A survey of wolffish (*Anarhichas* spp.) and wolffish habitat in Les Méchins, Quebec

Richard Larocque, Marie-Hélène Gendron, and Jean-Denis Dutil

Direction régionale des Sciences
Ministère des Pêches et des Océans
Institut Maurice-Lamontagne
850, route de la Mer
Mont-Joli, Quebec, G5H 3Z4

2008

Canadian Technical Report of
Fisheries and Aquatic Sciences 2786

Fisheries and Oceans Canada | Pêches et Océans Canada

Canada

Canadian Technical Report of Fisheries and Aquatic Sciences

Technical reports contain scientific and technical information that contributes to existing knowledge but which is not normally appropriate for primary literature. Technical reports are directed primarily toward a worldwide audience and have an international distribution. No restriction is placed on subject matter and the series reflects the broad interests and policies of Fisheries and Oceans Canada, namely, fisheries and aquatic sciences.

Technical reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report is abstracted in the data base *Aquatic Sciences and Fisheries Abstracts*.

Technical reports are produced regionally but are numbered nationally. Requests for individual reports will be filled by the issuing establishment listed on the front cover and title page.

Numbers 1-456 in this series were issued as Technical Reports of the Fisheries Research Board of Canada. Numbers 457-714 were issued as Department of the Environment, Fisheries and Marine Service, Research and Development Directorate Technical Reports. Numbers 715-924 were issued as Department of Fisheries and Environment, Fisheries and Marine Service Technical Reports. The current series name was changed with report number 925.

Rapport technique canadien des sciences halieutiques et aquatiques

Les rapports techniques contiennent des renseignements scientifiques et techniques qui constituent une contribution aux connaissances actuelles, mais qui ne sont pas normalement appropriés pour la publication dans un journal scientifique. Les rapports techniques sont destinés essentiellement à un public international et ils sont distribués à cet échelon. II n'y a aucune restriction quant au sujet; de fait, la série reflète la vaste gamme des intérêts et des politiques de Pêches et Océans Canada, c'est-à-dire les sciences halieutiques et aquatiques.

Les rapports techniques peuvent être cités comme des publications à part entière. Le titre exact figure au-dessus du résumé de chaque rapport. Les rapports techniques sont résumés dans la base de données *Résumés des sciences aquatiques et halieutiques.*

Les rapports techniques sont produits à l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur dont le nom figure sur la couverture et la page du titre.

Les numéros 1 à 456 de cette série ont été publiés à titre de Rapports techniques de l'Office des recherches sur les pêcheries du Canada. Les numéros 457 à 714 sont parus à titre de Rapports techniques de la Direction générale de la recherche et du développement, Service des pêches et de la mer, ministère de l'Environnement. Les numéros 715 à 924 ont été publiés à titre de Rapports techniques du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom actuel de la série a été établi lors de la parution du numéro 925.

Canadian Technical Report of
Fisheries and Aquatic Sciences 2786

2008

A SURVEY OF WOLFFISH (*Anarhichas* spp.) AND WOLFFISH HABITAT IN LES MÉCHINS, QUEBEC

by

Richard Larocque, Marie-Hélène Gendron, and Jean-Denis Dutil

Direction régionale des Sciences
Ministère des Pêches et des Océans
Institut Maurice-Lamontagne
850 route de la Mer
Mont-Joli, Quebec, G5H 3Z4
E-mail: Richard.Larocque@dfo-mpo.gc.ca

© Her Majesty the Queen in Right of Canada, 2008.
Cat. No. Fs 97-6/xxxE ISSN 1488-5379

Correct citation for this publication:

Larocque, R., M.-H. Gendron and J.-D. Dutil. 2008. A survey of wolffish (*Anarhichas* spp.) and wolffish habitat in Les Méchins, Quebec. Can. Tech. Rep. Fish. Aquat. Sci. 2786 : vi + 29 p.

TABLE OF CONTENTS

LIST OF FIGURES v
LIST OF TABLES v
LIST OF APPENDICES v
ABSTRACT vi
RÉSUMÉ vi
1. INTRODUCTION 1
1.1 CURRENT STATUS AND DECLINE 1
1.2 WORK OBJECTIVES 1
1.3 DISTRIBUTION, LIFE HISTORY, AND HABITAT 2
1.4 EXPECTED CONTRIBUTION TO RECOVERY STRATEGY 3
2. MATERIALS AND METHODS 4
2.1 SITE SELECTION 4
2.2 MULTIBEAM ACOUSTIC SURVEY 5
2.2.1 Procedure 5
2.3 DIVING OPERATIONS 5
2.3.1 Methods and equipment 5
2.3.2 Fish counts 5
2.3.3 Fish measurement method 6
2.4 STOCKING AND RELEASE EXPERIMENT 7
2.4.1 Breeding stocks and production 7
2.4.2 Tagging and fish preparation 7
2.4.3 Release strategy and method 7
3. RESULTS 9
3.1 HABITAT DESCRIPTION 9
3.2 WOLFFISH OBSERVATIONS 11
3.3 DESCRIPTION OF SHELTERS 11
3.4 FISH SIZE 13
3.5 SPECIES ASSOCIATIONS 13
3.6 STATUS OF FISH RELEASED IN 2004 14
3.7 NOTABLE OBSERVATIONS 14
4. DISCUSSION 15
4.1 HABITAT, SHELTER USE, AND COMPETITION 15
4.2 INSIGHTS ON REPRODUCTION 16
4.3 FISH RELEASE AND SURVIVAL 17

4.4 TECHNICAL LIMITATIONS AND INNOVATIONS 17
4.5 MULTIBEAM SURVEY.. 18
4.6 ON THE ROLE OF DIVERS 19
4.7 KNOWLEDGE GAPS AND FUTURE WORK 19
5. ACKNOWLEDGMENTS 20
6. REFERENCES.. 21

LIST OF FIGURES

Figure 1. Study area near Les Méchins, Quebec, Canada, including the 2004 fish release sites of *A. minor* and *A. lupus* 4
Figure 2. Fish head and shelter measurements using a dual beam laser device 6
Figure 3. Side view of the fish-release cage. Dimensions are in centimeters........ 8
Figure 4. Three-dimensional representations of multibeam data for reef C. 9
Figure 5. Three-dimensional representations of multibeam data for reef B 10

LIST OF TABLES

Table 1. Number of fish released, average fish length and mass (mean and standard deviation)........ 8
Table 2. Number of dives, number of wolffish observed, and mean depth of sightings (range in parentheses) for all sites during the three-year study period 11
Table 3. Individual wolffish sizes and shelter dimensions 12
Table 4. Correlation coefficients (R^2) for linear regressions between size of head features vs length for two groups of *A. lupus* 13
Table 5. Other species found in or around wolffish shelters. 14

LIST OF APPENDICES

Appendix A. Diving data summary 23
Appendix B. Typical wolffish shelters 24
Appendix C. Shelter descriptions and drawings 25
Appendix D. Detailed list of individual wolffish found during the 2005–2006 surveys 28

ABSTRACT

Larocque, R., M.-H. Gendron, and J.-D. Dutil. 2008. A survey of wolffish (*Anarhichas* spp.) and wolffish habitat in Les Méchins, Quebec. Can. Tech. Rep. Fish. Aquat. Sci. 2786: vi + 29 p.

Atlantic wolffish (*Anarhichas lupus*) and spotted wolffish (*A. minor*) are respectively listed as a species of special concern and as a threatened species under the Species at Risk Act (SARA) in Canada. The objectives of this work were to gather information on a near-shore wolffish population in the St. Lawrence estuary in eastern Quebec, to evaluate methods related to wolffish studies, and to assess the feasibility of wolffish release and in situ monitoring. The local *A. lupus* distribution was found to be vertically limited by temperature, with wolffish avoiding the surface layer affected by the Gaspé Current. The numbers of fish on the deeper reefs was relatively constant over the two years of the study, with many specimens spending long periods in the same shelters. Winter survival following a fish-release experiment was confirmed by scuba observations. Migration may explain the apparent low success rate of the release effort. Fish pairings and egg masses were observed, and this led to an evaluation of the role of coastal reefs in the life history of *Anarhichas* spp. A non-intrusive method for measuring fish was used by scuba divers and is described. The use of a high-resolution multibeam sonar survey as a tool for scuba divers and habitat-related work is also discussed.

RÉSUMÉ

Larocque, R., M.-H. Gendron, and J.-D. Dutil. 2008. A survey of wolffish (*Anarhichas* spp.) and wolffish habitat in Les Méchins, Quebec. Can. Tech. Rep. Fish. Aquat. Sci. 2786: vi + 29 p.

Le loup Atlantique (*Anarhichas lupus*) et le loup tacheté (*A. minor*) sont respectivement inscrites comme espèces préoccupante et menacée selon la Loi sur les Espèces en Péril (LEP). Les objectifs de ce travail étaient d'acquérir des connaissances sur une population côtière de loups de l'estuaire du Saint-Laurent dans l'est du Quebec, d'évaluer des méthodes d'étude de ces espèces et la faisabilité d'ensemencer des poissons puis d'en faire le suivi in situ. Il a été démontré que la distribution verticale de *A. lupus* est limitée par la température, les loups évitant la couche de surface sujette au courant de Gaspé. Le nombre de loups sur les récifs profonds est demeuré sensiblement constant sur deux ans avec plusieurs poissons occupant les mêmes abris pour de longues durées. La survie hivernale suivant une expérience d'ensemencement a été confirmée par des observations en plongée et la migration est suggérée pour expliquer le taux de succès relativement faible de cet effort. Des couples de loups et des masses d'œufs ont été observés et ceci a mené à une évaluation du rôle des récifs côtiers dans le cycle de vie de *Anarhichas* spp. Une méthode de mesure non intrusive des loups a été utilisée et est décrite. L'utilisation de relevés multifaisceaux à haute résolution comme outils pour les plongeurs et pour les travaux reliés à l'habitat est aussi discutée.

