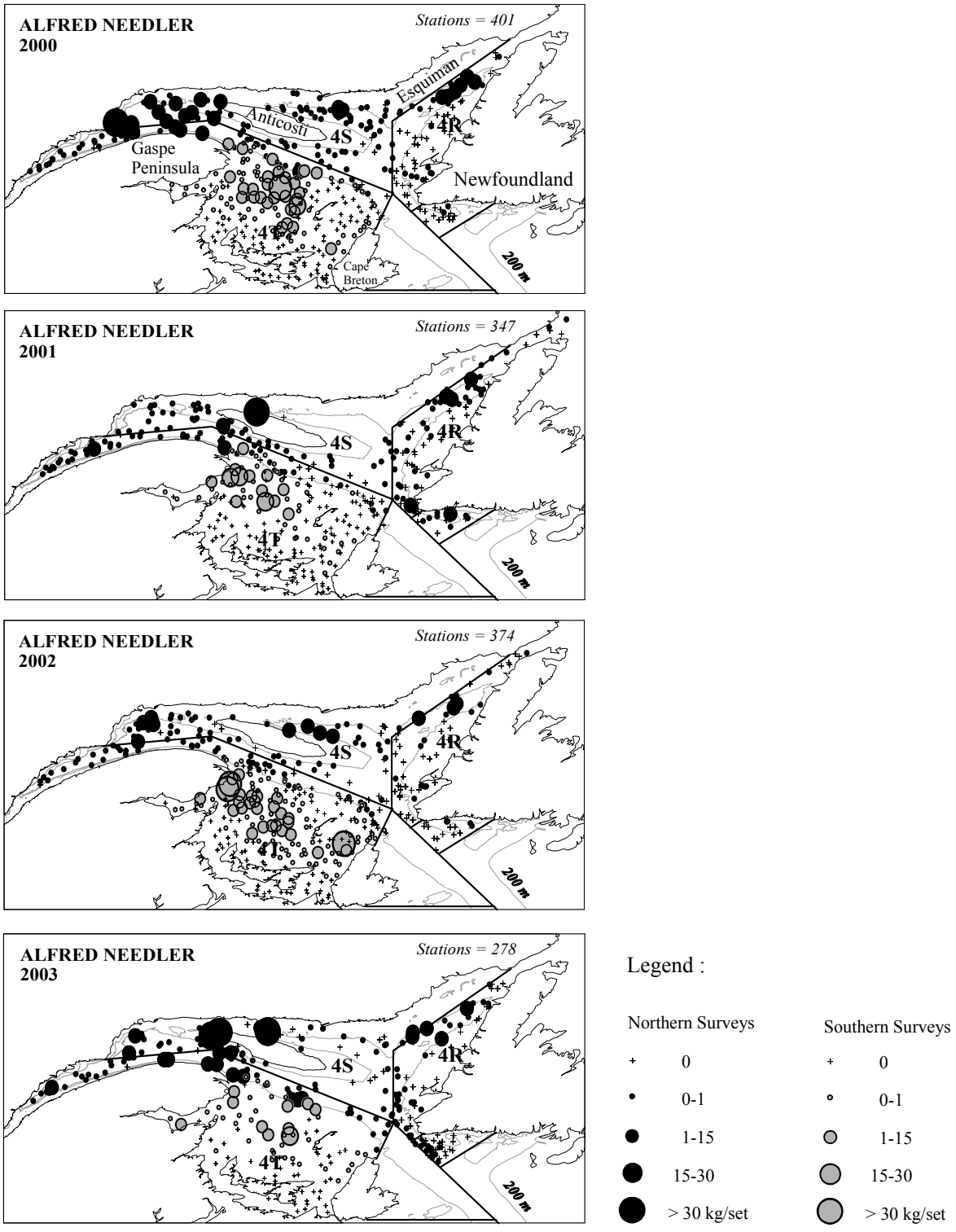

Figure 9. Maps of capelin catches (kg/set) made during the latest groundfish and shrimp abundance surveys in the northern and southern Gulf of St. Lawrence. These surveys use gear with different selectivity (data on 4T: courtesy of Gloria Poirier and Hugues Benoît, DFO, Moncton, NB).

of these maps (Figure 11A) clearly show the expansion that has occurred between 1990 and 2003 in areas where capelin is very likely to be found.

