Mitigation of Capture and Survival of Wolffish Captured Incidentally in the Grand Bank Yellowtail Flounder Otter Trawl Fishery

Prepared by

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Abstract

Three species of wolffish inhabit the marine environment in Atlantic Canada, the spotted (*Anarhichas minor*), northern (*A. denticulatus*), and Atlantic or striped wolffish (*A. lupus*). Recently, the spotted and northern wolffish were designated as threatened by the Committee on the Status of Endangered Wildlife in Canada and the Atlantic wolffish has been designated as a species of special concern. Wolffish are taken only as bycatch in Atlantic Canada and when catches are compared among gear types it is found that the trawl represents the single largest threat to the recovery of wolffish as all three species are mainly captured by this gear. The following study was conducted on board commercial trawlers directing for yellowtail flounder (*Pleuronectes ferruginea*) on the Newfoundland Grand Bank to assess the post-capture survival of wolffish. Also, in an effort to provide a means for ships captains to avoid wolffish grounds the summer distribution of all three species of wolffish is presented from an industry vessel survey of the Grand Bank yellowtail flounder fishing grounds during the time period 1996-2003.

Atlantic wolffish post-capture survival experiments were conducted under thermally stratified oceanographic conditions in late spring (June) and non-stratified conditions in late winter (December) of 2004. Neither spotted nor northern wolffish were captured during the fishing trips. All Atlantic wolffish used in the post-capture survival experiments were captured during commercial tows that were 2-2.5 hours in duration. In June, post-capture survival was assessed for air exposure durations of one and 1.5 hours while in December post-capture survival was assessed for five air exposure treatments: ≤30, 31-60, 61-90, 91-120, and >120 minutes.

All six Atlantic wolffish (90-108 cm total length [TL]) that were held out of the water for 1-1.5 hours in June survived a 4.75 day post-capture monitoring period which included 3.75 days in cages on the ocean floor. In December, post-capture survival was high (92%) among 37 Atlantic wolffish (65-112 cm TL) that spent up to 2-hours out of the water and 24-48 hours in holding tanks or 2.3 days in a combination of holding tanks and cages on the ocean floor. Four additional Atlantic wolffish (92-108 cm TL) that spent over 2-hours out of the water died within 24-hours.

Results of this study suggest the yellowtail flounder otter trawl fishery is unlikely to prevent the recovery of wolffish on the Newfoundland Grand Bank. This study corroborates DFO research vessel survey findings on the sparse and patchy distribution of spotted and northern wolffish on the southern Grand Bank, a condition that not only minimizes undetected mortality from gear encounters, but also post-capture mortality while directing for yellowtail flounder. This study confirmed the presence of concentrations of Atlantic wolffish in the southern and western region of the yellowtail flounder fishing grounds and hence their vulnerability to capture by otter trawl. However, this study also demonstrated that post-capture survival is high when the difference between the surface and bottom water temperatures at wolffish capture sites are within 5.8ºC and air temperatures in the processing ramp of commercial vessels are <13ºC. These temperature conditions typically prevail on the southern Grand Bank for at least a 7.5 month period from November to mid-June when the yellowtail flounder fishery closes for 1.5 months during the spawning season. Thus, for up to about 70% of the fishing season the mortality risk to Atlantic wolffish posed by the Grand Bank yellowtail flounder otter trawl fishery should be substantially reduced since the introduction of DFOs mandatory wolffish live release program in 2004.

Executive Summary

Three species of wolffish inhabit the marine environment in Atlantic Canada, the spotted (*Anarhichas minor*), northern (*A. denticulatus*), and Atlantic or striped wolffish (*A. lupus*). Their centre of distribution in Atlantic Canada is the Newfoundland Grand Bank to Labrador Shelf. Significant declines in numbers and weights of all three species occurred during the late 1970's and early 1980's and were followed by a decline in both intensity and extent of distribution during the time period 1980-2001. Subsequently, spotted and northern wolffish have been designated as threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and the Atlantic wolffish has been designated as a species of special concern.

Wolffish are taken only as bycatch in Atlantic Canada and when catches are compared among gear types it is found that the trawl represents the single largest threat to the recovery of wolffish as all three species are mainly captured by this gear. In 2002, bycatch of wolffish in the Grand Bank yellowtail flounder (*Pleuronectes ferruginea*) otter trawl fishery represented 34% of the total wolffish catch reported in the Newfoundland and Labrador region and about 1.5% of the catch of yellowtail flounder. Bycatch of wolffish in the yellowtail flounder fishery is attributed to an overlapping distribution of a large concentration of Atlantic wolffish on the southern Grand Bank. A large concentration of Atlantic wolffish in close proximity to commercial fishing grounds provides an ideal opportunity to determine whether proposed measures to minimize the impact of otter trawl fishing on the recovery of wolffish are effective. For example, it has been proposed that bycatch excluder devices could be used to mitigate the capture of wolffish in otter trawl fisheries and the mandatory release of wolffish is a condition of license in all Atlantic Canada fisheries, yet post-capture survival of wolffish is unclear.

This study was conducted on board commercial trawlers directing for yellowtail flounder on the Newfoundland Grand Bank to assess the post-capture survival of wolffish and determine whether a sorting grate can be used to mitigate the capture of wolffish. Unfortunately, poor weather conditions precluded investigations into the mitigative properties of a sorting grate. As an alternative to the sorting grate study and in accordance with the mitigation of capture objective the summer distribution of all three species of wolffish is presented from an industry vessel survey of the Grand Bank yellowtail flounder fishing grounds during the time period 1996-2003.

Summer distributions of wolffish on the Grand Bank were similar to those described by Fisheries and Oceans Canada (DFO) research vessel surveys conducted in the fall over the past several years. Spotted and northern wolffish were rarely encountered on the Grand Bank during the summer survey. They were taken in only two years of the eight year survey time series and were captured in only 1-2 tows in each year. Atlantic wolffish was the most common and wide spread of the wolffish species. Atlantic wolffish were captured in every year of the summer survey and aggregate distribution plots for the time period 1996-2003 appear to depict two centres of distribution west of the Southeast Shoal at 44º and 45º N latitude. In an effort to mitigate the capture of wolffish while directing for yellowtail flounder an aggregate distribution map for all three species of wolffish has been distributed among Fishery Product International (FPI) skippers to augment their traditional ecological knowledge of wolffish distributions on the southern Grand Bank. A concerted effort by FPI skippers to avoid the areas where wolffish are concentrated not

only reduces the likelihood of incidental capture, but also undetected mortalities from gear encounters and potential damaging and disruptive impacts on wolffish habitat.