1. INTRODUCTION

1.1 CURRENT STATUS AND DECLINE

From as early as 1996 (Kulka and DeBlois 1996), a sharp decline has been noted in the biomass of the three species of wolffish in Newfoundland and Labrador waters as well as in the Gulf of St. Lawrence. This decline continued although the fishing effort was reduced significantly (Simpson and Kulka 2002). In November 2000, the Atlantic wolffish (*Anarhichas lupus*) was declared a species of special concern by COSEWIC. The northern wolffish (*A. denticulatus)* and the spotted wolffish *(A. minor)* were designated threatened species in May 2001. All three species were listed in Appendix 1 of the *Species At Risk Act* in June 2003. The exact causes of the decline are unknown, but bycatch by other fisheries and environmental causes have been suggested as potential causes (Simpson and Kulka 2002). The status of these species is also difficult to establish since there are currently low catches and wolffish are often not identified to the species level in commercial catch data. This is especially true in the St. Lawrence, where the time series from commercial fisheries are short. This uncertainty calls for a conservative assessment of the current status of wolffish in the estuary and Gulf of St. Lawrence.

1.2 WORK OBJECTIVES

Although several aspects of wolffish biology can be studied within an experimental framework using fish raised in captivity, some information on fish and their habitats can only be obtained by direct observation in the natural environment. Unfortunately, *A. minor* is seldom found at depths that are accessible to divers, and remote observations of such an elusive species represent logistical and technical challenges that go beyond the scope of the present work.

To supplement the experimental work being done on fish interactions and habitat use by *A. minor* in our laboratory (Dutil et al. in prep.), the decision was made to also undertake scuba-based field work. The goal of this small-scale project was to gather qualitative and quantitative data on the use of rocky habitats by wolffish and to evaluate the feasibility of various in situ techniques to document specific aspects of wolffish biology in the St. Lawrence within a local coastal environment. Specifically, a technique for fish release and stocking was designed and its success evaluated. To our knowledge, this is the first documented study to release wolffish and attempt to monitor its success. A multibeam sonar survey was undertaken to describe the physical habitat and to create high-definition maps for use by divers during exploration. A series of dives were done over a two-year period to gather information, including fish size and numbers, on the local wolffish population off Les Méchins, Quebec. When possible, fish and shelter measurements were also made using modern imaging and measurement techniques as a low-impact alternative to live capture.

1.3 DISTRIBUTION, LIFE HISTORY, AND HABITAT

In the northwestern Atlantic, *A. minor* and *A. lupus* are mostly found off the coast of Labrador, along the coast of Newfoundland, on the Grand Banks, in the Gulf of St. Lawrence, and along the coast of Nova Scotia down to the state of Maine (Scott and Scott 1988, Simpson and Kulka 2002). In the estuary and Gulf of St. Lawrence, *A. lupus* is more common than *A. minor*. There are also occasional reports of *A. denticulatus* in the St. Lawrence. The historical and current distribution of wolffish in the Gulf of St. Lawrence will be described in a separate report.

Although widely distributed in the Northwest Atlantic, wolffish do not form dense concentrations and their distribution has become more dispersed and fragmented during the last 30 years (DFO 2004). *A. minor* and *A. lupus* numbers were high enough as a bycatch in commercial fisheries to make it to market. Most of the earlier landings in the Gulf of St. Lawrence were reported from north of the Laurentian Channel and off Anticosti Island. Their distribution has since expanded to include more areas along the edges of the channel (McRuer et al. 2000), but their stock structure in Canada is still largely unknown (DFO 2004).

Wolffish are demersal fish that can reach 150 cm in length and weigh close to 20 kg (O'Dea and Haedrich 2002). They have an elongated body, a large round head, protruding teeth and a continuous dorsal fin. Wolffish are considered a low-productivity fish because of their low growth rate and late sexual maturity (five to ten years) in the wild (Scott and Scott 1988). Egg production is low relative to fish size, but internal fertilization, large egg size, larval behaviour, and parental care (as observed for *A. lupus)* increase the survival potential (Keats et al. 1985). The wolffish diet consists of echinoderms, crustaceans, molluscs, and fish in varying proportions according to size, species, and time of year (Gonzalez et al. 2006). It is believed that each of the three wolffish species have a narrow temperature range, between 1.5 and 5°C, and are rarely found below 0°C (Kulka et al. 2004).

Wolffish reproductive patterns vary between areas, time of year and species. East of Newfoundland, *A. lupus* migrate to shallow waters in the spring and mate in September, and eggs hatch in mid-December (Keats et al. 1985); it is not clear whether these periods are the same for the St. Lawrence population. The reproductive behaviour of fish kept in tanks was characterized by an extended courtship behaviour beginning a few months prior to spawning. One study observed males and females lying together in what was believed to be copulation (Johannessen et al. 1993). There is no knowledge of reproductive behaviour in natural conditions beyond diving depths and observations have only been made for *A. lupus* (Keats et al. 1985, Kulka et al. 2004). Reproduction in *A. lupus* takes place either in shallow waters or at depths greater than 150 m (McRuer et al. 2000). Wolffish use nests, dens, and shelters located in rocky areas, in natural cavities, and under or between boulders (O'Dea and Haedrich 2002). Eggs are large (> 6 mm) and are laid in cohesive masses on the bottom. The male guards them inside the shelter and hardly feeds until hatching takes place (Keats et al. 1985). This behaviour has also been observed with the ocean pout, a species sometimes mistaken for wolffish by scuba divers. Newly hatched larvae are approximately 18 mm in size and remain close to the nest until the yolk sac is absorbed (McRuer et al. 2000). A review done by the Wolffish Recovery Team (2006) notes that nesting and parental care have never been described for *A. minor*. According to Templeman (1986), *A. minor* in the North Atlantic spawn during the summer but female fish kept in captivity matured from July to January, with a peak in October. *A. minor* eggs are also laid in clusters on the bottom, but this takes place in deeper waters than for *A. lupus* (O'Dea and Haedrich 2002). The incubation period is about 900 degree-days (similar to *A. lupus*). In tank-reared fish, larvae hatched approximately 16 to 17 weeks after fertilization (Falk-Petersen et al. 1999). For both species, larvae feed and live pelagically for several weeks until they reach approximately 40 mm (Falk-Peterson et al. 1999).

Wolffish habitats are poorly known in part because wolffish live at great depths where direct visual observations cannot be made. Most of the available information is derived from catches made during groundfish surveys, particularly in the Grand Banks area. The depth distribution of *A. lupus* extends from less than 50 m to more than 500 m, but they occur more frequently in the 100 m to 200 m range depending on the geographic area (O'Dea and Haedrich 2002). They are found on hard substrates and rarely on muddy bottoms (McRuer et al. 2000). *A. minor* shows a preference for hard and sandy bottoms associated with trenches in deeper waters, typically at depths of 200–750 m (Albikovskaya 1982). Kulka et al. (2004) noticed that *A. lupus* was not found in areas of reduced salinity; they were always found below major haloclines. They are occasionally observed close to shore by divers and have been observed in caves and crevices between and under large rocks that can serve as shelters for reproduction and possibly feeding areas. This species makes seasonal inshore migrations during spring to shallow waters (0–15 m) (Keats et al. 1985). However, migration studies suggest that wolffish are mainly sedentary (Templeman 1984). Some authors conceptualized wolffish habitat as a range of ambient temperatures rather than a particular physical location (DFO 2004, Kulka et al. 2004). Few studies have described the landscape and physical characteristics of the rocky inshore habitats used by *A. lupus* (Keats et al. 1985).

1.4 EXPECTED CONTRIBUTION TO RECOVERY STRATEGY

Very little is known of the typical habitat of these species. Significant knowledge gaps remain as to their distribution, life history, and environmental factors that can adversely affect the species at both the individual and population levels. This makes wolffish conservation a complex endeavour. Our work addresses three primary objectives of the recovery strategy: by improving our understanding of wolffish biology and life history, by identifying wolffish habitat, and by promoting wolffish population growth and recovery.

Most of what is known about *Anarhichas* spp. in Canada is derived from data and work that originate from the Atlantic Provinces and in particular from Newfoundland and Labrador. While the presence of wolffish in the St. Lawrence estuary and western Gulf is known, little work on wolffish biology has been done in this area. The site in Les Méchins appears to be favourable to wolffish. Observations from this site provide information on habitat use in an area that has not yet been studied. This will help to determine how significant shelter-rich rocky near-shore environments are as wolffish habitat. Since these areas are generally avoided by commercial fisheries operations, they may act as seed areas for the wolffish population as a whole and may thus warrant specific protective measures.

2. MATERIALS AND METHODS

2.1 SITE SELECTION

The site, locally known as the Ilets, is located 3.5 km west of the village of Les Méchins, a shipyard and fishing community, and 45 km northeast of Matane, Quebec, Canada. The feature that gives its name to the area is a 700m-long string of small islands parallel to shore. The site (Fig. 1) was chosen since it met most of our essential criteria, including easy access and the potential for monitoring by recreational divers. There is a long-term record of anecdotal wolffish (exact species is unknown) sightings by divers at this popular dive site (48°59.50'N, 067°01.20'W). Different habitats at different depths (0–30 m) are accessible within a small area; the site is easily accessible by boat and there are no known fisheries that could affect wolffish in this area. Interestingly, a new reef that had never been visited by divers was discovered during this work. This reef is located less than one kilometre east of reef B and can now be used as a reference site, undisturbed by divers or mobile gear fishing activities.