The second index indicates the mean probability of capelin occurrence in the Estuary and the Gulf of St. Lawrence. This index also shows an upward trend for the same period of time (Figure 10B). The mean probabilities are higher in the northern area of the Gulf (including the Estuary). All these indices have increased in 2003.

Areas with the most significant concentrations of capelin were expressed in terms of probabilities of finding catches greater or equal to 0.10 kg. These areas are

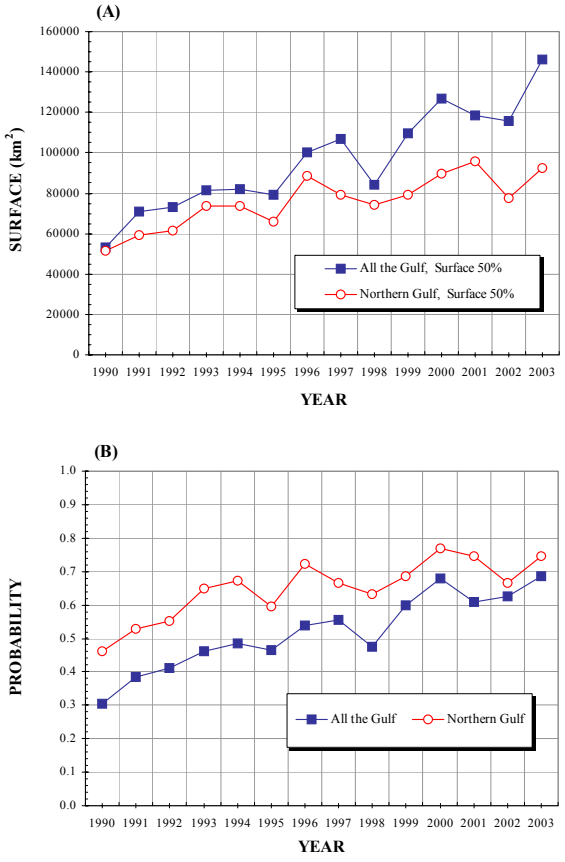

Figure 10. Annual areas (km^2) (A) of capelin occurrence with probability levels of 50 % and more and mean capelin occurrence probability (B) to find capelin in the northern (including the Estuary) and southern Gulf of St. Lawrence between 1990 and 2003.

in the Estuary, in the region located west of the Magdalen Islands, and on the west coast of Newfoundland (Figure 11B).

Point of view of the industry

The comments that follow come from various sectors of the capelin fishing industry of Newfoundland's west coast: (1) In 2003, capelin were abundant and of good size, as was the case with sand lance (*Ammodytes* sp.) in the fall. (2) In recent years, it was no longer possible to forecast the spawning period, which was short in duration when occurring. However, in 2003, spawning corresponded more closely to historical seasonal patterns, and was quite intense in certain areas. (3) Capelin abundance and size improved in 2003. (4) The low landings recorded since 1999 are the result of the loss of traditional markets to the Norwegians and Icelanders, and not the result of small capelin size or reduced abundance. (5) Early in the season, capelin is a huge problem for shrimpers in the Esquiman Channel. (6) The current abundance of the species does not justify fishery closure. (7) Before developing this fishery further, the industry requests that studies be conducted on the distribution and spawning changes noted in recent years. (8) No capelin fishing should be conducted in order to allow the return of cod. (9) The capelin fishing industry has demonstrated considerable dissatisfaction towards the TAC reductions of 40% implemented in 2003. During the last year, the industry repeatedly stated that this decision was based on the precarious status of capelin off the east coast of Newfoundland, whereas the capelin situation in the Gulf of St. Lawrence was not taken into consideration. (10) The industry wonders what would happen to capelin TACs should cod fishing open next season.