Atlantic wolffish post-capture survival experiments were conducted under thermally stratified oceanographic conditions in late spring (June) and non-stratified conditions in late winter (December) of 2004. Neither spotted nor northern wolffish were captured during the experimental fishing trips. All Atlantic wolffish used in the post-capture survival experiments were captured during commercial tows that were 2-2.5 hours in duration. On commercial trawlers, it is not uncommon for wolffish to remain out of the water for 1-2 hours in a holding ramp before they are sorted by the crew during processing. Therefore, in June, post-capture survival was assessed for air exposure durations of one and 1.5 hours while in December post-capture survival was assessed for five air exposure treatments: ≤30, 31-60, 61-90, 91-120, and >120 minutes. The effect of method of gill ventilation (assisted and unassisted) was also assessed in June. Post-capture survival assessments included monitoring the health status of wolffish in tanks on board commercial vessels and following simulations of release, which involved placing wolffish in cages and returning them to the ocean floor for 2-3.5 days.

All six Atlantic wolffish (90-108 cm total length [TL]) that were held out of the water for 1-1.5 hours in June and subjected to an unassisted gill ventilation treatment survived a 4.75 day post-capture monitoring period which included 3.75 days in cages on the ocean floor. Three Atlantic wolffish subjected to the 1.5 hour air exposure and an assisted gill ventilation treatment died in holding tanks within 3-6 hours. Neither the surviving wolffish nor the wolffish that died exhibited external wounds. When the trawl was hauled back after a 2 hour tow, Atlantic wolffish experienced a 5.6-5.8ºC increase in water temperature between the bottom at the capture site (2.1-2.3ºC) and surface (7.9ºC), they were exposed to moderate (11.8-12.9ºC) air temperatures for 1-1.5 hours, and surviving wolffish spent close to one day in a holding tank at 6.5-6.8ºC before they were returned to the ocean floor (2.3-2.8ºC) in cages.

In December, post-capture survival was high (92%) among 37 Atlantic wolffish (65-112 cm TL) that spent up to 2-hours out of the water followed by a 24-48 hour monitoring period in holding tanks or 2.3 days in a combination of holding tanks and cages on the ocean floor. Four Atlantic wolffish (92-108 cm TL) that spent over 2-hours out of the water died in holding tanks within 24-hours. Damage to wolffish in the form of fresh wounds was low (5%) in December and all damaged wolffish survived. There was little difference (<1ºC) between surface (5.0ºC) and bottom (4.1ºC) water temperatures at the wolffish capture sites in December and air temperatures rarely exceeded 10ºC while wolffish were exposed to air.

This study indicates the Atlantic wolffish is a very hardy species, capable of surviving capture by otter trawl and net entrainment for 2-2.5 hours, haul back through a thermocline, extended periods of exposure to moderate air temperatures, handling, and simulated release. Overall, this study suggests the yellowtail flounder otter trawl fishery is unlikely to prevent the recovery of wolffish on the Newfoundland Grand Bank. This study corroborates DFO research vessel survey findings on the sparse and patchy distribution of spotted and northern wolffish on the southern Grand Bank a condition that not only minimizes undetected mortality from gear encounters, but also post-capture mortality while directing for yellowtail flounder. This study confirmed the presence of concentrations of Atlantic wolffish in the southern and western region of the yellowtail flounder fishing grounds during the summer and hence their vulnerability to capture by otter trawl. However, this study also demonstrated that post-capture survival is high when the difference between the surface and bottom water temperatures at wolffish capture sites are within 5.8ºC and air temperatures in the processing ramp are <13ºC. These temperature conditions typically prevail on the southern Grand Bank for at least a 7.5 month period from November to mid-June when the yellowtail flounder fishery closes for 1.5 months during the spawning season. Thus, for up to about 70% of the fishing season (7.5 months/10.5 months) the mortality risk to Atlantic wolffish posed by the yellowtail flounder otter trawl fishery should be substantially reduced since the introduction of DFOs mandatory wolffish live release program in 2004.

High post-capture survival and low incidence of damage to Atlantic wolffish indicates current live release protocols, which includes the design and materials used in holding ramps and conveyors within FPI's otter trawl fleet, should promote the survival of wolffish and other species discarded at sea. However, the design of discard conveyors on board two FPI trawlers were identified for the potential to cause harm to wolffish. Fortunately, the design flaws can be easily remedied.

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1.0 INTRODUCTION

1.1 Background

Three species of wolffish occur in Atlantic Canada: the spotted (*Anarhichas minor*), northern (*A. denticulatus*) and Atlantic or striped wolffish (*A. lupus*). Their centre of distribution in Atlantic Canada is the Newfoundland Grand Bank to Labrador Shelf. The Atlantic and spotted wolffish are demersal, residing on or near the bottom, while the northern wolffish occurs in the open water for long periods of time and sometimes rises to the surface in search of food (Albikovskaya 1983). Wolffish are taken only as bycatch in Atlantic Canada and at one time Atlantic and spotted wolffish together comprised the second most abundant bycatch in trawl catches in the Newfoundland and Labrador region after skates (DFO 1996). Bottom trawl surveys conducted in the region during 1971-1980 showed that Atlantic wolffish was the most abundant, followed in descending order by the northern and spotted wolffish (Albikovskaya 1982; 1983). Significant declines in numbers and weights of all three species of wolffish occurred within the region during the late 1970's and early 1980's and were followed by a decline in both intensity and extent of distribution during the time period 1980-2001(Kulka and DeBlois 1996; Simpson and Kulka 2002). Subsequently, spotted and northern wolffish have been designated as threatened by the Committee on the Status of Endangered Wildlife in Canada and the Atlantic wolffish has been designated as a species of special concern (COSEWIC 2004). By definition, a threatened species is likely to become endangered if limiting factors are not reversed and a species of special concern is particularly sensitive to human activities or natural events, but is not an endangered or threatened species.

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Recently, a Fisheries and Oceans Canada News Letter (DFO 2004) announced that on June 1, 2004, it became illegal to kill, harm, capture, or take any endangered or threatened species protected under the Species at Risk Act (SARA). However, under the act, the Minister of Fisheries and Oceans may authorize fishers to continue fishing activities which may result in harm to some species. He may only do so, however, if he believes that these activities will not jeopardize the survival or recovery of species at risk. The Minister must also believe that all reasonable alternatives to fishing have been considered and that all feasible measures will be taken to minimize the impact of fishing on these species.