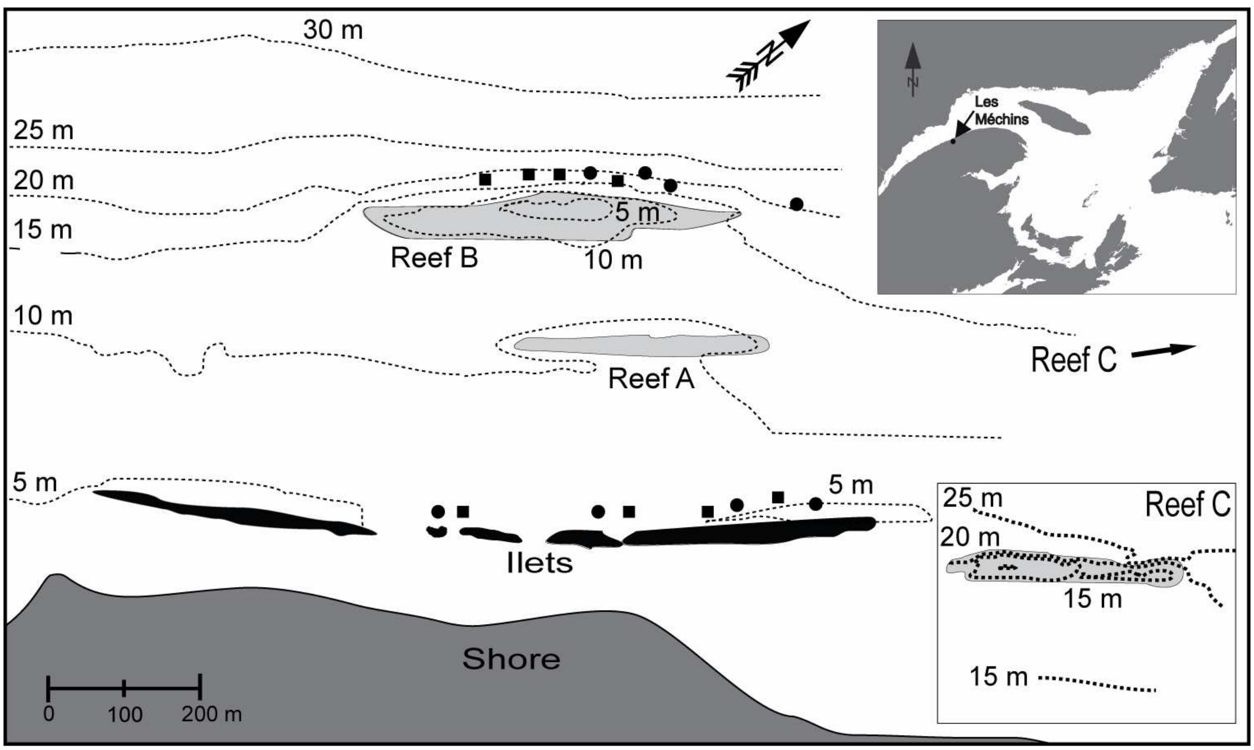


Figure 1. Study area near Les Méchins, Quebec, Canada, including the 2004 fish release sites of *A. minor* (■) and *A. lupus* (●).

2.2 MULTIBEAM ACOUSTIC SURVEY

2.2.1 Procedure

The area was surveyed using a MultiBeam Echosounder System (MBES) on 30-31 May 2005. The Kongsberg EM3002 MBES was used and operated by the Canadian Hydrographic Service (CHS) onboard the *Guillemot*, a 9.1 m fast survey launch. The objective of the survey was to create high-resolution maps of the seafloor for planning exploration dives and to identify new potential wolffish habitat, defined as areas offering a high probability of shelters and overhangs. The survey was performed using a full overlap of the swath patterns to optimize the quality of backscatter data on the full swath width. An area of approximately 1.75 km^2 was surveyed by the *Guillemot*. On 9 September 2005, this survey was completed by the CCGS *Frederick G. Creed* (20.4 m SWATH catamaran) while en route to the Gaspé area. The onboard Kongsberg EM1002, also operated by the CHS, was used to extend the survey area along the coast on both sides of the original study site. Although this second survey did not provide as much detail as the previous one, it was very effective in covering a large area (3.60 km^2) in a single day.

2.3 DIVING OPERATIONS

2.3.1 Methods and equipment

Twenty-four dives were made during this project, with a total dive time of over 19 hours. Supplemental dive data are presented in Appendix A. Dive times were limited by depth and diving cylinder size. Nitrox-36 (enriched air, 36% oxygen), large cylinders, and dive computers were used on all dives to increase non-decompression bottom times. Depth, time, and temperature were logged by both divers, and dive data were downloaded after each day of diving. All reported depths have been tide-corrected to the nearest 15 minute interval and are referenced to the lowest mean tide. The dives were conducted by two scuba divers supported by a surface/safety tender that remained in the boat. The boat was anchored in a shallow area near the sector to be investigated. For the offshore reefs, this meant anchoring above the reefs.

2.3.2 Fish counts

The search technique was identical for all sites. Once in the water, the divers swam to the designated areas and proceeded to explore all visible shelters. Any partly enclosed area was considered to be a potential shelter. The divers worked side by side at the maximum distance that visibility allowed and used powerful lights, both to search the holes and to signal their position and intentions to the other diver. When a wolffish was found, the time and its depth were noted on a notepad on the diver’s arm. Laser measurements (described in the next section) were made by one diver while the other took video footage of the operations. After these measurements were completed, the divers resumed their previous positions and continued their search. At the turnaround point, if the end of the sector had not been reached, a conspicuous marker was left on site and was used as the starting point for the following dive. The estimated positions of the start and end of the search were noted when back on the boat. Summary exploration of the sandy areas below reef B and between the Ilets and reef B were also undertaken to confirm the absence of wolffish in those areas.

2.3.3 Fish measurement method

Since wolffish are seldom encountered outside of their shelters, one objective of this project was to evaluate a method to estimate fish size from head features that could be remotely measured. At the same time, the projected area of the shelter openings would be estimated.

Using eight *A. lupus* specimens from the Maurice Lamontagne Institute's (MLI) brood stock, various measurements were made (Fig. 2) on anaesthetized fish. Head features were measured and correlated with fish length and weight. The objective was to find one or a combination of head measurements that would be highly correlated with length or weight. Eight more fish were measured during a groundfish survey to confirm the initial correlations. One year later, the validity of the method was confirmed on six additional fish from our brood stocks. Following these trials, we were able to estimate fish size remotely in the field using video cameras and fixed-width laser markers.

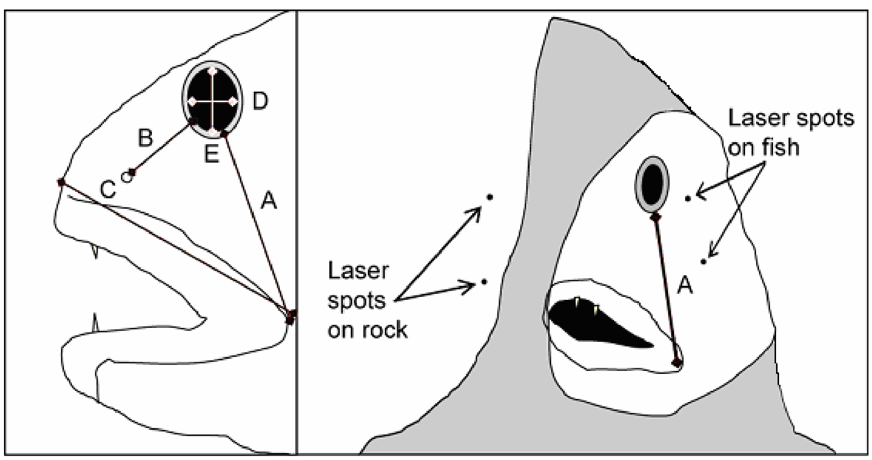


Figure 2. Fish head and shelter measurements using a dual beam laser device. A: Jaw to eye; B: Eye to nostril; C: Jaw to nose; D: Eye width; E: Eye height.

A system of three lasers at an equidistance of 5 cm was used in 2005. This device projected three bright red dots on or near the head or on features near the shelter's entrance. In 2006, a different system using two lasers separated by 8 cm was used. Video footage was shot at the same time and at the same angle as the lasers. In 2005, video was shot using a standard mini-DV camera (Sony VX2000); in 2006, a high definition video camera (Sony HDR-FX1) was used. Both systems were housed inside dedicated Amphibico (Montreal, Qc, Canada) housings and used with high intensity discharge (HID) lights.

Image analysis was done on images captured from video (Sony Vegas Movie Studio 6.0). When possible, several frames were captured for each fish and/or shelter. Head features and laser distances were measured in Photoshop CS (Adobe Corp.) and fish length was estimated based on a calibration regression. The surface areas of the shelter openings were estimated using size-calibrated images in Visio (Microsoft Corp.). Efforts were made to reduce parallax errors by positioning the laser and camera on the same plane as the opening.

2.4 STOCKING AND RELEASE EXPERIMENT

2.4.1 Breeding stocks and production

Experimental stocks of both species were produced in captivity at MLI. *A. minor* were reared from artificially fertilized eggs obtained from our brood stock, which is composed of individuals caught east of Anticosti Island in the Gulf of St. Lawrence. *A. lupus* were reared from a clutch of eggs obtained from another facility in February 2000. Prior to release, *A. lupus* had been fed capelin while the smaller *A. minor* received commercial fishmeal. After obtaining the required permits for fish introduction, a small-scale experimental release was undertaken in November 2004.

2.4.2 Tagging and fish preparation

After fish were anaesthetized with a benzocaine solution, a blue numbered tag (T-Bar anchor, FD-68B, Floy Tag Co.) was inserted in the muscle below the dorsal fin. All *A. lupus* already had PIT (Passive Integrated Transponder) tags (12/14 mm, Advanced ID Corporation). The PIT tags were not used with *A. minor* because of their smaller size. All fish were maintained at 4°C during their transport in 500 L insulated tanks equipped with forced aeration. At the time of the release, *A. lupus* and *A. minor* specimens were 58 and 10 months old, respectively.

2.4.3 Release strategy and method

Fish of both species were released in small groups using a novel release cage fitted with a remote video camera. The release cage consisted of a 52 cm (W) x 52 cm (D) x 32 cm (H) steel framed box with a sloping bottom that was covered with 7 mm nylon mesh and supported under a 63 cm high triangular frame (Fig. 3). A compact wide-angle S-video (Y/C) camera (Subsea Video Systems Inc.) fitted to the frame pointed towards the cage opening. The bottom of the cage had a sloping floor (narrow end: 22 cm) that led to a top-hinged door. A rubber bungee cord ensured that the door remained closed until released by the operator. Stability was improved by placing 1.5 kg weights at the cage's corners. The cage was lowered in the water by a nylon/Kevlar multi-conductor cable that also powered the camera and lights and sent back the video feed to the surface. A small nylon rope was used to operate the cage door.

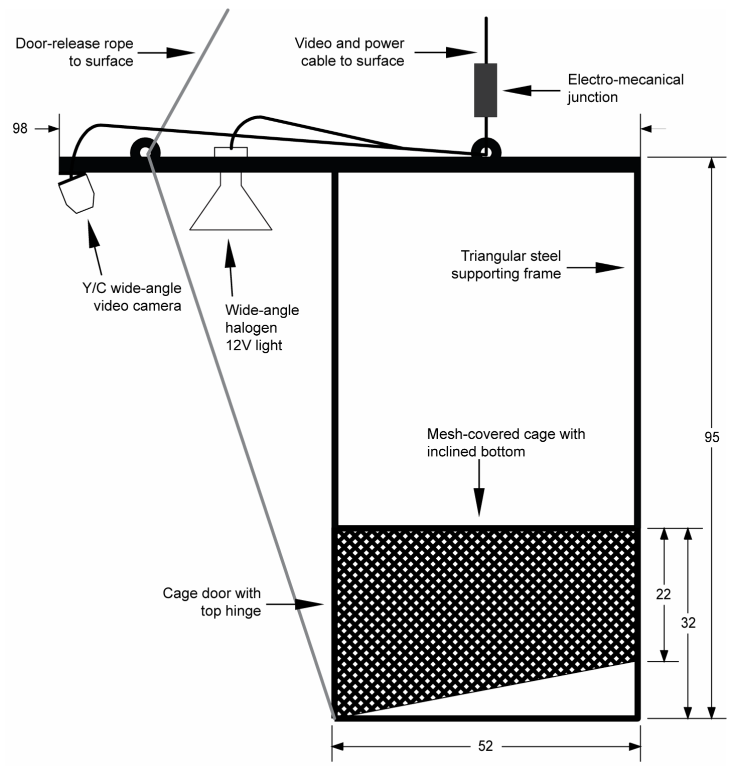


Figure 3. Side view of the fish-release cage. Dimensions are in centimeters.

