Local ecological knowledge and marine fisheries research: the case of white hake (*Urophycis tenuis*) predation on juvenile American lobster (*Homarus americanus*)[1]

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Abstract: Southern Gulf of St. Lawrence fish harvesters voiced the concern that white hake (*Urophycis tenuis*) were jeopardizing the recruitment of juvenile American lobster (*Homarus americanus*), through predation, into the commercially exploitable population. The harvesters insisted that marine science was not documenting this situation, since sampling was being conducted in the wrong places and at the wrong times of year. This paper reports on the results arising from a 2-year collaborative and interdisciplinary research project designed to examine fish harvesters' concerns. Several social research methodologies were used to identify and interview "local knowledge experts" about where and when sampling should occur. Following harvesters' advice, white hake stomachs were sampled over a 2-year period. Contrary to harvester expectations, American lobster was not found in any of the 3080 white hake stomachs sampled. Yet, harvesters' advice did result in successful sampling from within the places recommended and at the times of year specified. The research also demonstrates an interdisciplinary and collaborative approach that generates meaningful research results while incorporating marine harvester local knowledge and addressing their concerns.

Résumé : Les pêcheurs commerciaux du sud du golfe du Saint-Laurent se sont inquiétés de ce que les merluches blanches (*Urophycis tenuis*) mettent en danger par leur prédation le recrutement de jeunes homards d'Amérique (*Homarus americanus*) dans la population sujette à l'exploitation commerciale. Ils insistaient que les biologistes marins ne suivaient pas la situation adéquatement parce que l'échantillonnage se faisait aux mauvais endroits et au mauvais temps de l'année. Notre travail présente les résultats d'un projet de recherche multidisciplinaire de 2 ans, fait en collaboration et destiné à examiner les soucis des pêcheurs. Plusieurs méthodologies empruntées aux sciences sociales nous ont permis d'identifier et de questionner les « experts locaux » sur les endroits et les moments de l'échantillonnage. Selon l'avis des pêcheurs, nous avons prélevé des estomacs de merluches blanches sur une période de 2 ans. Contrairement aux attentes des pêcheurs, aucun homard d'Amérique n'a été trouvé dans les 3080 estomacs de merluches blanches prélevés, même si nous avons mené avec succès des échantillonnages dans les sites qu'ils avaient recommandés et aux périodes de l'année qu'ils avaient indiquées. Ce travail est aussi une illustration d'une approche interdisciplinaire et collaborative qui mène à des résultats scientifiques significatifs, tout en tenant compte des connaissances locales des pêcheurs marins et de leurs préoccupations.

[Traduit par la Rédaction]

Introduction

Over the last decade or so, considerable research and policy interest have developed respecting the prospect of incorporating what is termed variously as "local", "traditional", or "indigenous" ecological knowledge into natural resource assessment and management regimes (Sillitoe 1998; Berkes et al. 2000; Fisheries and Oceans Canada 2000). As Neis et al. (1999) asserted, "...[t]he body of information held by fishers has an important role to play in fisheries assessment. When this body of information matches scientific assessments, uncertainty is reduced and assessments become more convincing to resource users". In this view, resource users are assumed to work within and add to a local "system of knowledge" that has arisen from years of observations and experiences respecting the local environment and its ecol-

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ogy. After all, achieving livelihood success, today as well as in the past, is contingent greatly on users' abilities to access and extract resources through strategic applications of their knowledge about environmental factors, ecological relationships, and species behaviour.

Documenting and incorporating resource users' local ecological knowledge (LEK) for natural resource management purposes is assessed as critical to accessing new, ecologically and environmentally detailed information for the purpose of better understanding the marine ecology, of improving fisheries resource assessments, and for developing more effective management policies (Maurstad 2000; Neis and Felt 2000; Moore 2003). For instance, Hutchings (1996) has suggested that LEK might inform and strengthen fisheries science assessment research in three distinct ways. These are microlevel information on the seasons and directions of fish movements, on attributes such as stock structure, spawning grounds, and juvenile habitat, and on resource abundance. These potential areas for rich data directly arise from marine harvesters' knowledge of, and harvesting experiences within, local fishing grounds as well as from sources such as daily and seasonal catch records sited within specific locations.

It is well and good to propose, as many have, that incorporating LEK would provide broad-based benefits. But few have actually engaged in research processes with attributes that enable systematic access to, and documentation of, LEK (Davis and Wagner 2003). The Neis et al. (1999) paper is actually one of the few that attempts to delineate and to demonstrate means whereby marine harvesters' knowledge can be gathered systematically and thereafter incorporated into "fisheries science" assessments.

In this essay, we outline and "test" an interdisciplinary research design and methodology that documents and employs LEK as the basis for temporal and sample site selections in a study of fish predation on juvenile American lobster (*Homarus americanus*). Recently, numerous St. Georges Bay fish harvesters have contended that demersal fish, particularly white hake (*Urophycis tenuis*), were preying on juvenile (sublegal sizes) American lobster. This claim has been reported anecdotally by harvesters in settings such as assessment meetings, representative association meetings, research interviews, and personal communications. It is said to arise directly from observations made by them while "dressing" (gutting) catches. That is, harvesters claim that "small" (juvenile) lobsters have been observed frequently in white hake stomachs and that white hake, among other demersal fishes, commonly eat juvenile lobster. Consequently, they are concerned that as demersal fish populations recover during the fishing moratorium, there will be increased predation on juvenile lobster. This anticipated increase in predation is expected to diminish recruitment of juveniles into the harvestable size classes, thereby jeopardizing the economic viability of the lobster fishery (Hanson and Lanteigne 2000). This concern is amplified by the fact that the moratorium on white hake and Atlantic cod (*Gadus morhua*) fisheries has reduced the numbers of resources to which fish harvesters have access, thus accentuating livelihood dependency on the lobster fishery. Intensifying these concerns further is the fact that lobster landings have been declining in some areas since the early 1990s (Department of Fisheries and Oceans 2002*a*).