Of the 37 aquatic species currently protected under SARA, the northern and spotted wolffish have a greater likelihood of being captured incidentally through bycatch or gear entanglements by commercial fishers (DFO 2004). In 2004, the Minister issued SARA incidental harm permits for northern and spotted wolffish to commercial fishers who were most at risk of incidentally catching these species. This decision was based on the DFO Zonal Advisory Process review in May 2004, which indicated current populations of northern wolffish are stable and populations of spotted wolffish are increasing, even with existing bycatch levels. The Minister's decision was also based on efforts DFO has taken to help these species recover, such as requirements for live release of wolffish bycatch.

DFO is relying on all commercial fishers to diligently adhere to the conditions attached to incidental harm permits, and encourages industry to take active steps to protect species at risk. As part of the National Strategy for the Protection of Species at Risk the federal government established the Habitat Stewardship Program for Species at Risk (HSP) to sponsor local stewardship activities. The overall goal of the HSP is to "contribute to the recovery of endangered, threatened, and other species at risk, and to prevent other species from becoming a conservation concern, by engaging Canadians from all walks of life in conservation actions to benefit wildlife" (HSP 2004). The HSP provides funding to 'stewards' for implementing activities that protect or conserve habitats for species designated by COSEWIC as nationally at risk (endangered, threatened, or of special concern), which includes the northern, spotted, and Atlantic wolffish.

Wolffish are taken only as bycatch in Atlantic Canada and when catches are compared among gear types it is found that the trawl represents the single largest threat to the recovery of wolffish as all three species are mainly captured by this gear (Simpson and Kulka 2003). In 2002, 177 metric tonnes of wolffish were caught by otter trawl while directing for yellowtail flounder (*Pleuronectes ferruginea*) on the Grand Bank (NAFO Div. 3LNO). This bycatch of wolffish represented 34% of the total 2002 catch reported in the Newfoundland and Labrador region and about 1.5% of the directed yellowtail flounder catch. In 2004, this activity was forecasted to represent the single largest source of potential fishing related mortality on wolffish. The bycatch of wolffish in the yellowtail flounder fishery is attributed to an overlapping distribution of a large concentration of Atlantic wolffish on the southern Grand Bank. This large concentration of Atlantic wolffish in close proximity to commercial fishing grounds provides an ideal opportunity to determine whether proposed measures to minimize the impact of otter trawl fishing on the recovery of wolffish are effective. Specifically, it has been proposed that bycatch excluder devices could be used to mitigate the capture of wolffish in otter trawl fisheries and the mandatory release of wolffish is a condition of license in all Atlantic Canada fisheries. From a conservation perspective, release of wolffish bycatch can only be effective if an acceptable proportion of fish returned to the water survive capture, handling, and release.

This study represents a joint effort between Fishery Products International (FPI), the Canadian Centre for Fisheries Innovation (CCFI), Federal Government of Canada (Habitat Stewardship Program; HSP), the Groundfish Enterprise Allocation Council (GEAC), and Marine Institute of Memorial University of Newfoundland to promote stewardship during the rebuilding of wolffish populations in Atlantic Canada. This report addresses the at-sea research component of the Habitat Stewardship Program for Species at Risk Project entitled Mitigation of Wolffish Capture – Escapement and Live Release Project. GEAC submitted the proposal for the Project to the HSP. The second and final component of the Project – Curriculum Development and Delivery of a Training Program to Industry – will be presented in a separate report.

1.2 Objectives

This study had two key objectives; 1) investigate methods to mitigate the capture of wolffish in the Grand Bank yellowtail flounder otter trawl fishery and 2) collect information on the survival capacity of wolffish released after capture in the yellowtail flounder otter trawl fishery.

Investigate Methods to Mitigate the Capture of Wolffish

The purpose of this component of this study was to establish whether a grate used by FPI on a voluntary basis to reduce the capture of large Atlantic cod (*Gadus morhua*) in the Grand Bank yellowtail flounder otter trawl fishery could also reduce the capture of wolffish. The vertical bar spacing of the sorting grate prevents large cod from passing to the codend. Instead, large cod are diverted to an escape hole in the top of the trawl. Several of the wolffish captured incidentally in the yellowtail flounder fishery are very large, therefore it seems reasonable to assume that a grate could reduce the catch of wolffish. There is however anecdotal information from FPI skippers to suggest poor swimming capabilities of wolffish result in their becoming trapped within the grate, which could lead to increased stress and possibly mortality. Fishermen also believe the grate reduces the capture of the largest yellowtail flounder and may also increase bruising of yellowtail flounder, hence its voluntary use.

The Marine Institute's research team accompanied the crew of an FPI trawler on a fishing trip directed for yellowtail flounder in December 2004 with the intent of fishing for 2-3 days without the cod sorting grate and then 2-3 days with both the grate and an underwater camera system installed in the trawl to compare the size of the wolffish captured, examine the behaviour of wolffish at the grate, and establish whether wolffish are commonly trapped in the grate. Unfortunately, poor weather conditions during the trip precluded investigations into the mitigative properties of a grate with regard to wolffish capture. The location of the grate in the trawl and its stainless steel construction can make it a dangerous piece of equipment to use during rough seas.

Modifications to the flatfish trawl represent one method of mitigating the capture of wolffish. Identifying and avoiding areas where wolffish are concentrated represents another method and has the added benefit of reducing undetected wolffish mortalities from gear encounters and potential damaging and disruptive impacts of fishing gear on wolffish habitat. The importance of providing industry with some means of mitigating the capture of wolffish during this study led to an examination of FPI's summer survey data of the Grand Bank yellowtail fishing grounds. Depth stratified survey data for the month of July was collected from 1996-2003 and used here to illustrate the distribution of the three wolffish species. In addition to supplementing information on wolffish distributions obtained from DFO fall research vessel surveys, an analysis of summer distributions can also be used to augment the traditional ecological knowledge of FPI skippers on wolffish distributions and lead to greater avoidance of 'wolffish grounds' while directing for yellowtail flounder.

Survival Capacity of Trawl Captured Wolffish

The survival component of this study involved assessing the short-term survival of wolffish by monitoring their health status and survival in holding tanks on board a commercial vessel and after simulated release into cages set on the ocean floor. Conducting the wolffish survival experiments under commercial conditions provided a means of determining the survival capacity of wolffish during normal fishing and handling activities and included an assessment of live release protocols, which includes the design and materials used in holding ramps and conveyors.