The outer section of the Ilets and of reef B were chosen for this experiment based on what was believed to be favourable substrates and good prey availability. Potential release sites (Fig. 1) were identified and a 5 m rigid-hull inflatable boat was used for the release operation. Small numbers of fish were transported to the sites in coolers and were transferred to the release cage while the cage was partially submerged. The cage was lowered until the seafloor became visible on the video monitor. Once a suitable substrate was found, the door was opened and the fish released. The video feed made it easy to confirm that all fish had been released and had cleared the cage. A total of 91 fish were released (Table 1) at 16 positions (Fig. 1) where the substrate was deemed favourable, i.e., where large rocks and potential shelters were visible.

Table 1. Number of fish released, average fish length and mass (mean and standard deviation).

		A. lupus	*A. minor*
Les Ilets	Length (mm)	491 ± 25	200 ± 16
	Mass (g)	1058 ± 221	78 ± 24
		n = 21	n = 23
Reef B	Length (mm)	491 ± 15	209 ± 29
	Mass (g)	1052 ± 133	97 ± 50
		n = 23	n = 24

3. RESULTS

3.1 HABITAT DESCRIPTION

The multibeam survey confirmed the size and position of the smaller outcrop known as reef A. The exact size, shape, and extent of what is now called reef B was also confirmed. The main discovery from the surveys is that a previously undocumented submerged reef was found east of reef B which we call reef C (Fig. 4). It is a saddle-shaped outcrop, 300 m long by 35 m wide at its widest point with the upper portion at an average depth of 15 m. Its northern side is composed mainly of vertical cliffs while the southern part is a rocky slope that leads to a sandy plain towards the shore.

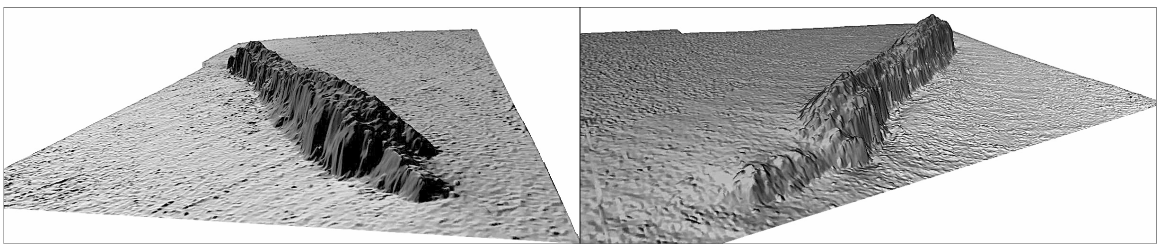


Figure 4. Three-dimensional representations of multibeam data for reef C. North is to the left on the left image and to the right on the right image (2.5x vertical exaggeration).

Both surveys also confirmed that there is no other diver-accessible reef further offshore from reef B (Fig. 5). The *F.G. Creed* survey failed to find any other significant features east or west of the main reefs. However, a group of four small areas with steeper gradients were found east of reef C (not shown). In other sectors, the more detailed high-resolution charts that were obtained from the *Guillemot* survey showed enough detail to identify individual rocks and boulders. The multibeam data were also used to create a detailed depth chart of the area (Fig. 1).

By combining the multibeam data with diver observations, the area's topology and associated macrofauna can be described in great detail. The 70 m wide channel that separates the islands from shore is only partially submerged at low tide, with no more than 3 m of water at its deeper parts. The northern side of the Ilets drops off to 10–12 m and is characterized by boulders and large rocks leading to a sandy bottom. Going further out, the substrate is a mixture of coarse gravel and sand. At 175 m off-shore from the islands, a small 300 m by 25 m by 2 m high rock outcrop (reef A) emerges from the bottom. A second reef (reef B) is 90 m further out. This is a massive structure measuring 430 m long by 65 m at its widest part, and it rises up to 3 m from the surface at low tide. Its north side is a steep slope that bottoms out at about 25 m. The base of the slope is best described as a complex maze of rocks and boulders measuring up to 3 m across sitting on a gravel and bedrock bottom. This creates a large number of overhangs, crevices, tunnels, and small grottos. Other than the southeast side of the Ilets, the area is not protected from waves, wind, or strong tidal currents.

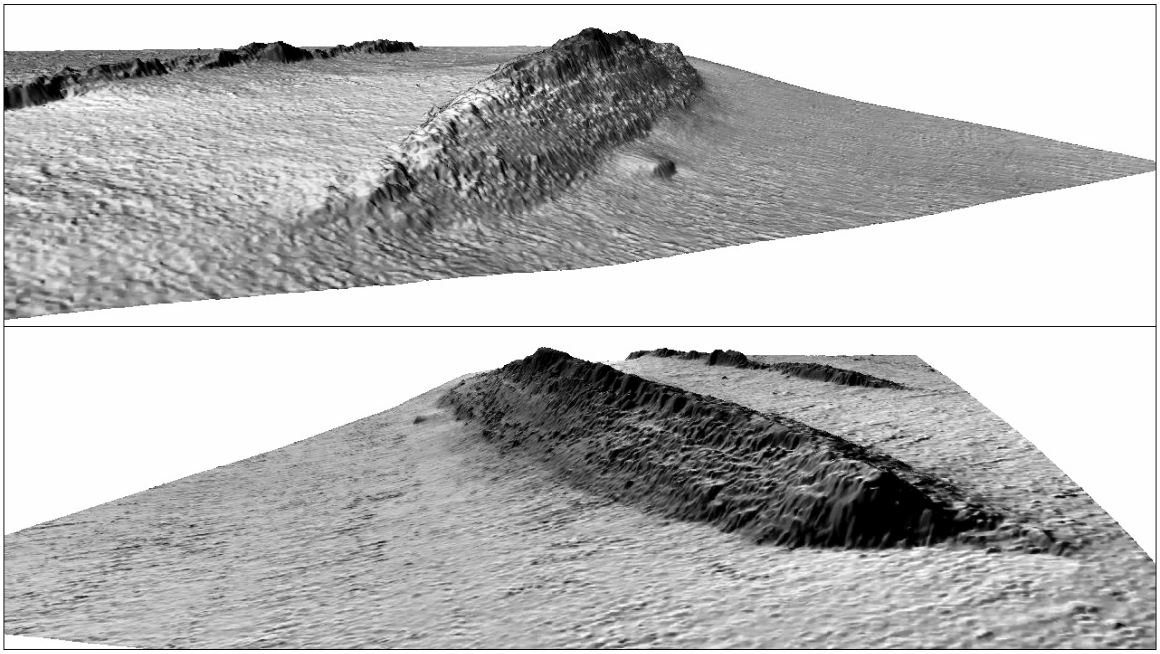


Figure 5. Three-dimensional representations of multibeam data for reef B, with reef A visible in the background. North is right on top image, left on bottom image (2.5x vertical exaggeration).

The area can be divided into three distinct sectors based on depth. The upper section from the surface to 5–7 m is characterized by large marine algae such as *Laminaria* spp. and the associated invertebrate fauna that lives among the holdfasts. This area is subjected to strong surface currents, occasional low salinities and strong waves. This area is where the longshore Gaspé Current is at its strongest. When combined with tidal effects, it is a limiting factor for diving. Beneath this surface layer and down to 20 m, the fauna is highly diversified and exceptionally dense on hard substrate areas, such as on the outer reefs. On the reefs, echinoderms, cnidarians, and crustaceans are abundant and provide the colourful environment that has made this site popular with divers. During summer, the area below 20 m is distinct from the top layers with little or no current. Fauna in the deeper areas is similar to the upper layer albeit at lower densities. Vertical stratification was present at all times but was stronger in August, when a strong thermocline was well established at a depth of 10 to 15 m, with temperatures dropping from 10°C or more to 4–6°C within a few metres. Another limiting factor was turbidity. Periods of high rains resulted in poor visibility related to increased river runoff. On some days in August 2006, surface visibilities were less than one metre because of a major bloom of the diatom *Skeletonema costatum*. Visibility was always greater below 20 m.

The charts were used to plan the dives and served as underwater navigation references to estimate what area was covered during each dive. Coupling visual observations with the multibeam data enabled us to identify areas where there was a high probability of finding wolffish. According to earlier in situ observations, areas with large boulders, rock piles, or transitions between hard and soft substrates were considered as being favourable sites for wolffish. Based on this information, the north (offshore) sides of the two outer reefs were targeted for most of the scuba-based surveys. One exploratory dive (not listed in Table 2) was also done on the largest of the four outcrops found east of reef C. It confirmed that these are areas where the bedrock is visible but where the bottom is flat with no boulders or other significant features.

3.2 WOLFFISH OBSERVATIONS

A. lupus were not distributed randomly across reefs. No fish were found at the Ilets site other than two *A. lupus* in 2004 that had been recently released. In contrast, 43 wolffish encounters were recorded for reef B (Table 2). Up to five wolffish were observed on every dive with the exception of one dive at the western end of the reef, where the substrate offered few potential shelters. The success rates were also high at reef C in both 2005 and 2006, with a total of 19 wolffish observations. Typically, wolffish were observed in shelters and not swimming around during daylight hours, when diving took place and visual observations were made. The fish usually showed no reaction to the laser device or to dive lights. Because surveyed areas sometimes overlapped, some wolffish were observed in their shelters over several days but were only counted once.

Table 2. Number of dives, number of wolffish observed, and mean depth of sightings (range in parentheses) for all sites during the three-year study period.