The results of recent seasonal feeding studies on Atlantic cod and white hake and seven other, common demersal fish species (e.g., Hanson and Lanteigne 2000; Hanson and Chouinard 2002; J.M. Hanson, unpublished data) do not support these concerns. Fish harvesters argue, however, that the feeding studies on white hake in particular were conducted in the wrong places and at inappropriate times of the year. To address these concerns, a research collaboration was formed between Interdisciplinary Studies in Aquatic Resources and Social Research for Sustainable Fisheries at St. Francis Xavier University, Fisheries and Oceans Canada (Gulf Region, Moncton, New Brunswick), and the Gulf Nova Scotia Bonafide Fishermens Association. The research program documented St. Georges Bay fish harvesters' LEK respecting the seasonal distribution and diet of demersal fishes, particularly white hake. This information was used to identify sampling sites as well as the times of the year when it was thought appropriate to sample. The resulting field study was designed, funded, and completed for the primary purpose of systematically responding to the perceptions of St. Georges Bay fish harvesters respecting the prevalence of white hake predation on American lobster and its potential to control recruitment to the lobster fishery.

One goal of this study was to sample a sufficient number of demersal fish stomachs, at the appropriate times and in the appropriate places, to assess accurately the extent of predation on juvenile American lobster. A second goal was to explore the extent to which social research methodologies designed to document fish harvesters' LEK might contribute to effective collaboration in the design and conduct of a study of marine fish predator–prey interactions. While addressing these concerns, this study also identified all of the prey eaten by white hake, filling an important void in our knowledge of the feeding patterns of this species.

Background and research context

American lobster in the southern Gulf of St. Lawrence (sGSL)

Roughly 50% of all lobster caught in Canadian waters are landed in the sGSL. Moreover, this species accounts for almost 50% of the total landed value in the sGSL fishing industry, supporting about 3700 lobster license holders in Lobster Fishing Areas 20, 21, 22, 23, 24, 25, 26A, and 26B (Lanteigne et al. 1998; Department of Fisheries and Oceans 2002*a*, 2002*b*). It is important to note that lobster fishing areas correspond to groups of commercial fishermen operating out of collections of communities and do not necessarily correspond to discrete populations of lobster. The number of licences in the sGSL has remained relatively stable since 1967 when regulations first came into place to limit access to the lobster fishery. The lobster fishery is managed currently by means of effort control. The number of licences, number and size of traps per licence, minimum legal carapace length (CL), presence of eggs, and timing of the season are regulated for each lobster fishing area (Miller 1995; Lanteigne et al. 1998).

Estimates of lobster landings for the sGSL reflect catches sold to processing plants. There are no estimates of lobster landed for private sales (e.g., sold at the wharf or from the back of trucks at the side of the road), gifts, and personal use. Lobster catches sold to processing plants have shown a large increase from <10 000 t/year in the 1960s and 1970s to an average of 22 215 t/year from 1990 to 1997, with a yearly landed value of CDN$220 million (Hanson and Lanteigne 2000). While overall landings have shown a slow decline since the early 1990s, there has been a slight increase in landed value of lobster owing to increased prices. In 2001, sGSL Gulf Region lobster license holders caught approximately 20 000 t of lobster with a landed value of more than CDN$235 million (Department of Fisheries and Oceans 2002*a*, 2002*b*).

In the sGSL, most American lobsters are found in waters <30 m deep during the ice-free season (Hanson and Lanteigne 2000). The cold intermediate layer (bottom water temperature <1 °C) contacts the bottom at depths between roughly 30–40 and 100 m (Koutitonsky and Bugden 1991; Gilbert and Pettigrew 1997), and American lobster appear to avoid these cold waters during the ice-free season. Thus, the depth distribution of American lobster overlaps very little with that of the principal large fish predator Atlantic cod (Hanson and Lanteigne 2000), but it overlaps broadly with the depths occupied by the coastal population of white hake.

White hake in the sGSL

White hake is a large demersal fish that occurs in continental waters of the western Atlantic Ocean (Scott and Scott 1988). In the sGSL, white hake are largely found on soft bottom habitats with water temperatures of 5–20 °C. There are two distinct subpopulations in the sGSL. One population occurs in the deep, warm (5–7 °C) waters of the Laurentian Channel. The second is confined to the coastal waters (i.e., <40 m deep) of the sGSL (Hurlbut and Clay 1998; Department of Fisheries and Oceans 2002*c*). Similar to American lobster, white hake largely avoid the 40–100 m depths of the sGSL where the cold intermediate layer contacts the bottom. Coastal waters in the sGSL often reach temperatures >20 °C during summer and the entire sGSL is usually ice-covered from January to March or April. The decline in water temperatures during autumn appears to cause all adult white hake to make a seasonal migration out of the shallows to overwinter in the Laurentian Channel (Clay 1991). Many small white hake enter estuaries to feed during late summer and early autumn (Hanson and Courtenay 1995; Bradford et al. 1997). These small white hake then leave the estuaries in November and presumably overwinter in the Laurentian Channel (Hurlbut and Clay 1998).

White hake are harvested throughout their geographical range, but the fishery in the sGSL is the most directed, i.e., fishermen target the species rather than landing it as bycatch from another fishery (Hurlbut and Clay 1998). In the 1960s and 1970s, white hake landings in the sGSL ranged between 3600 and 7200 t. With an increase in fishing effort in the early 1980s, white hake landings peaked at 14 039 t in 1981. A steady decline in landings occurred thereafter, with an all-time low of only 1000 t landed in 1994. In 1995, the white hake fishery was closed in the sGSL (Hurlbut et al. 1998) and the closure will likely remain in place into the foreseeable future. Annual trawl surveys show that very few white hake are present in several historically important spawning locations such as Baie Verte, New Brunswick (reviewed by Hanson and Lanteigne 2000). Currently, the distribution of white hake (ice-free season) is limited to the eastern end of the Northumberland Strait. The only known remaining spawning area is in St. Georges Bay (Poirier et al. 2000; Hurlbut and Poirier 2001). White hake numbers are not expected to recover unless mortality from fishing is kept very low (Department of Fisheries and Oceans 2002*c*).

The only published data that we know of on the diets of sGSL white hake are those of Hanson and Lanteigne (2000). This study sampled 2300 white hake stomachs between August and October 1996 and only recorded the presence or absence of lobster in the stomachs. The results did not support the idea that white hake were an important predator of American lobster (only three stomachs contained lobster). However, the authors noted that they might have underestimated predation by white hake on juvenile American lobster because sampling did not include fish in shallower waters (<20 m). White hake diet studies conducted in the Gulf of Maine and Georges Bank suggest that adult white hake (>45 cm) are primarily piscivores (Vinogradov 1984; Garrison and Link 2000), while smaller white hake (<45 cm) eat mostly small crustaceans such as shrimp and mysids (Tyler 1972; Bowman and Micheals 1984; Garrison and Link 2000).