2.0 MATERIALS AND METHODS

2.1 Distribution of Wolffish on the Grand Bank Yellowtail Flounder Fishing Grounds

2.1.1 Survey Location and Vessel

A depth-stratified survey of the bulk of the yellowtail flounder distribution on the Newfoundland Grand Bank was conducted yearly on board the CFV *Atlantic Lindsey* during the month of July from 1996-1999 (Figure 1). In 2000, the survey area was expanded to the west and north in an effort to confirm DFO research vessel survey evidence of an expanded range distribution of yellowtail flounder (Figure 1). The *Atlantic Lindsey* is a 45 m stern trawler with a mass of 600 gross tons and a power output of 1,450 hp.

2.1.2 Trawl

All survey tows were conducted with an Engel 95 high lift trawl outfitted with two bridles and 1,500 kg No. 7 oval doors. Trawl specifications were as follows: 18.3 m bridle length; 91.5 m ground warp length; 29 m head rope length; 30.5 m footrope length; and 45 cm diameter rollers. Mesh sizes were as follows: 135 mm in the codend; 150 mm in the belly and lengthening piece; and 170 mm in the wings. All trawl tows were made at a speed of 2.9 knots. Trawl tow durations, defined as the period of time the trawl was on the ocean floor, were 30 minutes.

2.1.3 Wolffish Distribution Maps

All wolffish captured during the summer survey were identified to species and the tow coordinates recorded. These data were used to produce maps of the distribution of wolffish by species and year of capture. Aggregate distribution maps for the time period 1996-2003 are also provided.

2.2 Survival of Wolffish Captured by Otter Trawl

2.2.1 Fishing Vessels

Size and Power Output

Two separate wolffish survival experiments were conducted on board FPI commercial trawlers during directed yellowtail flounder fishing trips. The first experiment was conducted in June 2004 on board the CFV *Atlantic Claire*, a 45 m stern trawler with a mass and power output of 661 gross tons and 1,500 hp, respectively. The second experiment was conducted in December 2004 on board the CFV *Cape Ballard*, a 50 m stern trawler with a mass and power output of 992 gross tons and 2,500 hp, respectively.

Processing Deck and Conveyor Systems

Once the trawl is hauled onto the trawl deck the catch is dumped to a holding ramp in the hold of the vessel to await processing (Figure 2 and 3). The drop height from the trawl deck to the holding ramp ranges from about 1-1.5 m (Figure 3). The holding ramp on the CFV *Atlantic Claire* was open to the processing deck, which allowed the research team to gain complete access for removal of wolffish for experimental purposes (Figure 4). The ramp of the CFV *Cape Ballard* was closed to the processing deck. The only access to the ramp was through a small hatch (Figure 5), which allowed members of the research team to view the catch and remove wolffish that were close to the hatch.

Once processing began, fish were carried from the holding ramp to the processing (gutting) stations by means of an open conveyor system. On the CFV *Atlantic Claire* the conveyor was constructed of stainless steel and carried fish 1-2 m to the processing stations (Figure 6). The *Atlantic Claire* did not possess a mechanized discard system. When non-commercial species and species at risk were encountered they were tossed or manually lifted and carried to a discard chute where they slid a distance of about 1 m to the surface of the ocean.

In 2004, FPI decommissioned the CFV *Atlantic Claire* and CFV *Atlantic Lindsey*, two 'Atlantic' class vessels built for FPI in the early 1970's. Currently, all FPI stern trawlers operating in the Newfoundland and Labrador region are equipped with mechanized discard systems, which consist of a system of conveyors and chutes designed to carry non-commercial species and species at risk back to the ocean (e.g., Figure 7, 8, and 9).

Once fish exited the holding ramp on the CFV *Cape Ballard* they were carried 3-4 m by conveyor along the processing deck to the processing stations. All conveyors on board the *Cape Ballard* were constructed of high density plastic. A second conveyor system, a discard conveyor, carried non-commercial species and species at risk to a discard chute. When fish are passed to the discard conveyor they must first slide down a chute to floor level (Figure 8). However, due to their size, large fish are generally manually lifted and placed on the discard conveyor. The discard conveyor was equipped with 20 cm high flights that served to compartmentalized sections of the conveyor as it carried fish a distance of about 1.5 m along the floor of the processing deck before rising at an angle of about 60º and to a height of 2 m to the discard chute (Figures 8 and 9). Fish slid down the discard chute a distance of about 1 m to the surface of the ocean.

Assessment of Wolffish Discard System

The general suitability of the discard conveyor system with regard to quick and harmless release of wolffish was assessed on board the CFV *Cape Ballard* by observing wolffish as they passed along the conveyor and back into the ocean during commercial activities.

2.2.2 Trawl

Commercial tows were conducted with a 125 Engel trawl outfitted with three bridles and 1,600 kg perfect doors. Trawl specifications were as follows: 30.5 m bridle length; 110 m ground warp length; 38 m head rope length; 52 m footrope length; 45 cm diameter (centre) and 41 cm diameter (ends) rollers. Mesh sizes were as follows: 151 mm in the codend; 146 mm in the belly; 150 mm in the lengthening piece; and 160 mm in the wings. The trawl was deployed, fished, hauled back, and dumped to the holding ramp in a manner the crew was accustomed to. All tows were conducted at a speed of 3.1 knots. Tow durations, defined as the period of time the trawl was on the ocean floor, ranged from 2-2.5 hours.

The following times (Newfoundland Standard Time) were recorded during a monitored tow: trawl deployment time, fishing start time (based on hydroacoustic trawl sensors), haul back time, time when the catch was landed on the trawl deck, and time when wolffish were transferred to a temporary holding tank on the processing deck. These records were used to calculate the tow duration, haul back duration, and air exposure duration experienced by individual wolffish.

2.2.3 Study Location and Time

Wolffish survival experiments were conducted on the southern Grand Bank within the Canadian Exclusive Economic Zone of NAFO subdivision 3N in the spring (12-18 June) and early winter (8-13 December) of 2004 (Figure 10 and 11).