Site	Year	Number of dives	Total dive time (min)	Number observed	Depth (m)
Ilets	2004	1	60	2	6 (6-6)
	2005	4	220	0	--
Reef B	2005	7	314	28	19 (13-23)
	2006	5	218	15	20 (17-23)
Reef C	2005	4	208	13	23 (21-25)
	2006	3	141	6	22 (22-23)

3.3 DESCRIPTION OF SHELTERS

Shelters were located at an average depth of 20 m (Table 2), below the thermocline and the zone affected by the strong surface currents. Most shelters were at the base of large rocks and boulders and located near the area where the rocky slope ends. Shelters typically had a small opening from which only the fish head was visible facing outside. Sessile invertebrates such as sponges, anemones, and bryozoans often covered the entrance. In most cases, a small mound of sand and shell debris was present in front of the opening. It is believed that this mound is the result of fish activity and some level of active excavation. The height of the shelter openings averaged 14 cm (range 5.4–26.0 cm) while the width varied from 8.2 to 150 cm (mean = 37.8) (Table 3). For six encounters, fish and shelters could both be measured reliably (Table 3). There was no relationship between shelter width and fish size for the small sample available (P=0.786, R^2 =0.0204, n=6). In some shelters, the fish head occupied most of the available area. The depth (length) of each shelter could not be measured without disturbing the fish. Based on diver observations, we estimate that the depth of the shelters was typically close to twice the fish length. One shelter where two fish were repeatedly found had a larger opening than most others (1082 cm^2, no. 46). Photographs of typical shelters are presented in Appendix B and detailed drawings of most shelters are presented in Appendix C.

Table 3. Individual wolffish sizes and shelter dimensions. "n": number of images used to estimate fish size. Missing values indicate that no video data was available.

Fish / shelter no.	Height (cm)	Shelter Width (cm)	Opening (cm^2)	Estimated wolffish length (cm)
11[1]	15	100		75
12[1]	15	100		70
13[1]	10-15	150		130-150
14[1]	25			80-100
16[1]	15-20			40-45
17[1]	15	30		35-40
27	8.78	11.6	67.4	82.5 (n = 2)
28	15.2	18.0	140.9	88.0 (n = 3)
29[1,2]	10.4	75.5	648.7	67.7 (n = 2)
34				51.3 (n = 3)
35	13.7	13.2	154.9	82.8 (n= 4)
36	14.3	17.2	112.7	59.9 (n = 5)
37	14.7	14.6	151.4	90.3 (n = 3)
45	18.3	12.2	97.4	
46[3]	18.1	81.9	1082.0	83.8 (n = 4)
47[4]	19.6	19.1	164.8	
49[5]	8.6	16.8	146.2	
50	21.7	44.6	855.9	
51	7.8	25.9	133.9	
52	13.2	8.6	88.6	
56	15.3	12.8	160.3	
57	5.5	8.2	51.6	
58[6]	26.0	34.5	390.5	
59	5.4	17.7	82.1	
60	9.7	17.6	171.5	

[1]: Visual estimations using rulers; values may not be comparable to laser measurements
[2]: Tagged *A. lupus,* eye position not reliable
[3]: Wolffish with egg mass, same shelter was used by wolffish couple in 2005
[4]: Redfish in front of shelter
[5]: Isolated boulder
[6]: Shelter with two openings

3.4 FISH SIZE

Four head features (Fig. 2) were identified as being highly correlated with fish length (Table 4). A single measurement (distance from jaw to eye, "A" value in Fig. 2) was identified as yielding a correlation that was robust enough to be used in the field. The following equation was used to estimate fish size in Les Méchins from all available data:

$$\textit{Fish length} = 0.0894 \times \textit{jaw-to-eye length} - 12.013$$

Table 4. Correlation coefficients (R^2) for linear regressions between size of head features vs length for two groups of *A. lupus.* Head measurements (A, B, C, D, E) are described in Fig. 2.

	A	B	C	D	E
First group[1]	0.988	0.815	0.974	0.815	0.828
	n = 8	n = 8	n = 8	n = 6	n = 6
Second group[2]	0.966	0.131	0.957	0.378	Not
	n = 14	n = 3	n = 8	n = 8	measured

[1] Eight fish, measurements made on tank-reared *A. lupus*
[2] Eight fish from the northern Gulf of St. Lawrence (multispecies survey) and six tank-reared fish (MLI)

Out of 64 encounters with wolffish, 14 could be measured, including eight using the more reliable laser-spot method. The estimated average length was 756 mm (range 513–903 mm, n=8).

3.5 SPECIES ASSOCIATIONS

During the 2005 survey, it was noted that other fish species were often found near or in the shelters occupied by wolffish. Arctic shanny (*Stichaeus punctatus*), redfish (*Sebastes* spp.), ocean pout (*Zoarces americanus*), Greenland cod (*Gadus ogac*), and Atlantic cod (*Gadus morhua*) were the most common (Table 5). These fish often swam away when the divers approached and could not be documented. However, fish that were visible in the video footage were also identified.

During the surveys, many shelters were revisited within 2 to 3 days. It was noted that if the wolffish left its shelter, it would often be replaced by one of the two cod species. Cod were very common on reefs B and C and appear to use a wide range of shelter shapes and sizes. Cod is often found under overhangs, but it will also use the same crevices as the larger wolffish. Other than fish, shrimp of the *Pandalus* genus were also very common in and near the shelters.

Table 5. Other species found in or around wolffish shelters. Fish numbers refer to Appendix D.

Fish / Shelter identification	Observations of species that co-occur with *A. lupus*
19	*Stichaeus punctatus* and *Zoarces americanus* in front of opening
21	*S. punctatus* in front of opening
22	*S. punctatus* beside opening
23	Two wolffish in same shelter
27	*S. punctatus* inside shelter with wolffish
39	*Sebastes* spp. near opening
40	Two *Sebastes* spp., one in front of wolffish, one near opening
43	*Gadus morhua* in shelter with wolffish
45	*G. morhua* and *S. punctatus* within 1 m of opening

3.6 STATUS OF FISH RELEASED IN 2004

One objective for exploring the various sites was to confirm that the released fish survived and remained in the same area. Four days after the release in November 2004, two tagged *A. lupus* were found together at a depth of 8 m in the eastern sector near the Ilets. No other tagged fish were ever found near the islands. However, on 20 June, 2005, one tagged *A. lupus* specimen was found at a depth of 17 m in an area where fish had been released seven months earlier, on reef B. The presence of the characteristic blue dorsal tag (visible on the video) confirms that this was one of the released fish. The wolffish was hiding in a deep crevice and could not be measured accurately. On 7 June 2005, one *A. minor* was observed near the western portion of reef B, approximately 20 m from the bottom of the reef at a depth of 19 m. The fish was located deep inside a small hole and retreated before it could be captured on video. No other *A. minor* were observed during this study. Since the fish was of the same size as the fish released earlier, it is likely that it was indeed one of the fish released by our team even though the blue tag was not observed. There were no other reports of tagged wolffish observations in Les Méchins.

3.7 NOTABLE OBSERVATIONS

On 9 June 2005, two wolffish were found together in an unusually large crevice at the bottom of reef C. This pair was seen during the following days. On 1 July, 2005, two wolffish were again observed in the same shelter, presumably the same fish as earlier. On 17 August, 2006, one wolffish was found protecting an egg mass at the same spot. This fish was also observed the following day with its tail wrapped around the egg mass in the opposite direction, indicating that there had been movement between the two observations. There is not enough information to determine if the same fish was present in 2005 and 2006 or to determine if it was male or female. Two other wolffish with egg masses were also observed on the eastern section of reef B on 21 August 2006. In one case, the egg mass was outside the shelter and not protected. No egg masses were observed for the 41 individual wolffish observations in 2005. Also of note is the fact that on 21 June, 2005, a fresh *A. lupus* carcass was found on reef C.

4. DISCUSSION

4.1 HABITAT, SHELTER USE, AND COMPETITION

The most notable finding of this work is that *A. lupus* in Les Méchins were found to systematically avoid shallow seabeds. The average depth of observations was 20.5 m (mean low tide), and no wolffish were found above 13 m. This indicates that this species avoids the turbulent top layer, where temperature, salinity and turbidity vary on small temporal scales. In Les Méchins, the top layer is subject to the strong influence of the Gaspé Current. The exact depth of this layer most probably varies seasonally. However, the presence of a steep thermo-halocline was noticed by divers between May and August, when this work was undertaken. Below the 5 m macrophyte-dominated zone immediately below the surface, the physical habitat is identical to the deeper sections of the reefs. Temperature is the only variable that separates these zones all year. This is in accordance with the published preferred temperatures of 1–10°C for *A. lupus*. It is also an indication that temperature is an important criterion in defining the essential habitat for this species.

In Newfoundland and Labrador, ocean pout (*Zoarces americanus)* has a reproduction pattern similar to *A. lupus* (coastal migration and egg guarding) (Keats et al. 1985) and could be a competitor at our study site since it was observed during most dives on the deeper reefs. However, it was seldom found in shelters that would be considered adequate for wolffish. Other species such as cod (*Gadus* spp.) were more common in shelters where wolffish had been observed on earlier dives. The presence of other species near or in the shelters could be explained if the shelters are used mainly for wolffish reproduction, since feeding stops and teeth are replaced during this period. The presence of eggs could also attract other species. Furthermore, the wolffish diet appears to be composed mostly of echinoderms, molluscs and crustaceans (Gonzalez et al. 2006). Fish is typically not an important fraction of stomach contents. Smaller species may find a certain level of protection by staying close to a large non-feeding predator.

Based on our observations, some wolffish will occupy the same shelters for several weeks while others will be present for only hours or days. This could be explained by observations made by Kulka et al. (2004) in Newfoundland, where shelters are used mainly for mating and where wolffish show little substrate preference outside of the reproduction period. The wolffish in Les Méchins could be using the area’s favourable geology for reproduction while spending most of their lives in deeper waters on sandy or gravel surfaces. It is also notable that in Quebec waters, wolffish sightings by divers are always reported in rocky environments and seldom if ever on sandy bottoms (first author, pers. obs.). This could be due to a bias in dive-site selection, as featureless sandy bottoms are rarely favoured as dive sites. However, based on the first author’s personal observations, wolffish swimming or resting on the bottom outside of shelters in shallow water, as reported by Keats et al. (1985), is either rare or under-reported in Quebec. During this study, no wolffish were observed on the flat, sandy areas below or above the reefs. More work on habitat use is needed to confirm how wolffish use and migrate to coastal reef habitats.