Research design

The LEK information used in selecting sample sites and in identifying temporal preferences was gathered through a multiphase research design (Appendix A). A recent review of the most commonly cited LEK research literature shows that in most of the studies, the methodologies employed either were not described or were nonsystematic (Davis and Wagner 2003). This is judged to be unacceptable in that documenting LEK, particularly with a view to presenting LEK as a touchstone for local “voice” and empowerment respecting resource management, requires research designs and methodologies that provide confidence-building, defensible results. Assuming that LEK is a locally held and referenced “system” of knowledge developed over years of harvester experiences and observations, it is reasonable to anticipate that LEK will be distributed unevenly among local fish harvesters as a result of factors such as length of fishing careers, success at making a living from fishing, and the extent to which harvesters are embedded within fishing families. Consequently, each community of local harvesters is anticipated to contain, by reputation, a number of individuals considered by their peers to be especially knowledgeable about the local fishing grounds. A multiphase research design employing a stratified random sample followed by face-to-face interviews was developed as a means to identify and to access harvesters reputed by their peers to be particularly knowledgeable. This research design provides confidence that the experiences and observations of those considered to be “most knowledgeable” about fishing and fishing grounds will be the focus of LEK research, an outcome akin to identifying the “elders” with whom to work within indigenous peoples settings. Furthermore, such a design and methodology documents harvester experiences and observations systematically, thereby establishing the core attributes of the LEK system while also providing a substantive research basis for harvesters and others to understand and to assess LEK as something other than a suite of mere anecdotes.

The first phase of the research was completed by August 1998. A random sample of 174 persons, stratified on the basis of fishing harbour, was drawn from a list of all 304 current lobster license holders within a region extending from Lismore, Pictou County, to Mabou Mines, Inverness County. This stratified random sample was contacted and interviewed by telephone. Seventy-three percent (127 of 174) of those contacted participated in the interview.

While designed to gather basic background information respecting attributes such as fishing activities, fishing capacity, and social background, the primary goal of the survey was to identify the persons considered by their peers to be reputed as particularly knowledgeable about the local fishing grounds. This was accomplished by asking the question "other than yourself, who would you say knows the most about the local fishing grounds?" The names of as many as five persons were solicited in this manner from each interview participant. Participants were also asked to specify whether the persons identified were currently fishing or retired. The majority of those interviewed specified no more than three persons, with many noting only one or two.

A rank-ordered list of local knowledge experts for each fishing port area was constructed from the recommendations. The rank order embodies both the total number of mentions a person received and the sequence of the mentions, i.e., first mentioned, second mentioned, and so on, on the presumption that each participant's sequence of mentions reflects an implicit ranking. In total, 138 individuals were specified as local knowledge experts, of whom 15.2% were identified as retired. The 117 active fishermen named account for 38.5% of all current lobster license holders. These results demonstrate that the persons interviewed did draw clear distinctions among local fishermen respecting knowledge of the fishing grounds. In fact, over 50% of all active lobster license holders did not receive as much as one mention.

Fifty-three persons within the entire research area received a minimum of at least two first mentions or three total mentions. The criterion of two first mentions or three total mentions was determined as a reasonable breakpoint for the purposes of identifying at least five persons specified as local knowledge experts in each peer-referenced community area. Those nominated from two harbour areas, Ballantyne's Cove – Livingstone's Cove and Cribbon's Point, were the focus for the current study, as these sites contained both the harvesters' who were expressing concerns about white hake predation and the harvesters who had targeted white hake prior to the moratorium. A total of 14 fish harvesters were identified. These persons were selected for inclusion in the second phase of the study. In this phase, in-depth, face-to-face interviews were conducted between June 2001 and February 2002 for the purpose of documenting LEK respecting the four most important species fished within the fishing port community area. Our design has identified a minimum of five potential interviewees as critical to satisfying the methodological goal of achieving at least three independent observations for each local knowledge claim (Appendix A).

Nautical charts of the local fishing grounds were used to record information about each fishery, information such as locations fished within the local grounds in relation to time of year and attributes of the marine environment and ecosystem associated with valued resources. Participants were also asked to identify qualities such as spawning areas (Appendix A). In total, 12 interviews were completed with peer-recommended local knowledge experts fishing within the two community areas, i.e., Livingstone's Cove – Ballantyne's Cove and Cribbon's Point. Two refused our invitation to participate in this phase of the study. The sample sites and temporal recommendations derived from this research arose from associating the information that each interviewee provided with respect to the principle of seeking a minimum of three independent observations for each attribute represented. The sample sites and time of year selected were indicated independently by three or more of the LEK experts interviewed as associated with finding hake that were preying on juvenile lobster. On the basis of this research design and methodology, we are confident that the sample sites specified and the time periods recommended represent accurately local LEK respecting demersal fish predation on juvenile lobster.

But to examine the methodological and empirical strengths of the systematic social research design, we also gathered the same kinds of information from local fish harvesters employing another approach, opportunistic sampling. This approach consisted of an informal roundtable discussion held in early July 2001 with volunteer fish harvesters (i.e., general meetings with stakeholders). During this discussion, the participants were asked to identify on nautical charts the specific locations, times of year, and other factors that have to be considered to carry out the sampling necessary to document accurately white hake predation on juvenile American lobster. Juvenile lobster in this context referred to animals one to two moults from entering the fishery (i.e., lobster of 50–69 mm CL) rather than sexually immature animals. In the sGSL, 50% of females become sexually mature at CLs of 70–72 mm (Moriyasu et al. 2001). This procedure identified the three sites, referred to herein as the "outside" sites. The initial round of sampling was conducted on these sites during September 2001.