2.2.4 Holding Tanks

Holding tanks were installed on the processing deck of each commercial vessel. FPI constructed four large (inside dimensions: 2.44 m long × 0.91 m wide × 0.61 m deep) holding tanks on the CFV *Atlantic Claire* for American plaice (*Hippoglossoides platessoides*) live release experiments conducted in 2003 and 2004 (Figure 12). These holding tanks were also used for the wolffish survival experiments conducted in June 2004. Each tank was fitted with two transverse baffles located at about 0.8 m intervals along the length of a tank. These baffles prevented excessive movement of seawater in a tank while the vessel was at sea. Each baffle was raised 0.2 m off the bottom to allow free movement of fish throughout the tank and the baffles possessed 3 cm holes to allow adequate movement of water between compartments. A rubber hose attached to the bottom of each baffle prevented injury to wolffish when they swam between compartments. Each tank possessed a flow through water system whereby fresh seawater entered from the bottom at one end of the tank and exited near the top of the tank at the opposite end. Water supplying the holding tanks was taken from just below the surface of the ocean at a depth of about 1.5 m. Location of the drainage holes resulted in a tank capacity of 1,066 litres. Separate water valve controls were provided to each tank to regulate the flow of water and minimize variability in flow rates among tanks. The flow rate was maintained at 24-27 litres/minute, which corresponds to a seawater retention time of 39 to 44 minutes. Each tank was aerated (four 8 cm air stones/tank) and a separate air valve control was also provided for each tank. Each tank was fitted with a plywood cover and small holes were drilled in the cover to allow a minimal quantity of light to enter a tank. Low light levels and an inability of wolffish to see passing crewmen when the lids were closed was assumed to help calm the wolffish.

Six insulated fish tubs (inside dimensions: 1.42 m long × 1.12 m wide × 0.67 m deep) were used as holding tanks on the CFV *Cape Ballard* during the December survival experiments (Figure 13). Each tank was equipped with an insulated lid and possessed a flow through water system whereby fresh seawater entered from the bottom at one end of the tank and exited near the top at the opposite end of the tank. Location of the drainage hole resulted in a tank capacity of 890 litres. Separate water valve controls were provided to each tank and flow rates were maintained at 23-26 litres/minute, which corresponds to a seawater retention time of 34 to 39 minutes. Baffles and an aeration system were not installed within the insulated holding tanks.

2.2.5 Cages

The cages used in this study were previously used in a snow crab discard survivability study (Grant 2003). Each cage was constructed of PVC coated wire with a gauge and square mesh size of 3 mm and 38 mm, respectively (Figure 14). Cage dimensions were 1.52 m long × 0.99 m wide × 0.76 m high and were modified so as to contain two equal size compartments, each providing a floor surface area of 0.75 m^2.

The cages were rigged for use at-sea by attaching a frame constructed of 16 mm round steel to the bottom of each cage and a 0.2 m diameter trawl float was suspended from the haul line approximately 1.0 m above a cage. These modifications were performed to increase the likelihood of the cages descending through the water column and settling on the ocean floor in an upright orientation. Each cage was deployed separately and the location was visibly marked with two large indicator buoys. Lengths of chain each weighing approximately 15 kg were attached to the cage end of the haul line about 25 to 30 m from the cage. These chains acted as anchors to prevent the indicator buoys from moving a cage along the ocean floor during high seas.

Two to three wolffish were randomly transferred from the holding tanks to one of the cage compartments, which correspond to a stocking density of 2.7-4 fish/m^2. A supplementary food source was not provided to the caged wolffish. It was decided not to provide food in the form of herring or squid as the carcasses may attract predators or scavengers that may prey on the caged wolffish, particularly those that were injured or weakened.

2.2.6 Temperatures Experienced by Wolffish

A thermograph set to record temperature and depth at three-second intervals was attached to the codend of the trawl immediately prior to monitored tows. This thermograph recorded seawater temperatures within the lower 0-3 m of the water column while the trawl was being towed along the ocean floor and a depth-temperature profile was obtained as the trawl was hauled to the surface. This provided information on the ambient bottom water temperatures wolffish experienced prior to capture and any change in water temperature they experienced when the trawl was hauled back through the water column.

Thermographs set to record air temperature at one-hour (June) and 90 second (December) intervals were placed on the trawl deck, in the holding ramp, and on the processing deck to provide information on the air temperatures experienced by wolffish prior to holding tank assignment. Thermographs were also placed in a holding tank to monitor water temperatures experienced by wolffish. During both the June and December experiment, a thermograph was attached to a cage to monitor the water temperature wolffish experienced when they were returned to the ocean floor. All thermographs used in this study are calibrated annually for accuracy.

2.2.7 Wolffish Survival Experiments

The wolffish is a strong fish that typically forces its way up through other species in the holding ramp to lie on top of the catch. Ultimately the ability of a wolffish to force its way to the top will depend on its activity level or health status when the catch is landed and the overall weight of the catch. Sluggish or injured animals are not likely to force their way to the surface and even the most active wolffish would find it difficult to force its way to the surface when the total catch weight is very high. Nevertheless, Atlantic wolffish have been observed forcing their way to the surface of the catch 15-30 minutes after processing commenced due in part to sloshing action in the ramp and gradual removal of the catch. This behaviour combined with the floor location of the conveyor within a holding ramp generally results in a great majority of wolffish in a catch not being encounter by crewmen until most of the catch is processed which may take one to two hours and in some cases longer when the total catch weight is high and yellowtail flounder are small. Therefore, an attempt was made to quantify the survivorship of wolffish when they are held out of the water up to and including two hours.

June 2004: CFV Atlantic Claire

The spring wolffish survival experiment focused on the influence of air exposure duration and method of seawater ventilation to the gills of wolffish captured in a two-hour tow. Two air exposure treatments, 60 and 90 minutes, and two seawater ventilation treatments, unassisted and assisted were tested. In the unassisted ventilation treatment, fish were simply randomly placed in a holding tank with a current flow of 24-27 litres/minute. In the assisted treatment the flow rate was increased to 65-70 litres/minute and over a 30 minute period fish were periodically oriented so that water flowed directly into the mouth and bathed the gills. These wolffish were then placed in a holding tank receiving seawater at a flow rate of 24-27 litres/minute.

Immediately after the catch was dumped, wolffish were removed from the processing ramp and randomly assigned to an air exposure treatment of 60 or 90 minutes. All wolffish were lifted by cradling the head and pelvic region (Figure 15) or by using the pectoral fins to support the weight of the animal (Figure 16). During the air exposure treatments, wolffish were simply held in tote boxes on the floor of the processing deck. Air temperatures were cooler in the holding ramp, but it was impractical to keep wolffish in the ramp of the *Atlantic Claire* for the predetermined air exposure treatments. Prior to tote box assignment wolffish were identified to species, measured for total length (±1 cm), their health status was visually assessed, and an individually number T-bar anchor tag was applied behind the head and in the dorsal epaxial musculature. The T-bar anchors tag provided an accurate means of tracking information on each wolffish. Visual health status categories were as follows: 1) lively and vigorous, 2) sluggish, and 3) dead. When they were handled, lively and vigorous wolffish exhibited powerful sinusoidal movements of the body and commonly exhibited a rapid reflex action of the head in an attempt to bite the handler. Sluggish was a broad category, which included wolffish that exhibited little to no movement when handled or were flaccid. Only when wolffish were stiff (rigor mortis) or both flaccid and exhibited a cloudy colouration to the mucus covering the body and a cloudy appearance to the eye were they considered to be dead. When present, the location and number of fresh wounds or bruising on the body were also recorded.