It is a common error to assume that *A. lupus* and *A. minor* individuals share a common habitat made of shelter-rich hard substrate. However, because of their similar biology and life cycles, they are often grouped in the same "species complex", where information gained on one species can also be valid for the other. This is in line with the current recovery strategy (Wolffish Recovery Team 2006). Overall, coastal reefs in Les Méchins appear to be an area highly favourable to *A. lupus*, but they are not used by *A. minor*. Elsewhere in the St. Lawrence Estuary, divers will rarely find more than one wolffish during a single dive. In contrast, some areas like the eastern sector of reef B in Les Méchins could yield up to five observations during one dive, and these numbers could have been higher if the divers didn't spend time recording their observations. Similar densities were observed at reef C at different times between May and August. Landscape features of the Gaspé Peninsula would suggest that favourable habitats are available along the shores of the Gaspé coast all the way from Les Méchins down to Forillon National Park and Bonaventure Island. If findings for the Les Méchins area are indicative of an overall pattern in coastal areas of Quebec, near-shore habitats may potentially play an important role in maintaining population integrity by providing safe refuges and nesting areas for adult *A. lupus*. Because of the nature of their substrate, these areas are generally not exploited by commercial fisheries using mobile gear.

4.2 INSIGHTS ON REPRODUCTION

This work also provided insights on reproduction. The egg masses found in 2006 and what appears to be the continuous use of a shelter over two years by two wolffish raise the question of courtship and couple formation. If the 2005 fish were indeed the same as in 2006, this would imply that the couple stayed together for an extended period of time, presumably for one year or more. In 2006, two egg masses were observed on reef B. One was similar to the one on reef C and was protected while the other was found outside the opening of a shelter and was not protected. Since it had not yet been eaten by scavengers, this suggests that it had been shed recently. It could not be determined if these eggs had been fertilized. These observations indicate that egg laying in this sector is probably synchronous and happens between July and August since larvae and pigmented eyes were not clearly visible within the egg masses.

Recent unpublished information from R. Hooper (retrieved 15 October, 2007, http://www.bonnebay.mun.ca/Research/Wolffish.html) indicates that near Norris Point (northwest Newfoundland), mating in *A. lupus* occurs in the summer and fall and eggs hatch in the winter. Keats et al. (1985) reported a spawning period in September and October in eastern Newfoundland. However, as mentioned by Keats et al. (1985), there is considerable geographical variability, with spawning occurring between winter and late autumn. Our limited seasonal coverage over two years does not provide conclusive evidence on the spawning period in the St. Lawrence estuary but suggests that pairing may last for an extensive period and that spawning occurs in July or early August.

4.3 FISH RELEASE AND SURVIVAL

The stocking experiment was undertaken with the clear understanding that the goal was primarily to evaluate methods and that it would not provide sufficient information to evaluate stocking as a recovery strategy, although it should not be excluded. Finding a single tagged *A. lupus* and one (probable) *A. minor* out of 47 fish released several months earlier is an apparent low success rate. However, considering the low probability of finding tagged fish in burrows and in the complex environment we have described, this stocking experiment provided valuable information. The implication is that tank-reared fish survived the winter and found suitable prey on reef B. These two fish may have migrated to reef B after being released near the Ilets*,* but this cannot be verified. Even after much effort (measured in underwater dive-hours), no tagged fish could be located in 2005 in the Ilets sector, although two had been located by divers a few days after their release in 2004. This tends to confirm that the Ilets area is probably not a favourable wolffish habitat.

Historically, divers have often reported (to local clubs and shops) wolffish sightings along the Ilets. The choice of releasing some of the fish in this sector was based on these observations and on the assumption that this could be a potentially favourable habitat. Based on hundreds of dive-hours both before and during this study and at different times of the year by the first author, we cannot confirm that indigenous wolffish have ever been present along the Ilets in Les Méchins. It is believed that ocean pout (*Zoarces americanus*) is often mistaken for wolffish. This species is common near shore and is often seen by recreational divers. This is a reminder that a minimum of training in species identification is essential to get good data from divers.

More work is required to establish whether migration is important and how habitat affects survival. Observations in Newfoundland have shown that few fish were found in an area where reproduction had taken place a few months earlier (Keats et al. 1985). If juveniles (<50 cm) live at greater depths, and since all fish released in Les Méchins were smaller than 50 cm, migration could explain why few small fish were found. Immediate survival following the release could not be determined, and predation and other causes of mortality are also unknown. Without this data, colonization success is difficult to establish. Further release experiments should concentrate on areas where monitoring is easier than on reef B. Monitoring should also begin sooner after release and be sustained over many months. The submerged cage method has proven to be effective and involves simpler logistics than using scuba divers. Unlike a release at the surface, it provides confirmation that the fish are in a suitable physical environment. However, whenever possible, divers should be used as they can pinpoint the release position and can verify if the fish has kept to one shelter over days or months. Diver-carried PIT tag readers could be used to provide in situ individual fish identification. Recapture could also be an option to determine growth rate. If such work were to be undertaken in Les Méchins, reef C has most of the required characteristics of a good release site where follow-up would be easier.

4.4 TECHNICAL LIMITATIONS AND INNOVATIONS

The first challenge that was encountered was to find safe, efficient and optimal techniques to do underwater work in a strong current, at depth, in cold water, and for durations that approached non-decompression limits. Excessive task loading can often lead to dangerous situations and a progressive approach was used in 2005. The workload was restricted and adjusted until the divers and their surface support had acquired the skills and confidence to handle all the tasks and equipment. Another challenge was that on reef B, the potential habitat extends vertically over a great distance. The search swaths covered an estimated width of 20 m and the number of potential shelters was significantly higher than on the other sites, thereby increasing the probability of missing wolffish. Because reef C is basically a horizontal environment at the bottom of a cliff, there's a high probability that all fish present during a dive were indeed counted.

The use of video combined with laser measurements has proven to be a good non-intrusive strategy for in situ measurements. It provides a fast method of measuring wolffish head features (a proxy for fish length), even from a distance of over one metre. However, the 2006 observations took place later (August) than in 2005, and most if not all fish were then hiding much deeper inside the crevices, making measurements more difficult and often impossible. Although the method is effective and there is a good correlation between head features and fish lengths, uncertainty remains as the control fish used to establish this relationship came mostly from tank-reared individuals. The few available control specimens from trawl surveys showed more variability. Great care must also be taken while handling the lasers and video camera underwater to keep the parallax error to a minimum. Yoshihara (1997) mentions that a similar method used to measure fish lengths with lasers yields significant errors when the laser-to-camera distance is greater than 2.5 m. This method was also used to measure the den openings. At less than 15 cm, the average height of the holes appears to be small for fish of this size. Because of the varying angles of measurement, it was often impossible to measure the opening size beyond the front mound. This may lead to heights being underestimated.

High-definition video was an asset as it provided more detailed grabbed frames for measurements, but camera and laser movements had a detrimental effect on precision. Handling a large HD camera with lights plus the lasers and a secondary aiming light can also be challenging in tight areas. A future iteration of this setup should provide for smaller lasers installed permanently on the camera's lens axis. This would keep parallax errors to a minimum and improve reproducibility. Moving from a full-size HD camera to a compact HD model would also help in positioning the camera and the attached lasers where space is limited.

4.5 MULTIBEAM SURVEY

The multibeam survey provided very detailed 3-dimensional maps of the study area. Areas to the north, east and west were also surveyed, albeit at a lower resolution. These maps were referenced with sub-metre precision and were used throughout the project. They were used to plan the dives and to determine which areas had been covered during each dive. The accuracy was sufficient to identify individual underwater features that could be subsequently located by the divers. The survey led to the discovery of a new reef and other minor features to the east. The reef turned out to be of major interest for this work. The other smaller outcrops were quickly dismissed as being too small to provide wolffish shelters. It was hoped that the area to the north would yield another ridge or outcrop similar to the other reefs but the survey failed to find anything of interest. The same is also true for the sector further west. The data generated by this survey have been integrated into corporate databases by the Canadian Hydrographic Survey and will be used in future marine map updates.

The backscatter data that were acquired during the survey were not presented here since no detailed analysis was performed and they did not contribute new information in their preliminary form. If multibeam surveys are to be used in conjunction with diving operations, great care must be taken to attain the maximum possible resolution. This is important information for divers working within a complex environment such as reef B. Future work should look into logging the exact positions of divers, fish and shelters using an acoustic positioning system. These data could be overlaid on the multibeam data to provide an overall 3-dimensional representation of habitat use within a geographical information system (GIS). Overall, the multibeam survey proved to be extremely useful, both for planning exploration dives and for finding a new potential wolffish habitat.

4.6 ON THE ROLE OF DIVERS

Wolffish, a large predatory fish with a menacing look, is a prized observation for scuba divers. Although relatively uncommon, *A. lupus* are present at some of the most popular dive sites in eastern Quebec, such as Les Escoumins, Bonaventure Island and Forillon National Park. Divers will often visit the same site during a season and can therefore be valuable sources of information to learn more about trends in abundance or movements, even if identification can sometimes be problematic. An example of this is anecdotal evidence from Bonaventure Island (Percé, Quebec), where *A. lupus* have been observed for several years at various sites at 20–35 m. Divers reported that in 2006, wolffish were absent from areas where they used to be common. This is thought to be correlated with higher-than-usual temperatures at these sites, an observation that correlates with the concept that wolffish prioritize suitable temperatures when seeking adequate seabed configurations (D.W. Kulka pers. comm.). Another example is that divers in Quebec do not favour sandy bottoms that are generally featureless and considered to be uninteresting dive sites. This reduces the probability of encounters with *A. minor* even if historical data suggest that it is sometimes captured near shore at depths that are accessible to scuba divers (<40 m). Although *A. minor* could presumably use habitats found in the study area and that one released fish was found to have survived the winter, it would be imprudent to extrapolate these findings from one species to the other. If fact, there are no documented diver observations of *A. minor* in Quebec. At this time, the in situ monitoring or study of *A. minor* by divers at accessible depths remains elusive, possibly owing to their current low abundance. However, the previous points do illustrate that divers, clubs and diving organizations could be used to gain more insight into wolffish distribution and habitat.