In social research jargon, these sites were nominated "opportunistically" or through an opportunistic sampling procedure. This basically means that the researchers extracted information from whomever was available and willing to talk. The attributes of research designs and methodologies reported in the most cited LEK research suggest that opportunistic sampling is among the most common procedures employed (Davis and Wagner 2003). Yet, this is a flawed research practice insofar as results cannot be claimed to represent much more than the experiences and observations of those directly consulted. To do otherwise is to assume that all harvesters within any local community acquire and employ a more or less identical understanding of the local fishing grounds and their ecology. Such an assumption potentially diminishes the richness of human ecological experiences and understandings, limits documentary depth, and compromises the extent to which harvesters' LEK may be examined and understood as much more than a collection of anecdotes. Thus, the white hake – juvenile lobster predation research provided an opportunity, as an ancillary goal, to examine and to assess the relative merits and necessities of employing systematic versus opportunistic sampling procedures in LEK research.

Field sampling

Through these procedures, commercial fish harvesters identified six sites in St. Georges Bay (Fig. 1) where large numbers of white hake would be found and where sublegal-sized American lobster would most likely be preyed upon by these fish. The fish harvesters were also asked to specify the compass direction whereby the fleets of sampling nets should be set. Three of these sites (numbered 1, 2, and 3 in Fig. 1) were located in waters 30–40 m deep (deep stations), with the remainder (numbered 4, 5, and 6 in Fig. 1) located in waters 15–30 m deep (shallow stations). Phase I of this study was conducted between 4 and 20 September 2001 and captured white hake in the three deep stations, i.e., those nominated by the "opportunistic sampling method". Phase II sampling sites, nominated by systematically identified "local experts", was conducted between 14 and 30 July 2002 and captured white hake in the three shallow stations. Phase III was conducted between 3 and 11 September 2002 and sampled white hake from all six sites, allowing concurrent collection of white hake stomachs from the two depth zones.

Sampling procedure

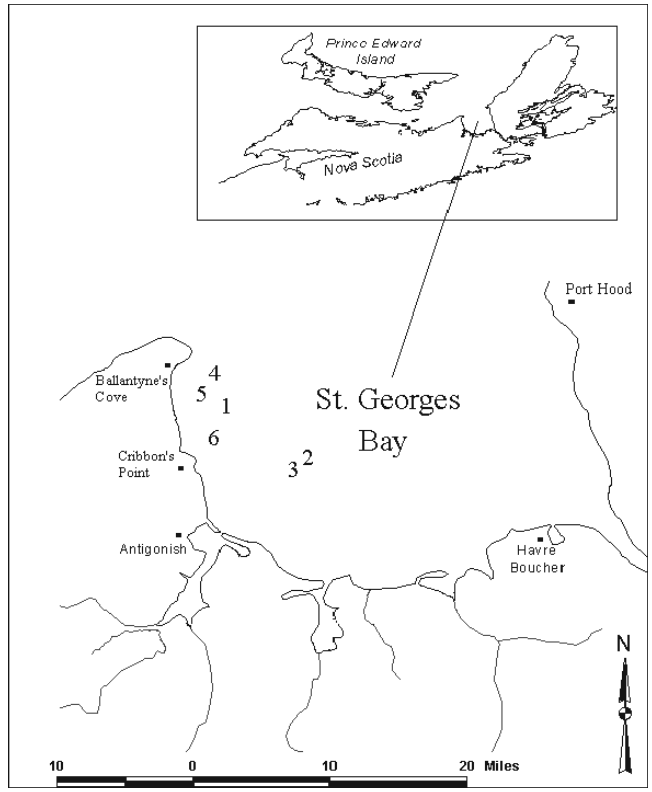
The fish were captured using gill nets because earlier studies have shown when fishes, such as white hake, are rapidly hauled to the surface in trawls, the expansion of gas in the swim bladder of live fishes often causes food to be regurgitated (Bowman 1986). The use of gill nets for this purpose was effective because only 3.2% of the 3093 white hake captured during this study had vomited.

Each of the six sites was sampled with a single string of gill nets. Each string was composed of four nets, and each net was 180 m long. These strings had alternating nets of 140- and 152-mm stretched mesh. For Phase III, an additional 114-mm-mesh size net was added to each string for the purpose of collecting smaller fish, thereby increasing the range of fish sizes sampled. The smaller meshed net was inserted in each string at random. With only three strings of gill nets in use during Phase III sampling, two strings were rotated through the deepwater stations, while the remaining gill net set was rotated through the shallow-water stations. The time of setting and recovery of each gill net was recorded and the catch-per-unit-effort (CPUE) was standardized to number of hake captured per hour of soak time. On two occasions, the soak time could not be estimated and these data were omitted from the CPUE analysis. The fish captured on these two days were used, however, in diet analysis and included in the length–frequency for September 2001.

Stomach sampling

All fish were taken out of the nets onboard the fishing vessel, measured (total length (TL) (centimetres), and their stomachs removed and placed in individual plastic bags. Each stomach was labelled with site, date, species, TL, and (in 2002) sex of the fish. The plastic bags were immediately placed on ice and stored in insulated boxes. Upon return to the wharf, stomachs were placed in a freezer and later taken to the laboratory for analysis. Each stomach was thawed in cold water and cut open and prey were identified to species level (if possible) and blotted wet weight recorded (usually to the nearest milligram). Empty stomachs were included in the sample size for diet analysis, while stomachs where the fish had vomited were discarded. White hake smaller than 45 cm were excluded from the analysis to remove the potential influence of the smaller meshed gill nets used during September 2002.

Fig. 1. Location of sampling sites (numbered 1–6) in St. Georges Bay (45°50′N, 61°40′W), Nova Scotia, Canada (1 mile = 1.609 km).



Results and discussion

White hake CPUE and size distribution

The average CPUE for white hake differed significantly between sampling groups (one-way ANOVA, $F_{[3,98]} = 31.3$, $P < 0.001$). The average CPUE in shallow water during July was much lower than that observed in September of either year (Table 1). The average CPUE in September 2001 was significantly lower than in September 2002. The catch rate in the deep stations did not differ from that in the shallow stations during September 2002.

The very low catch rate observed during July 2002 was unexpected. Despite intensive fishing efforts, only 159 white hake were caught, indicating that large numbers of white hake were not present in waters 15–30 m deep during July 2002. The timing and location of this phase of the study were based on consultations with experts identified by their peers. These local experts had predicted that large numbers of white hake would be collected in waters 15–30 m deep during July and that these fish were likely to prey upon juvenile lobster. Neither prediction was supported by the field

Table 1. Mean ± 95% confidence interval CPUE (as number of white hake per hour) and TL of white hake sampled in St. Georges Bay during 2001 and 2002.