At the end of each air exposure treatment wolffish were randomly assigned to an unassisted or assisted gill ventilation treatment. Health status was assessed immediately prior to being assigned to a ventilation treatment, and at 1, 3, 6, and 12 hours, and immediately prior to cage assignment. Once fish were in a holding tank their health status could be assessed with minimal disturbance. For example, lively fish were in an upright orientation and ventilatory (gill cover) movements were readily apparent. Sluggish fish were on their side and ventilatory movements were apparent over a 1-2 minute observation period. Dead fish were also on their side but showed no ventilatory movement, were stiff and the mucus on the skin developed a cloudy appearance. Upon detection, all dead wolffish were removed from a holding tank.

Surviving wolffish remained in a holding tank for about 23-24 hours before they were transferred to a cage for immediate deployment. A rubber mesh dip-net was used to remove wolffish from a holding tank and they were individually transferred to a cage on the deck of the vessel in a perforated plastic basket (Figure 17). The cage was held in a large tub filled with fresh seawater to reduce air exposure of caged wolffish during the transfer. The cage was deployed over the side of the vessel at 45°47.87' N latitude and 50°13.51' W longitude and a depth of 75 m (Figure 10).

December 2004: CFV Cape Ballard

Wolffish survival experiments carried out in December focused only on the influence of air exposure duration of wolffish captured in 2-2.5 hour tows. All wolffish were placed in holding tanks with a low current flow, therefore gill ventilation was unassisted. Wolffish captured on the morning of 9 December were placed in holding tanks for a short period of time before they were returned to the ocean floor in cages. Wolffish captured on the afternoon of 9 December and on 10 December were held in tanks on board the vessel throughout the monitoring period. The health status of wolffish was monitored for up to 2.3 days after they were subjected to five air exposure treatments: ≤30 minutes, 31-60 minutes, 61-90 minutes, 91-120 minutes, and >120 minutes. To meet the timing requirements for the air exposure treatments, wolffish were manually removed from the holding ramp or from the processing conveyor as they exited the ramp. Compared to the June experiments, this sampling methodology was more representative of industry conditions and subjected wolffish to the relatively cooler air temperature conditions typically found in the holding ramp. Once removed from the conveyor or directly from the ramp wolffish were identified to species, tagged, measured, and health status assessed in the same manner as that described for the June experiment. Subsequently, wolffish were randomly assigned to a holding tank and health status was assessed again at 6, 24, 36, and 48 hours, or immediately prior to cage assignment.

During the caging component of the experiments, surviving wolffish remained in a holding tank for about 3-10 hours before they were transferred to a cage. A rubber mesh dip-net was used to remove wolffish from a holding tank and they were individually transferred to a cage on the trawl deck in a large feedbag. Four cages were deployed in close proximity in an area bounded by approximately 44°20.20' N to 44°21.04' N latitude and 50°07.49' W to 50°07.71' W longitude (Figure 11) and at depths ranging from 49 to 55 m (mean, 51.7 m).

3.0 RESULTS

3.1 Wolffish Distribution Within Grand Bank Yellowtail Flounder Fishing Grounds

Northern and spotted wolffish were rarely encountered on the Grand Bank yellowtail flounder fishing grounds during the 1996-2003 summer industry vessel survey (Figure 18 and 19). Atlantic wolffish was the most commonly encounter and broadly distributed wolffish species within the survey area during 1996-2003 (Figure 20).

Northern wolffish were captured in only two years (2002 and 2003) of the eight year survey time series examined and catches were low with one individual captured in a single tow in each year (Figure 21 and 22). Catches of spotted wolffish were also restricted to two years (2000 and 2002) of the eight year survey time series (Figure 23 and 24). Catches of spotted wolffish were limited to one individual in a single tow in 2000 and one individual within each of two tows in 2002. Atlantic wolffish were captured in each year of the eight year survey time series (Figures 25-32) and the aggregate plot of the distribution for the time period 1996-2003 (Figure 20) appears to depict two concentrations west of the Southeast Shoal, one centered at 44ºN and the second at 45ºN latitude. Relatively few tows were conducted between the two concentrations to confirm or disconfirm the occurrence of a single larger concentration. Atlantic wolffish occurred in 16-23% of the survey tows during the period 1996-1999 and 16-27% of the tows when the survey area was expanded during the period 2000-2003. Best catches of Atlantic wolffish occurred in 2001 (Figure 30).

3.2 Post-Capture Survival of Wolffish

3.2.1 June Experiments

Wolffish Catches

Atlantic wolffish were captured in only one of the 50 tows conducted during the June 2004 commercial fishing trip directed for yellowtail flounder (Table 1; Figure 33) and the total catch in this tow was relatively low (790 kg) compared to the mean total catch weight for the trip (2,716 kg). The northern and spotted wolffish were not captured during the June fishing trip. Survival experiments were also conducted on American plaice during the June trip and given the relatively low capture rates of wolffish on the most productive yellowtail flounder fishing grounds during the spring-summer of 2004 it was decided to focus the June experiments on American plaice and defer the lion’s share of the wolffish experiments for autumn-winter. The first tow of the June trip was conducted about an eight hour steam to the south of the most productive yellowtail grounds (most southern site illustrated in Figure 33) in an attempt to collect a sufficient number of wolffish for a cage survival experiment. Nine Atlantic wolffish were taken in this tow.

Temperature Experience

Bottom water temperatures where Atlantic wolffish were captured in June ranged from 2.1-2.3ºC and depth ranged from 57-60 m. The water column was thermally stratified (Figure 34). From the near bottom to the surface the water temperature increased gradually from a low of 2.1ºC to a high of 7.9ºC, a temperature difference of 5.8ºC. A haul-back time of 10 minutes was recorded and represented the time interval between the moment when the winches engaged to the moment when the codend of the trawl was pulled onto the trawl deck. Fish experienced a trawl deck air temperature of 14.1ºC (Figure 35) for seven minutes before they were dumped to the holding ramp. All wolffish were removed from the 7.8ºC air temperature in the holding ramp (Figure 36) within 10 minutes. Wolffish subjected to the 60-minute air exposure treatment were exposed to processing deck air temperatures of 12.5-12.9ºC (Figure 37) for an additional 43 minutes (i.e., 60 minutes minus 10 minutes in the holding ramp minus seven minutes on the trawl deck = 43 minutes). Wolffish subjected to the 90 minute air exposure treatment experienced processing deck air temperatures of 11.8-12.9ºC (Figure 37) for an additional 73 minutes.