4.7 KNOWLEDGE GAPS AND FUTURE WORK

Another unexpected outcome of this study is the realization that much more work on *A. lupus* behaviour and habitat use could be undertaken in situ than was previously thought possible. Time-lapse videography, red and infrared lighting and automatic monitoring and logging are now all technically feasible at a low cost. Accurate fish and diver positioning systems are also available. These could be used to fill some of the important knowledge gaps that remain: What are the mating/reproduction patterns of wolffish? What is the typical feeding strategy? How far from the den do wolffish go for feeding? What are the attributes of a “good” shelter? How faithful are wolffish to one shelter? What is the effect of competition for shelters by other wolffish and other species?

Although limited in its geographic scope, the study site at Les Méchins has proven to be well suited for work on wolffish. It is home to an apparently healthy population of adult *A. lupus* and has the potential to support *A. minor*. It is hoped that the site will be kept in its current state so that future work can be undertaken on what is an apparently undisturbed habitat.

5. ACKNOWLEDGMENTS

The multibeam survey and data processing done by the Canadian Hydrographic Service was supervised by Roger Côté and Louis Poliquin. Paul Robichaud was in charge of video operations, took part in most of the dives and made major contributions to field logistics. Catherine Dion, Pierre-Marc Scallon-Chouinard and François Tremblay contributed significantly to the technical aspects of this project. Benoit Arbour and Johanne Noël gave expert advice on graphics and charts. Andrea Weise kindly reviewed the various drafts of this document. The help of Roger Lacasse with some of the 2005 dives is also acknowledged. This work was supported by the SARCEP and Inter-departmental Recovery Fund programs. Marie-Hélène Gendron’s salary was paid in part by the Federal Public Sector Internship Program. Bernard Morin and Mark Simpson have graciously accepted to review this report.

6. REFERENCES

Albikovskaya, L.K. 1982. Distribution and abundance of Atlantic wolffish, spotted wolffish and northern wolffish in the Newfoundland area. NAFO Sci. Counc. Stud. 3: 29–32.

DFO 2004. Proceedings of a case study review of critical habitat identification for aquatic species-at-risk; December 7–10, 2004. DFO CSAS Proceed. Ser. 2004/047. xiv + 111 p.

Falk-Petersen, I.-B., Hansen, T. K., Fieler, R., and Sunde, L. M.1999. Cultivation of the spotted wolffish *Anarhichas minor* (Olafsen) - a new candidate for cold-water fish farming. Aquacult. Res. 30: 711–718.

Gonzalez, C., Paz, X., Roman, E., and Alvarez, M. 2006. Feeding habits of wolffishes (*Anarhichas denticulatus, A. lupus, A. minor)* in the North Atlantic. NAFO SCR Doc. 06/52 16 p.

Johannessen, T., Gjosaeter, J., and Moksness, E. 1993. Reproduction, spawning behaviour and captive breeding of the common wolffish *Anarhichas lupus* L. Aquaculture 115: 41–51.

Keats, D. W., South, G. R., and Steele, D.H. 1985. Reproduction and egg guarding by Atlantic Wolffish (*Anarhichas lupus:* Anarhichidae) and ocean pout (*Macrozoarces americanus:* Zoarcidae) in Newfoundland waters. Can. J. Zool. 63: 2565–2568.

Kulka, D.W., and DeBlois, E.M. 1996. Non traditional groundfish species on Labrador Shelf and Grand Banks - wolffish, monkfish, white hake and winter flounder. DFO Atl. Fish. Res. Doc. 96/97 49 p.

Kulka, D. W., Simpson, M.R., and Hooper, R.G. 2004. Changes in distribution and habitat associations of wolffish (Anarhichidae) in the Grand Banks and Labrador Shelf. CSAS Res. Doc. 2004/113 43 p.

McRuer, J., Hurlbut, T., and Morin, B. 2000. Status of Atlantic Wolffish (*Anarhichas lupus)* in the Maritimes (NAFO Sub-Area 4 and 5). CSAS Res Doc. 2000/138 57 pp.

O'Dea, N. R., and Haedrich, R.L. 2002. A Review of the Status of the Atlantic Wolffish, *Anarhichas lupus*, in Canada. Can. Field-Nat. 116: 423–432.

Scott, W. B., and Scott, M. G. 1988. Atlantic Fishes of Canada. Can. Bull. Fish. Aquat. Sci. 219, 731 pp.

Simpson, M. R., and Kulka, D.W. 2002. Status of three wolffish species (*Anarhichas lupus*, *A. minor* and *A. denticulatus*) in Newfoundland waters (NAFO Divisions 2GHJ3KLNOP). CSAS Res Doc. 2002/078. 48 pp.

Templeman, W. 1984. Migrations of wolffishes, *Anarhichas* sp., from tagging in the Newfoundland area. J. Northw. Atl. Fish. Sci. 5: 93–97.

Templeman, W. 1986. Some biological aspects of Atlantic wolffish (*Anarhichas lupus)* in the Northwest Atlantic. J. Northw. Atl. Fish. Sci. 7: 47–55.

Wolffish Recovery Team 2006. Recovery strategy for Northern Wolffish (*Anarhichas denticulatus)* and Spotted Wolffish (*Anarhichas minor)*, and management plan for Striped Wolffish (*Anarhichas lupus)* in Canada [Proposed]. St. John's, NL., Fisheries and Oceans Canada: Newfoundland and Labrador Region: iv + 129 p.

Yoshihara, K. 1997. A fish body length measuring method using an underwater video camera in combination with laser discharge equipment. Fish. Sci. 63: 676–680.

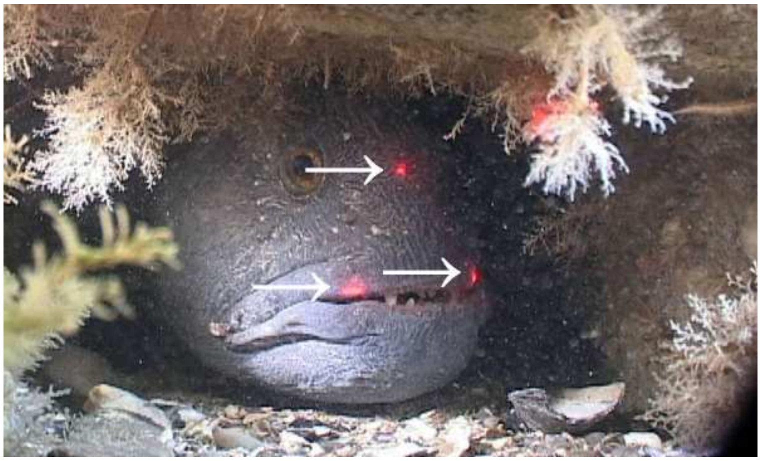
Appendix A. Diving data summary. Depths are corrected to the mean low tide.

Dive*	Date (dd-mm-yy)	Dive time (min)	Max. Depth (m)	Avg. Depth (m)	Temp. at max. depth (ºC)	Number of wolffish observed
04-Sup	21-11-04	60	11	9	-	2
05-1-B	06-06-05	39	23	21	3	5
05-2-I	06-06-05	44	8	6	5	0
05-3-I	07-06-05	57	8	6	6	0
05-4-B	07-06-05	50	22	14	7	3
05-5-C	07-06-05	31	24	12	7	1
05-6-B	08-06-05	46	22	16	7	5
05-7-B	08-06-05	37	21	17	7	2
05-8-I	08-06-05	63	6	5	12	0
05-9-B	09-06-05	42	23	18	7	5
05-10-C	09-06-05	42	23	17	10	3
05-11-I	09-06-05	56	6	4	8	0
05-12-S	09-06-05	26	1	1	9	0
05-13-B	20-06-05	51	21	14	5	3
05-14-S	20-06-05	65	2	1	10	0
05-15-C	21-06-05	45	25	22	4	4
05-16-B	21-06-05	49	23	17	7	5
05-Sup	01-07-05	90	26	17	5	5
06-0-B	15-05-06	35	22	15	1	1
06-1-C	17-08-06	43	23	19	7	4
06-2-C	17-08-06	50	25	19	7	2
06-3-B	17-08-06	38	23	17	8	5
06-4-C	18-08-06	48	23	17	7	0
06-5-B	21-08-06	47	23	17	5	5
06-6-B	21-08-06	48	23	16	4	4
06-7-B	21-08-06	50	21	13	4	0
06-8-E	22-08-06	42	14	12	6	0

*: Dive Identification**:** Year-number-site. Sites:

S- Shore, south side of islands
I- Ilets, north side of islands
B- Reef B
C- Reef C
E- Exploration
Sup: Supplemental dive

Appendix B. Typical wolffish shelters.



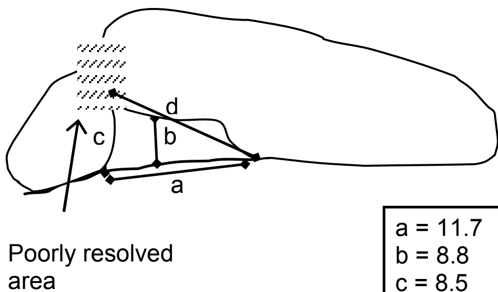
a) Video grab of wolffish head showing laser spots.

b) Typical shelter with shell debris.

c) Shelter with narrow vertical opening.

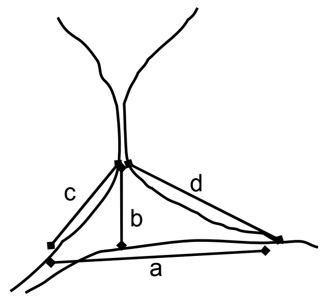
Appendix C. Shelter descriptions and drawings (dimensions are in centimeters).