Depth (m)	Date	No. of sets	No. of white hake	CPUE	Mean TL (cm)
30–40	Sept. 2001	36	1618	1.41±0.37*a*	63.4±0.33*a*
15–30	July 2002	42	159	0.17±0.05*b*	60.4±0.97*b*
30–40	Sept. 2002	15	781	2.72±0.92*c*	59.8±0.49*b*
15–30	Sept. 2002	6	535	3.16±2.32*c*	58.0±0.66*c*

Note: Means followed by different letters differ significantly (Sheffe's test, $P < 0.05$). The soak times were not available for six sets during September 2001; hence, these tows were not included in calculating CPUE.

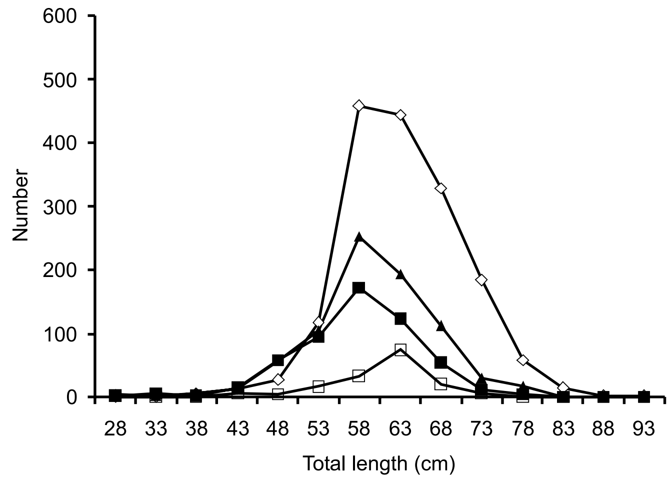
program (the diet information is described below). We noted that 25% of the white hake captured during July were females in spawning condition, which suggests that spawning activities may have affected the availability of white hake to the gear. The location of the spawning grounds for white hake in St. Georges Bay, however, is not known. There was a large increase in the number of white hake captured in shallow-water stations between the July 2002 and September 2002 phases. This increase in CPUE suggest a general movement of fish onto the "inside grounds" between the two sample dates. As there is little previous work illustrating local white hake migration, we cannot conclude that this is a normal event or whether the timing is the same in every year.

The average CPUE during September 2002 was higher than in September 2001, which suggests that population abundance may be increasing. There was, however, the addition of a small-mesh panel with the goal of capturing more small (<45 cm TL) fish. The inclusion of smaller mesh only increased the capture of fish <45 cm TL marginally between September 2001 and 2002 (1% of white hake caught in 2001 versus 3% in 2002). If the CPUE was restricted to fish >50 cm, the catch rate for September 2002 was still 1.8 times that of September 2001 for the deepwater stations.

There were significant differences (one-way ANOVA, $F_{[3,3157]} = 94.2$, $P = 0.0006$) in the mean lengths of white hake among the four sampling groups; however, the differences were small (maximum difference 5 cm) (Table 1). The average TL of white hake caught during September 2001 was significantly larger than for any group of fish captured during 2002. The shortest average length was observed for white hake caught in the shallowest stations in September 2002 and this was due to the presence of more fish >65 cm long in the deeper sets than in the shallow stations — the numbers of small fish (e.g., <50 cm) were very similar for the two depth zones during September 2002. The average length of white hake caught in shallow stations during July 2002 and in deep stations during September 2001 did not differ. From a feeding study point of view, these differences in fish size distributions between sampling dates and depths are minor. The vast majority of the fish sampled were longer than 45 cm and likely feeding on similar prey.

The length–frequency distributions of the four groups of hake (Fig. 2) all differed significantly ($\chi^2 = 351.3$, df = 39, $P < 0.0001$). All pairwise comparisons of frequency distributions differed significantly from all others ($P < 0.005$). The difference between the length–frequency distributions of September 2001 and 2002 was disturbing. When combined with the difference in CPUE, there was more medium-sized (50–69 cm TL) white hake caught during September 2002 compared with September 2001; however, large hake appeared to be less common in 2002. While almost 18% of the September 2001 sample were 70 cm or longer, less than 6% of the white hake caught in 2002 were 70 cm or longer. When corrected for the difference in CPUE, there were 1.6 times as many large hake in 2001 (0.25 per set) compared with 2002 (0.16 per set). While this difference may indicate nothing more than a sampling anomaly, it may also suggest a decline in either the occurrence or the availability of larger white hake. This latter prospect would be more troubling given the continued closure of the fishery for hake because of low population size (Department of Fisheries and Oceans 2002*c*). Additional research is required to clarify the situation and its implications.

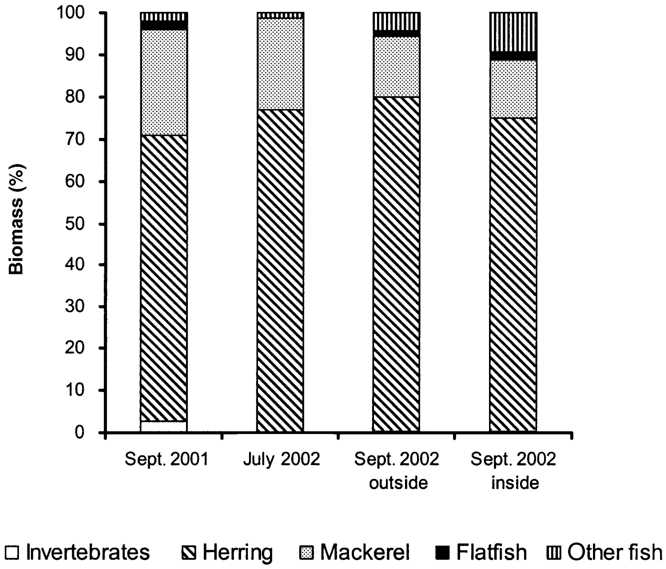
Fig. 2. Length–frequency distributions for white hake captured in St. Georges Bay during September 2001 deep stations (diamonds), July 2002 shallow stations (open squares), September 2002 deep stations (triangles), and September 2002 shallow stations (solid squares). The numbers on the *x* axis represent the midpoints of 5-cm length classes.