As for the Estuary of St. Lawrence, many comments were made concerning the large number of capelin caught through weir fishing. On the Quebec's North Shore, a very large number of

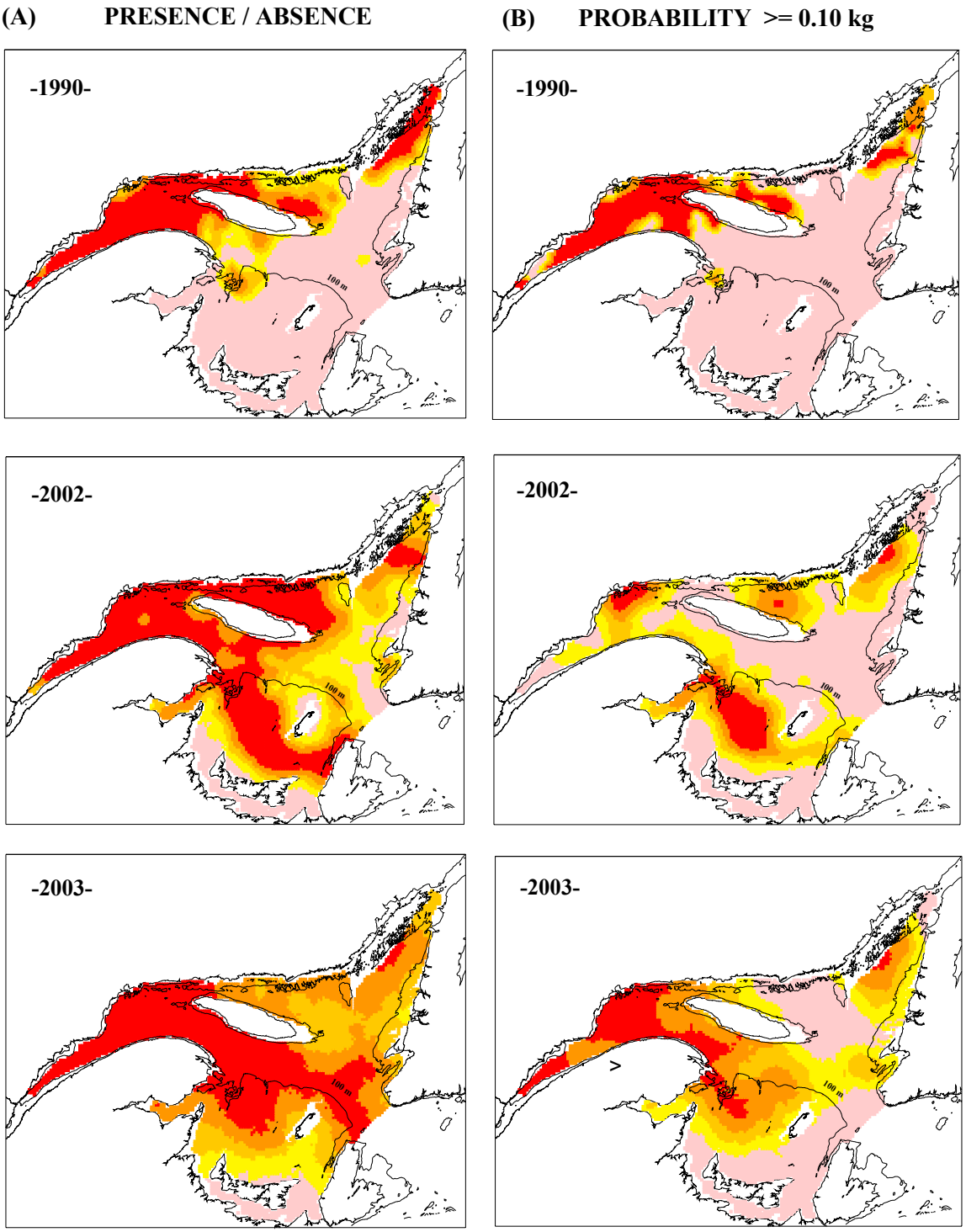

Figure 11. Perimeters of capelin occurrence probability area (%) (A) and where it is possible to find 0.10 kg or more of capelin (B) for surveys conducted in the Estuary and Gulf of St. Lawrence in 1990 and in 2002 and 2003 (the 100 m isobath is also indicated).

females were found dead on the beach, whereas males normally dominate the spawning death rate. In that same area, spawning was very intense.