05-13-B, Wolffish 25



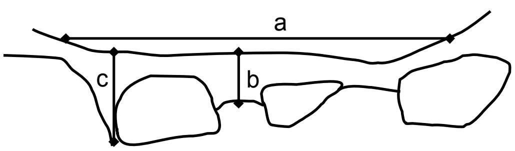
a = 11.7
b = 8.8
c = 8.5
d = 11.6

05-13-B, Wolffish 26



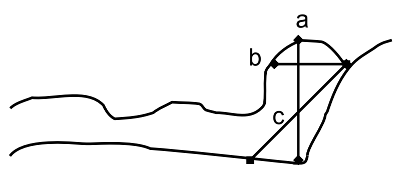
a = 18.1
b = 15.3
c = 18.1
d = 21.3

05-13-B, Wolffish 27



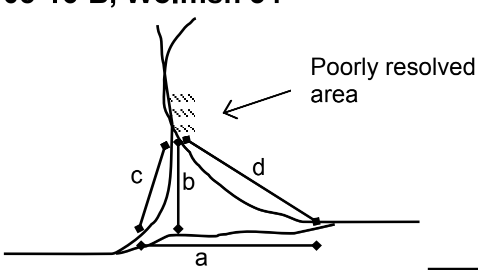
a = 75.5
b = 14.1
c = 10.4

05-16-B, Wolffish 33



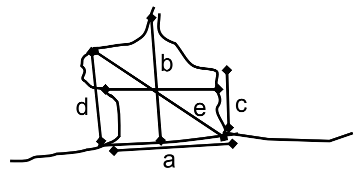
a = 13.7
b = 16.6
c = 22.2

05-16-B, Wolffish 34



a = 17.3
b = 14.4
c = 16.0
d = 19.2

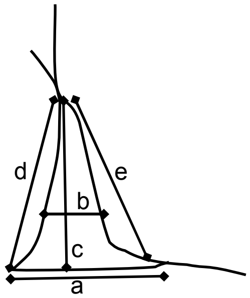
05-16-B, Wolffish 35



a = 14.6
b = 14.7
c = 14.5
d = 11.0
e = 17.1

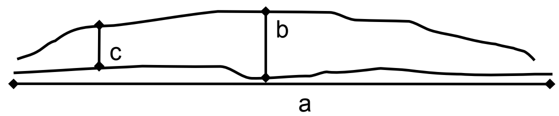
Appendix C. Cont.

06-01-C, Wolffish 38



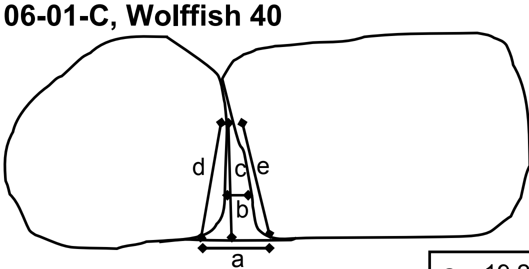
a = 12.3
b = 5.7
c = 18.4
d = 17.3
e = 18.5

06-01-C, Wolffish 39



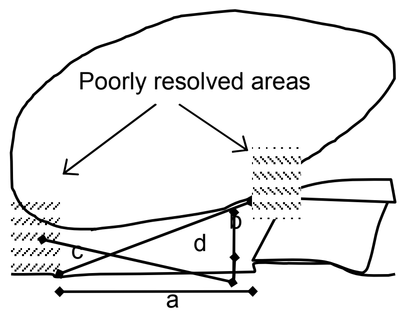
a = 81.9
b = 18.1
c = 18.0

06-01-C, Wolffish 40



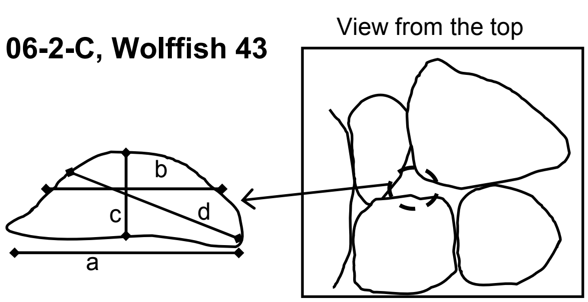
a = 19.2
b = 7.8
c = 19.7
d = 12.7
e = 15.6

06-2-C, Wolffish 42



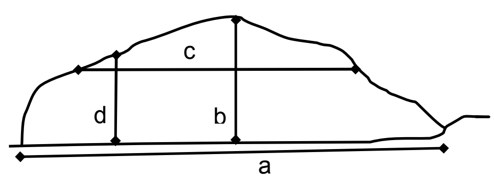
a = 16.9
b = 8.7
c = 19.4

06-2-C, Wolffish 43



a = 44.6
b = 26.1
c = 21.7
d = 47.4

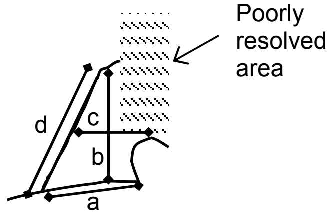
06-3-B, Wolffish 44



a = 26.0
b = 5.8
c = 7.9
d = 5.0

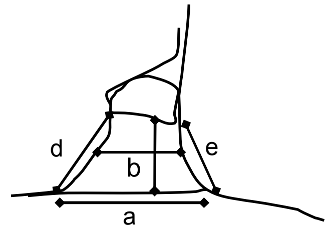
Appendix C. Cont.

06-3-B, Wolffish 45



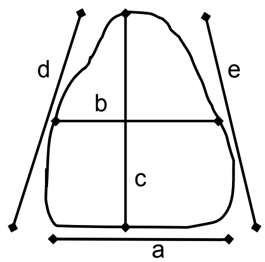
a = 8.6
b = 6.5
c = 13.2
d = 17.8

06-5-B, Wolffish 49



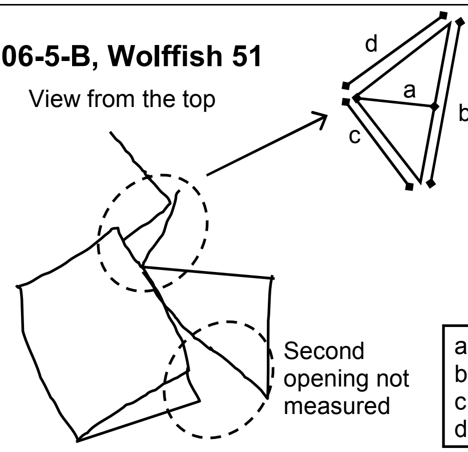
a = 12.9
b = 11.4
c = 15.3
d = 13.4
e = 13.4

06-5-B, Wolffish 50



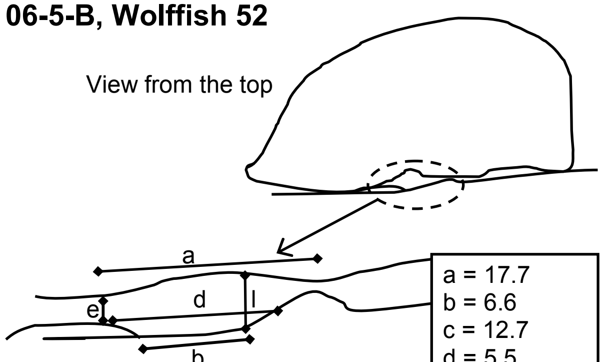
a = 8.2
b = 5.5
c = 5.6
d = 7.3
e = 7.1

06-5-B, Wolffish 51



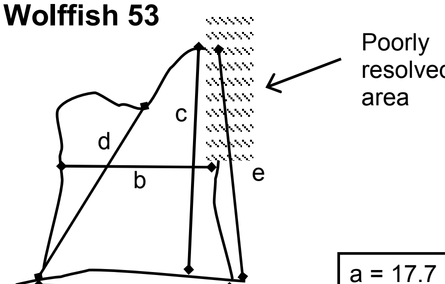
a = 16.3
b = 26.0
c = 21.8
d = 32.3

06-5-B, Wolffish 52



a = 17.7
b = 6.6
c = 12.7
d = 5.5
e = 2.0

06-5-B, Wolffish 53



Shelter with two openings.

a = 17.7
b = 4.6
c = 9.8
d = 11.7
e = 15.7

Appendix D. Detailed list of individual wolffish found during the 2005–2006 surveys. Depths are corrected to the mean low tide.

Dive	Fish no.	Species	Depth (m)	Observations
04-sup	2	*A. lupus*	6	Tagged fish
05-1-B	2	*A. lupus*	21	Photographs only
	3	*A. lupus*	21	
	4	*A. lupus*	22	
	5	*A. lupus*	22	
	6	*A. lupus*	23	
05-4-B	7	*A. lupus*	15	
	8	*A. minor*	19	Tag not visible, but species is confirmed and size similar to stocked *A. minor*
	9	*A. lupus*	14	
05-5-C	10	*A. lupus*	21	
05-6-B	11	*A. lupus*	17	Shelter and fish sizes
	12	*A. lupus*	19	Shelter and fish sizes
	13	*A. lupus*	19	Shelter and fish sizes
	14	*A. lupus*	19	Shelter and fish sizes
	15	*A. lupus*	19	
05-7-B	16	*A. lupus*	18	Shelter and fish sizes
	17	*A. lupus*	16	Shelter and fish sizes
05-9-B	18	*A. lupus*	21	Low battery, video limited to 30 min.
	19	*A. lupus*	23	
	20	*A. lupus*	23	
	21	*A. lupus*	23	
	22	*A. lupus*	21	
05-10-C	23-24	*A. lupus*	22	Two *A. lupus* in shelter
	25	*A. lupus*	23	
	26	*A. lupus*	21	
05-13-B	27	*A. lupus*	13	Shelter and fish sizes
	28	*A. lupus*	20	Shelter and fish sizes
	29	*A. lupus*	17	Tagged fish, blue tag is visible Wolffish size estimate is not reliable
05-15-C	30	*A. lupus*	24	Dead, not in shelter
	31	*A. lupus*	25	Laser failure
	32	*A. lupus*	25	
	33	*A. lupus*	25	

Appendix D. Cont.

Dive	Fish no.	Species	Depth (m)	Observations
05-16-B	34	*A. lupus*	22	Wolffish size estimated
	35	*A. lupus*	20	Shelter and fish sizes
	36	*A. lupus*	19	Shelter and fish sizes
	37	*A. lupus*	20	Shelter and fish sizes
	38	*A. lupus*	14	
05-sup	39	*A. lupus*		Supplemental dive, no measurements
	40	*A. lupus*		
	41	*A. lupus*		
	42	*A. lupus*		
	43	*A. lupus*		
06-0-B	44	*A. lupus*	23	No video
06-1-C	45	*A. lupus*	22	
	46	*A. lupus*	22	Wolffish with egg mass, size estimated
	47	*A. lupus*	22	
	48	*A. lupus*	22	
06-2-C	49	*A. lupus*	23	
	50	*A. lupus*	23	
06-3-B	51	*A. lupus*	22	No video
	52	*A. lupus*	22	No video
	53	*A. lupus*	22	No video
	54	*A. lupus*	22	
	55	*A. lupus*	21	Small wolffish
06-5-B	56	*A. lupus*	19	Egg mass outside of shelter
	57	*A. lupus*	22	
	58	*A. lupus*	22	
	59	*A. lupus*	19	
	60	*A. lupus*	19	
06-6-B	61	*A. lupus*	17	No video
	62	*A. lupus*	22	
	63	*A. lupus*	22	With egg mass
	64	*A. lupus*	17	Large wolffish