White hake diet analysis

Contrary to expectations of the fish harvesters, American lobster was not found in any white hake stomachs collected during this study (Fig. 3). Pelagic fishes were the dominant prey eaten by white hake >45 cm TL in St. Georges Bay. Atlantic herring (*Clupea harengus*) was the principal prey (range 68–80% of prey biomass) followed by Atlantic mackerel (*Scomber scombrus*) (range 14–25% of prey biomass). Other fishes represented a small portion of the diet (range 1.0–7.4%) and included snakeblenny (*Lumpenus lumpretaeformis*), cunner (*Tautogolabrus adspersus*), shorthorn sculpin (*Myoxocephalus scorpius*), ocean pout (*Marcrozoarces americanus*), white hake, and Atlantic cod. Flatfish were a minor component of the diet of white hake (range 0.3–2.1% of prey biomass) and included American plaice (*Hippoglossoides platessoides*), yellowtail flounder (*Pleuronectes ferrugineus*), and winter flounder (*Pleuronectes americanus*).

Fig. 3. Contribution of various fishes and invertebrates to the diet of white hake in St. Georges Bay for 2001 and 2002. White hake <45 cm TL were excluded from the analysis.



Invertebrate prey only represented a minor fraction of prey consumed by hake (range 0.1–2.7% of prey biomass) and was mainly short-finned squid (*Illex illecebrosus*). However, four white hake consumed the axiid shrimp (*Axius serratus*), a species that resembles a small American lobster.

After eliminating fish that clearly had vomited, empty stomachs were common during all three sampling periods. Of the 1607 stomachs examined during September 2001, 51% were empty compared with 62% of 156 stomachs from July 2002 and 29% of 1232 stomachs from September 2002. Elsewhere, Garrison and Link (2000) reported that 38% of the 6049 stomachs of white hake >50 cm TL were empty and other gadoids showed a range of 29–75%. This suggests that a high frequency of empty stomachs is not unusual for large, piscivorous hakes. High occurrence of empty stomachs is not a characteristic of all gadoid fishes because empty stomachs only represented 7% of 1700 large (>50 cm) Atlantic cod sampled in the sGSL during July–September 1990–2001 (J.M. Hanson, unpublished data).

While lobster was not found in white hake stomachs during this study, these results are not unique. Hanson and Lanteigne (2000) sampled 2287 white hake in the sGSL (eastern Northumberland Strait and St. Georges Bay) in 1996. They found that only three white hake had consumed a lobster. These white hake were adults (>50 cm TL) and the lobsters that they consumed were very small juveniles (14–15 mm CL). Stomach analyses of white hake in other ecosystems show similar results. Bowman and Michaels (1984) sampled 535 white hake along the US continental shelf. They did not report any lobster in hake stomachs. Garrison and Link (2000) analysed over 11 000 white hake stomachs sampled from the northeast US continental shelf ecosystem and the southwestern Nova Scotia shelf (8–400 m depths). They too did not mention American lobster as a prey item.

The occurrence of *A. serratus* in the stomachs of four white hake may explain some of the reports by fish harvesters that white hake prey on juvenile American lobster. A decapod crustacean, *Axius* is very similar in appearance to juvenile American lobster (Squires 1990), especially when partially digested. *Axius* reach a maximum size of about 30 mm CL and can be distinguished from juvenile American lobster by the morphology of their claws and the shape of the abdomen. Hence, it is possible that some of the organisms in white hake that fish harvesters have previously identified as lobster were actually *Axius*, inflating the harvesters' perception of the frequency of occurrence of lobster in hake stomachs. When presented with the research outcomes and the findings respecting *Axius*, many of the harvesters participating in these association meetings expressed surprise and interest. None of those participating in these meetings expressed prior knowledge of *Axius* or of the taxonomic differences between *Axius* and juvenile American lobster. Furthermore, not one harvester contested the possibility that the observations of *Axius* in white hake stomachs were misinterpreted as juvenile lobster.

General discussion

This study shows that during the times of year and at locations specified by local fish harvesters (including peer-identified local LEK experts), white hake did not eat lobster. Previous work in the adjacent waters of eastern Northumberland Strait and in St. Georges Bay itself did find three lobsters in the 2300 white hake stomachs examined (Hanson and Lanteigne 2000). Taken together, the present study and that of Hanson and Lanteigne (2000) have examined 5380 stomachs of white hake from eastern Northumberland Strait and St. George's Bay. Only three lobsters were found in these stomachs. Clearly, consumption of American lobster by white hake is a rare event and therefore would not have any measurable effect on the growth and recruitment of juvenile lobster into the fishery. Our results, combined with those of a previous study (Hanson and Lanteigne 2000), indicate that white hake, like Atlantic cod and five of the seven other common demersal fish species, are not major predators on juvenile lobster in the sGSL (lobster remains were detected in the stomachs of a small number of cunner and shorthorn sculpin). Together, these studies have directly tested and rejected the hypothesis, based on perceptions of fish harvesters, that predation by the principal demersal fishes (i.e., by Atlantic cod and white hake) is an important source of mortality for sublegal-sized American lobster in the sGSL. The role of predation by demersal fish in controlling American lobster abundance represents a long-standing controversy across the range of American lobster.