The holding tank water temperature was 7.7-8.0ºC when wolffish from the 60- and 90-minute air exposure treatments were first placed in the tanks (Figure 38). However, within two hours the water temperature had fallen to 6.5-6.8ºC and remained within this temperature range until the fish were removed from the holding tanks 23-24 hours later. The 1.2-1.5ºC decline in the holding tank water temperature from 18:00 to 22:00 hours is attributed to lower surface water temperatures encountered as the vessel journeyed northward after completing the tow for wolffish.

A cage containing wolffish was deployed on 13 June at 18:50 hours. Wolffish were quickly transferred from the holding tanks to a cage on the deck of the vessel, experiencing air temperatures of 9-10ºC during the 2-3 minute air exposure associated with the transfer and cage deployment (Figure 35). All wolffish were active and difficult to handle during the transfer to the cage. Water temperature within 0.5 m of the ocean floor showed little variability over the 3.5-day caging period, ranging from 2.3-2.8ºC (Figure 39). Bottom water temperatures at the cage site were similar to those wolffish experienced at the capture site (Figure 34).

Survival

Three of the nine Atlantic wolffish captured in June were randomly subjected to the 60-minute air exposure and unassisted gill ventilation treatment. The six remaining wolffish were subjected to the 90-minute air exposure treatment and then evenly and randomly distributed among the assisted and unassisted gill ventilation treatments.

Regardless of air exposure duration, all six Atlantic wolffish from the unassisted ventilation treatment survived the 4.75 day post-capture monitoring period, which consisted of close to one day in a holding tank and 3.75 days on the ocean floor (Table 2). These wolffish appeared much livelier after being on the ocean floor and proved very difficult to handle when removed from the cage at the end of the monitoring period. The three Atlantic wolffish from the 90-minute air exposure and assisted gill ventilation treatments died within 3-6 hours after being placed in a holding tank.

All three wolffish from the 60-minute air exposure treatment were characterized as lively when they were placed in the unassisted gill ventilation treatment (Table 2). They immediately exhibited an upright orientation and maintained a lively health status throughout the monitoring period.

Five of the six (83%) wolffish subjected to the 90-minute air exposure treatment were characterized as sluggish when they were placed in the gill ventilation treatments (Table 2). The single wolffish characterized as lively immediately exhibited an upright orientation when placed in the unassisted gill ventilation treatment. The two sluggish wolffish subjected to the unassisted ventilation treatment were on their side when first placed in the holding tank. These fish were found in an upright orientation after one hour and maintained a lively health status throughout the remainder of the monitoring period (Table 2).

Two of the three sluggish wolffish from the 90-minute air exposure and assisted gill ventilation treatment exhibited an upright orientation within 2-5 minutes of exposure to the direct current flow, but fell back to their side within the next 5-10 minutes and remained on their side throughout the remainder of the treatment and when they were placed in the holding tank. The third sluggish wolffish from the 90-minute and assisted gill ventilation treatment group remained on its side throughout the ventilation treatment and when it was placed in the holding tank.

3.2.2 December Experiments

The December survival experiments consisted of two components, survival of caged wolffish and survival of wolffish held in holding tanks. The initial intent of the caging component of this study was to keep wolffish in cages on the ocean floor for 3-4 days. However, poor weather conditions and a forecast of deteriorating weather forced the removal of the cages from the ocean floor in just under 2-days (46-47 hours). The initial intent of the holding tank experiments was to hold wolffish for 2 to 4 days to compare tank survival with cage survival. If survival was low in the cages, but high in the tanks than one could conclude there was a cage effect and visa versa. Unfortunately, poor weather conditions made it difficult to hold wolffish in the tanks on board the vessel for extended periods of time. Tank moorings became unstable on more than one occasion, which created a dangerous situation and fresh seawater lines broke free on three tanks on more than one occasion.

Wolffish Catches

Thirty-one tows were carried out on what may be considered ‘wolffish grounds’ (Figure 40) in an effort to capture sufficient numbers of wolffish for the survival experiments and to assess the discard and handling systems on board the CFV *Cape Ballard*. A total of 95 Atlantic wolffish were captured in 25 of the 33 tows conducted (Table 3; Figure 40). Neither the northern nor the spotted wolffish were captured during the December fishing trip.

Variation in Total Catch Weight

Post-capture survival was assessed for 41 wolffish captured over seven tows (Tow 3, 4, 5, 6, 7, 9, and 13; Table 3). Total catch weight in these tows ranged from 1,193 kg in Tow 13 to 5,057 kg in Tow 4. Total catch weight in Tows 3, 4, and 5 were well above the mean total catch weight (2,810 kg) for the fishing trip.

Temperature Experience

During the December experiment, Atlantic wolffish were captured at depths of 46-49 m (Table 3). Bottom water temperatures in the region ranged from 4.1-5.0ºC. The water column was not thermally stratified at the fishing sites (Figure 41). Fall-winter mixing of the water column resulted in wolffish experiencing little change (<1ºC) in water temperature from the bottom to the surface during haul back (Figure 41). Trawl deck air temperatures ranged from a low of 4.1ºC while wolffish from Tow 9 were on deck to a high of 8.2ºC during Tows 3 and 4 (Figure 42). Air temperatures in the holding ramp varied from a low of 5.2ºC while wolffish from Tow 9 were in the ramp to a high of 11.4ºC for Tow 3 (Figure 43). High variability in air temperature within the ramp is attributed to exposure to the cooler trawl deck temperatures when the catch was dumped to the ramp and the periodic spraying of cool (~5ºC) seawater from the surface of the ocean to wash fish toward the conveyor. This is a common practice and may provide a survival advantage when surface seawater temperatures are cooler than the air temperature in the ramp. Air temperatures varied by as much as 3.1 to 3.8ºC while wolffish from Tows 3, 7, and 9 were in the holding ramp. Processing deck air temperatures ranged from 12.0 to 16.2ºC when wolffish exited the ramp (Figure 44). These wolffish were immediately removed from the conveyor. Wolffish experienced processing deck air temperatures for 4-5 minutes while they were tagged and health status was assessed and then they were placed in a holding tank containing seawater. Wolffish from Tow 3 experienced the highest seawater temperatures in the holding tank (6.3ºC), but only for a short period of time (~1 hour) before the water temperature declined to 4.5-5.6ºC (Figure 45). Wolffish from Tows 3, 4, and 5 were transferred to the cages at 10:00 hours on 10 December. Shortly thereafter, sloshing within the holding tanks dislodged several of the lids and the thermograph. Subsequently, holding tank water temperatures were not available again until the following day when the dislodged thermograph was discovered (Figure 45).