Assessment and outlook

Predation

Capelin is one of the most important forage fish species of the Estuary and Gulf of St. Lawrence. This species plays a key role in transferring energy in the marine ecosystem from primary and secondary producers (on which it feeds) to species at higher trophic levels (its predators). Indeed, many fish, marine mammals, and seabirds are dependant on capelin for their survival. In the mid-1980s, large cod and redfish were capelin's main predators (Figure 12A). In the mid-1990s, these two species were replaced by cetaceans and harp seal (Figure 12B). According to data gathered since 1993, large cod has been feeding less on capelin and invertebrates and more on other species of fish (Figure 13). The occurrence of capelin in the stomach contents of cod depends on where samples were taken and on the type or selectivity of the fishing gear used. For example, in cod measuring between 20 cm and 50 cm, capelin is found more often in the stomachs of cod caught off the coast by the mobile-gear sentinel fishery than by scientific bottom trawl surveys conducted by the CCGS *Alfred Needler* (Figure 14). However, capelin is most often found in the stomachs of cod sampled near the coast by the fixed-gear sentinel fishery.

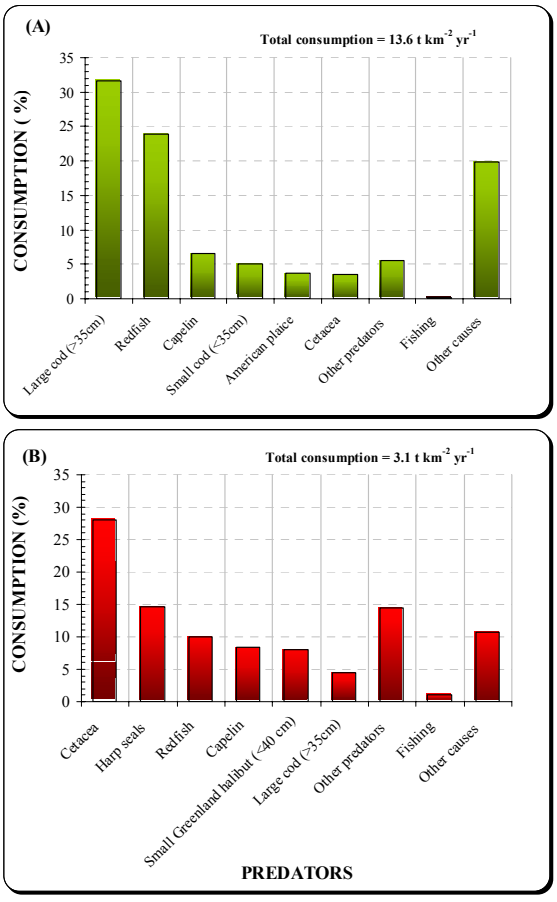

Figure 12. Capelin consumption (t km^{-2} yr^{-1} expressed in %) by main predators in the northern Gulf of St. Lawrence in the mid-1980s (A) and 1990s (B) (C. Savenkoff and M. Castonguay, DFO, MLI, pers. comm.).

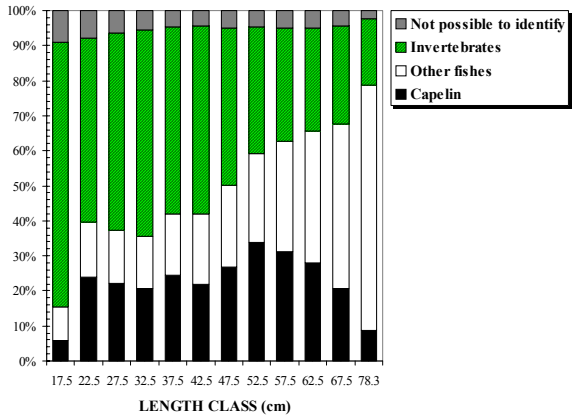

Figure 13. Annual mean percentage of stomach content (weight) by length-class among cod sampled since 1993 in research surveys conducted by the DFO and the fixed- and mobile-gear sentinel fisheries (D. Chabot, DFO, MLI, pers. comm.).