The published information dealing with the importance of predation by demersal fishes in controlling abundance of American lobster is contradictory. Some authors simply state that demersal fishes, such as Atlantic cod, eat large numbers of American lobster but provide no supporting data (Herrick 1909; Bigelow and Schroeder 1953; Scott and Scott 1988). In an early example of using LEK, Acheson and Steneck (1997) concluded that predation by demersal fish was a major factor responsible for changes in American lobster abundance based on interviews with 60 fishermen and the observation that the increase in lobster landings in the 1930s and 1940s occurred after demersal fish stocks had declined (no figure provided). A more recent study by Worm and Myers (2003) goes further. They plotted landings of American lobster against those of Atlantic cod from the northwest Atlantic from 1960 to 2000 and concluded that there is a significant inverse relationship. A major flaw in this study is the fact that most (>75%) of the Atlantic cod landings are from the offshore northern cod stocks (e.g., North Atlantic Fisheries Organization Divisions 2GH, 2J, 3KL, 3LMO, 3Ps, 4RS, and 3Pn), which overlap little, or not at all, in distribution with any American lobster population. Curiously, the authors also did not perform any statistical analysis to evaluate the predictive strength of the purported inverse relationship between cod and lobster catches, yet did extensive regression analysis between cod and shrimp abundance indices in the same paper. Moreover, the data as plotted (no time lags) imply that Atlantic cod are able to swallow commercial-sized lobster (>81 mm CL in most lobster fishing areas) because the graph shows commercial catches for both species. Nevertheless, Worm and Myers (2003) concluded that predation by fish can suppress abundances in the lower trophic levels, specifically shrimp, crabs, and lobster, and suggested that the next research step is to use diet composition to establish the predator–prey linkage. This diet analysis (and regression analysis) has already been done for the case of Atlantic cod preying on American lobster. Hanson and Lanteigne (2000) were unable to detect a significant inverse relationship (using regression analysis and a range of time lags) between American lobster landings and Atlantic cod biomass estimates in the sGSL, which is where over 50% of all Canadian landings of American lobster occur. In addition, they examined seasonal patterns in diet based on stomach contents of over 34 000 Atlantic cod (previously published studies and their own sampling program) and concluded that consumption of American lobster was a rare event, possibly because the distributions of Atlantic cod and American lobster overlap very little in the sGSL. Indeed, in their review of the literature, Hanson and Lanteigne (2000) failed to find any study outside the sGSL where an Atlantic cod ate a lobster.

The question of whether white hake could eat substantial numbers of juvenile lobster in the sGSL is not quite resolved. The white hake examined in this study and Hanson and Lanteigne (2000) rarely ate American lobster. Because the current study was constrained to test fish harvesters' perceptions of when and where white hake would prey upon "juvenile" lobster, no fish were collected in water <15 m deep. Despite not fishing water <20 m deep, Hanson and Lanteigne (2000) found that few lobster were eaten by white hake and the lobster eaten were very small individuals (14–15 mm CL). Both of these studies were constrained to where white hake are fished commercially. While adequate to assess potential predation on lobster 2 to 3 moults prior to entering the fishery (i.e., as small as 40 mm CL), the studies do not cover the smaller sizes of lobster. Very small lobster (e.g., <25–30 mm CL) occur typically in water <10 m deep (Lawton and Lavalli 1995); hence, neither study assessed the potential for white hake (or any other fish species) to eat very small juvenile lobster in a habitat where these small lobster are most abundant. It would seem logical that the next step in assessing the importance of fish predation as a source of mortality of juvenile lobster would be to sample the diets of fishes collected directly from locations where small juvenile lobster are most abundant. At present, the locations of nursery areas for American lobster are poorly known for the sGSL. If the effect of fish predation is truly a concern for management of lobster fisheries, then efforts should be focussed on first identifying the major nursery areas for lobster and then assessing fish predation, seasonally, at these sites.

Why then is the perception that demersal fish, particularly white hake, eat large numbers of juvenile lobster so widespread? Although some instances may have been misidentification of *A. serratus* for juvenile lobster, we think that St. Georges Bay fish harvesters have indeed observed American lobster in the stomachs of white hake. Hanson and Lanteigne (2000) found that one of roughly every 1000 white hake captured during autumn had eaten a small lobster. While the predation rate is low, a fisherman cleaning several thousand white hake per day could expect to see at least one lobster per day, making it an "every day" event. However, the commonly expressed opinion that white hake are important predators of lobster may be explained by well-studied social psychological phenomena. Here, established research in recall, memory, and frequency approximation demonstrates that what people recall seeing is influenced by the personal meaning attached to what is being observed. For example, seeing things that are potentially important to one's livelihood and its future will be remembered with much greater detail and sharpness than observations of what is felt to be less important. Indeed, the personal meaning of what people observe has been shown to influence their sense of how often meaningful observations are made. That is, meaningful observations will seem to occur more often than is actually the case. This effect has been characterized as the "availability heuristic" (Tversky and Kahneman 1973). In all likelihood, St. Georges Bay fish harvesters' concerns about white hake predation on juvenile American lobster have arisen from a very human experience such as this. The fact that their livelihood depends on the lobster fishery, combined with the moratorium on commercial white hake fishing and declining lobster catches, has contributed to a concern that white hake are increasingly preying on juvenile lobster. If the predation rate was high, it could depress recruitment into commercially exploitable populations. Recollections of white hake predation on juvenile American lobster, in this set of circumstances, become sharpened and remembered as more common than is the case. As a result, concern about the negative meaning of this for the commercial viability of lobster populations heightens. Hopefully, the results from this research will provide fish harvesters with relief from concerns respecting the prospect and impact of white hake predation on lobster.

This study has greatly improved our knowledge of white hake feeding habits in the sGSL. Before this study, little was known about white hake feeding habits in shallow, coastal waters. The most comprehensive published study was conducted in shelf waters (8–400 m deep), primarily in the Gulf of Maine. Silver hake (*Merluccius bilinearis*), sand lance (*Ammodytes* sp.), smaller white hake, unidentified clupeids, and Atlantic herring were important prey of white hake >50 cm TL, but unlike in the present study, the white hake did not eat many Atlantic mackerel (Garrison and Link 2000). This illustrates that availability is a major factor in determining the prey consumed, e.g., silver hake do not occur in the shallow waters of the sGSL and could not be eaten by sGSL hake. Nevertheless, one general conclusion is that adult white hake eat mostly pelagic fish and the species eaten seems to depend on which prey species are dominant in the specific ecosystem being studied, assuming that the prey species occurred near the bottom.

In addition to documenting white hake stomach contents systematically within the St. Georges Bay setting, this research contributes to two other potentially important considerations. On the one hand, it demonstrates that consulting and incorporating fish harvesters' ecological knowledge will enhance the design and conduct of studies aimed at exploring the ecology of marine fishes. While the content analyses of the white hake stomachs sampled do not support fish harvester's concerns about high levels of predation on juvenile lobster, the fish harvesters' advice respecting the time of year for and location of sampling did produce successful catch results during September (but not during July). These outcomes support the contentions of researchers such as Hutchings (1996) and Neis et al. (1999) respecting the categories of information held by marine harvesters that would be beneficial to marine science and fisheries assessments. Moreover, this research has also demonstrated the research design, research outcomes, and dissemination benefits of developing and working within fish harvester organization, university, and government science collaborations. As examples, the results of this collaboration have clarified the role of white hake predation within the sGSL ecosystem, have shown the sensibility of incorporating fish harvester's LEK in the research design and sample site selection process, and have been welcomed by harvesters, as evidenced in their reception of the research outcomes during presentations to association meetings, as a serious-minded and substantial response to concerns that they have voiced.

On the other hand, this research demonstrates that fish harvesters' observations and experiences have much to contribute to marine research, especially with respect to the design and conduct of research focused on examining local ecosystem concerns. Yet, the results do not demonstrate clear advantages in, or benefits from, employing systematic social science methodologies targeted on reliably documenting LEK and incorporating it into the design and conduct of marine science research. The systematically selected "local experts" did specify that sampling should occur at markedly different places, times of year, and water depths than those specified by the "opportunistically sampled" participants in the roundtable. While the sampling results during the September periods showed general similarities in the CPUE and size composition of catches between the two depth zones, the CPUE from the LEK "local expert" sites was higher. Yet, the most disappointing sampling results occurred in July 2002, at the time of year and on sites specified by the systematically selected LEK experts. From the results, it is apparent that the hake had yet to arrive on these grounds in any number. Moreover, the disproportionate numbers in spawning condition suggest that spawning was in progress. White hake do not feed extensively until *after* they have completed spawning. Given these qualities, it is highly unlikely that hake sampled during July on the "inside" sites, especially if they were spawning, would contain much food, let alone any juvenile lobster.

Needless to say, these outcomes are associated with but 2 years of sampling. It is possible that environmental anomalies and (or) other "special circumstances" altered hake behaviour in 2002. LEK, as a "system of knowledge", arises from and embodies experiences and observations with respect to "usual" conditions and circumstances. A more substantial and reliable "test" of the veracity of the LEK predictions and the benefits of documenting LEK through systematic social research practices would require that studies such as this one be run over a sufficient number of years to identify and to capture "usual" conditions and circumstances. This appears to be especially true for hake behaviour associated with the early summer time period and the shallow water locations, which contrast notably with the consistency and character of outcomes from the two September sampling periods. On the basis of the similarities and differences in results obtained, the reliability, representativeness, and confidence benefits of systematically designed and conducted social research are essential to both documenting LEK and employing LEK in marine science. Furthermore, LEK documented systematically provides harvesters with the prospect of greater "voice" in, and engagement with, marine science and resource management.

Of course, the outcomes do reflect the extent to which the LEK underscoring site selection and time frames for sampling is shared among local marine harvesters, irrespective of whether particular fish harvesters are considered by their peers to be "local experts". This methodologically demonstrated quality of LEK is critical to linking marine science research design and sampling with marine harvesters' LEK. While social science research methods may assure systematic documentation of experiences and observations, the fish harvesters' willingness to engage enthusiastically and to share their experiences and knowledge with this research illustrates the potentials of developing an approach that is inclusive, sincere, and effective.

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Appendix A

The telephone survey study was actually conducted prior to the beginning of the Social Research for Sustainable Fisheries project. It was carried out as one component of the St. Georges Bay Ecosystem Study sponsored by the Interdisciplinary Studies of Aquatic Resources program at St. Francis Xavier University. Dr. Daniel MacInnes, Department of Sociology and Anthropology, lead this phase, although Anthony Davis designed the study, drew the stratified random sample, and participated in the development of the survey instrument. The Interdisciplinary Studies of Aquatic Resources study of St. Georges Bay was also developed in collaboration with the Gulf Nova Scotia Bonafide Fishermen's Association. This phase of the study was supported by a grant from the Centre for Regional Studies, St. Francis Xavier University. A copy of the questionnaire is available from www.stfx.ca/research/srsf.

The primary purpose of the telephone survey was to solicit named peer recommendations respecting those considered to be most knowledgeable within each harbour/community site about the local fishing ground. Notably, within most of the harbour/community sites, one or two persons usually received a clear and distinguishing number of mentions, especially first mentions, as local knowledge experts. That is, in each community area, a select few are identified as highly reputed local knowledge experts. However, among those receiving only one or two mentions overall are many persons who received first mentions. Over 30% (23 of 76 persons) of those mentioned one or two times are mentioned first. Of course, this pattern may reflect little more than the fact that fisheries LEK in each setting constitutes a local "system" that is broadly shared. Indeed, several of those interviewed refused to name local experts, claiming that everyone knows "...about the same". Finally, a surprising number of those noted frequently as local knowledge experts received mentions from persons fishing and living in community areas other than their own. But, with few exceptions, these areas are adjacent. The rare exceptions to this are persons who have fished from a variety of ports. Only one woman, a local fish plant owner, received as much as one mention. This pattern demonstrates that use of the phrase "local fishing grounds" in the survey question was understood as intended and did effectively solicit responses that identify peer-referenced LEK expertise within each specific community area. It needs to be noted that the peer-referencing approach runs the risk of underrepresenting the likelihood of nonfishing and socially marginalized fish harvesters being nominated as local ecological knowledge experts, even though it is possible that persons falling within these categories may be very knowledgeable about local fishing ecology

The face-to-face interviews were guided by an interview schedule organized into three main sections. The interviews opened with a focus on the participants' family fishing genealogy. The purpose here was to document the depth and character of the familial social content with respect to participation in fishing. This opening focus was followed by detailed documentation of the participants' personal history of involvement in fishing, beginning with their first fulltime experiences. The participants were asked questions ranging from the name and attributes of the boats on which they fished and the social attributes of the persons with whom they were fishing, through the types of fishing that they were doing and the quantity of gear that they were fishing, to the locations of the grounds that they were fishing and the times of year that they pursued various fisheries.

The final section of the interview asked the participants to describe attributes of their experiences in and knowledge of the fishing grounds and specific fisheries. The opening attributes of this questioning were organized with respect to the names of some of the boats on which the participants fished. Boats named in the life history section were selected as a means to assist the participants to locate their recollections and experiences in both space and time. This approach was intended to provide a relative chronology of time and space experiences for each participant in sufficient detail that would enable the association and comparison of participants' experiences and observations about particular fishing and fishing grounds. A copy of the interview schedule is available from www.stfx.ca/research/srsf.

The interview information was transcribed and developed into a qualitative database. The Atlas-ti software package is being employed to conduct systematic searches and analyses of these data. Additionally, the information recorded on the nautical charts is being digitized through use of the MapInfo software package.