Environment

Recent water temperature fluctuations in the Gulf of St. Lawrence appear to have had a big impact on various aspects of the

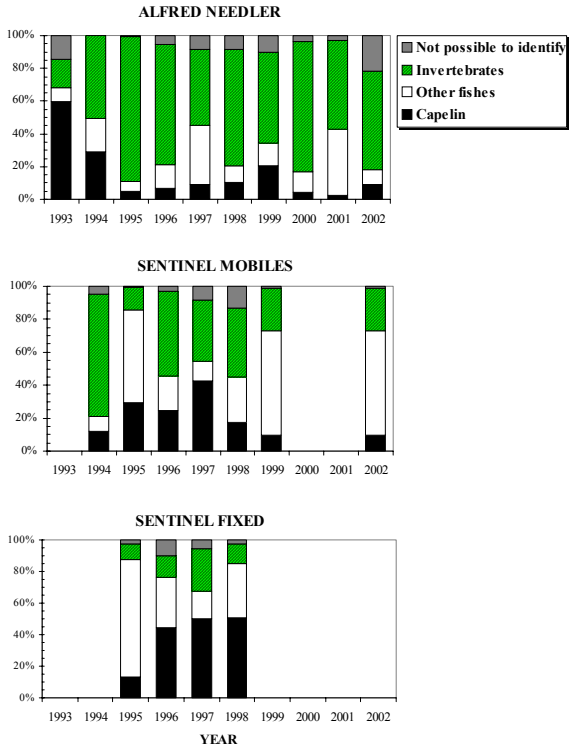

Figure 14. Annual mean percentage of stomach content (weight) among cod measuring between 20 cm and 50 cm sampled since 1993 in research surveys conducted by the DFO and the fixed- and mobile-gear sentinel fisheries (D. Chabot, DFO, MLI, pers. comm.).

lifecycle of certain commercial fish. In the capelin's case, the area of the Magdalen Shallows that is covered by water below 1ºC seems to be linked to the expansion of the species' distribution in this part of the Gulf of St. Lawrence (Figure 15). Cooler waters off the west coast of Newfoundland could explain the decrease in size observed in the early 1990s. It is not currently known what impact these water temperature fluctuations have had on capelin's natural mortality, production, and recruitment. In addition, very little data is available on traditional and new capelin spawning grounds that could be associated with recent changes in the species' distribution.

Fishing mortality

Fishing mortality does not appear to have a noticeable effect on the population at the current landing levels, even though it is not currently possible to evaluate it. It is also impossible to evaluate the impact that a significant increase in landings has had on the capelin population and the rest of the ecosystem, as changes in the species abundance are first and foremost the result of natural factors. As capelin has a short lifespan, its abundance is subject to sharp changes because the population consists of only a few age groups. Fishing effort is strongly correlated to the size of female capelin in order to satisfy market demand. The industry has a greater interest in regions where environmental conditions are more favourable to capelin growth. This explains the weak capelin demand in Divisions 4S and 4T.

Even if fishery does not appear to have an impact on capelin abundance, we recommend that any TAC **increase** be made **progressively** due to capelin's prominent role in the marine ecosystem, and due to a lack of knowledge regarding its biology.

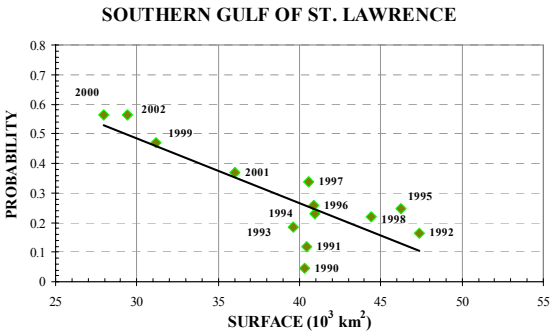

Figure 15. Relation between the Magdalen Shallows area (10^3 km^2) covered by waters below 1ºC (K. Drinkwater, DFO, Halifax, pers. comm.) and mean capelin occurrence probabilities for the period 1990-2002.

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