Atlantic wolffish were quickly transferred from the holding tanks to a cage on the deck of the vessel, experiencing air temperatures of 6.6-7.0ºC during the 10-15 minute air exposure associated with cage deployment. Wolffish that recovered to a lively health status while in the holding tanks were active and difficult to handle during the transfer to the cage. Water temperature increased gradually from 4.0 to 5.3ºC while wolffish were on the ocean floor (Figure 46).

Survival

All nine Atlantic wolffish from the ≤30 minute (mean, 20 minutes) air exposure treatment survived and sluggish wolffish recovered to a lively health status (Table 4). One individual (11% of the wolffish examined) was characterized as sluggish when removed from the holding ramp, but recovered to a lively health status after 4 hours in a holding tank at a stocking density of 3.8 fish/m^2. Two of the four wolffish held in tanks at the highest stocking density (5 fish/m^2) for close to 10 hours exhibited a decline in health status from a lively to sluggish condition, but recovered while on the ocean floor.

Survival was high (87.5%) among the 16 Atlantic wolffish from the 31-60 minute (mean, 43-minutes) air exposure treatment and all survivors recovered to a lively health status (Table 5). All wolffish were alive when they exited the holding ramp; 11 (69%) were characterized as lively and five (31%) as sluggish. Two of the sluggish wolffish died within 6- and 24-hours while in the holding tanks. Of the remaining three sluggish wolffish, two recovered to a lively health status within three hours of being placed in a holding tank while the third recovered within 24 hours. One wolffish that was lively when placed in a holding tank at the highest stocking density (5 fish/m^2) exhibited a decline in health status over a nine hour period, but recovered while on the ocean floor. A wolffish that was found to possess a fresh superficial wound on the back of the head exhibited a lively health status throughout the monitoring period.

The two Atlantic wolffish from the 61-90 minute (mean, 67-minutes) air exposure treatment were characterized as sluggish when they exited the holding ramp (Table 6). One of these wolffish was still sluggish after about 9 hours in a holding tank at the highest stocking density (5 fish/m^2), but recovered while on the ocean floor. The other sluggish wolffish recovered to a lively health status after 3 hours in the holding tank at a moderate stocking density (3.8 fish/m^2) and maintained a lively health status while on the ocean floor.

Survival was high (90%) among 10 Atlantic wolffish from the 91-120 minute (mean, 108-minutes) air exposure treatment and all but one of the survivors exhibited a lively health status at the end of the 1-2.25 day monitoring period (Table 7). All wolffish were alive when they exited the holding ramp; one (10%) was characterized as lively and nine (90%) as sluggish. The lively wolffish maintained this health status throughout a 2.25 day monitoring period. One of the sluggish wolffish died within 24 hours in a holding tank and another was still found to be sluggish even after two days on the ocean floor. The latter wolffish possessed a fresh superficial wound on the base of the left pectoral fin. Two wolffish held at the highest stocking density (5 fish/m^2), which included the injured wolffish, did not recover from the sluggish health status while in the holding tank. Only after being returned to the ocean floor did one of these wolffish recover. The combined effects of a high stocking density during initial recovery and trawl induced stress and injury cannot be ruled out as a possible explanation for the lack of recovery of the other sluggish wolffish that was returned to the ocean floor.

There were no survivors among four Atlantic wolffish that experienced an air exposure duration greater than 120-minutes (Table 8). All wolffish were alive but sluggish when they exited the holding ramp and were found dead in the holding tanks after 24 hours.

There were no external wounds or other visible markings to explain the wolffish mortalities in this study and autopsies were not performed. All wolffish that died came from monitored tows with the lowest total catch weights (i.e., Tow 6, 7, and 13; Table 3). Also, wolffish that did not recover to a lively health status or exhibited a decline in health status while in the holding tanks were held at the highest stocking density (5 fish/m^2).

Overall, 100% survival was observed among the Atlantic wolffish that were returned to the ocean floor for 46-47 hours. These wolffish came from the three largest monitored tows (Tows 3, 4, and 5) with total catch weights ranging from 3,386-5,057 kg (Table 3). Similar to the June survival experiments, when pre-and post-caging activity levels were compared it appeared that wolffish characterized as lively were much livelier (very difficult to handle) after they had spent 46-47 hours on the ocean floor in December.

Influence of Air Exposure Duration on Health Status

The incidence of Atlantic wolffish exhibiting a sluggish health status increased with air exposure duration in December. Eleven percent of the wolffish from the ≤30 minute treatment group were sluggish (Table 4), which increased to 31% in the 31-60 minute treatment group (Table 5), and 90-100% in all treatment groups that were >60 minutes (Table 6,7, and 8).

Assessment of Discard Conveyor System

Where the discard conveyor was inclined at an angle of 60º, both small and large Atlantic wolffish were observed falling back from one compartment to the other and in some cases wolffish fell back repeatedly, requiring 2-4 lifts before they were deposited back into the ocean.

4.0 DISCUSSION AND CONCLUSIONS

This study has demonstrated that Atlantic wolffish ≥65 cm TL are very hardy. Atlantic wolffish survived capture by otter trawl and net entrainment for up to 2-2.5 hours, haul back through a thermocline, extended periods of exposure to air, handling, and simulated release during commercial fishing operations. Few Atlantic wolffish were subjected to the experimental procedures in June when air and water temperature differences experienced by wolffish in this study were most severe. Nevertheless, 100% survival of Atlantic wolffish subjected to the unassisted gill ventilation treatment after passing through a 5.8ºC thermocline and exposure to moderate (11.8-12.9ºC) air temperatures for 60-90 minutes is encouraging. Moreover, high (92%) survival among the 37 Atlantic wolffish that were exposed to air for up to 2-hours in December suggests DFOs mandatory live release requirement with regard to wolffish bycatch will help to rebuild wolffish populations in the Newfoundland and Labrador region. Mortality of all Atlantic wolffish exposed to air for more than two hours suggests this represents the critical air exposure duration for the capture, holding, handling, and environmental conditions Atlantic wolffish experienced in December.

In the current study, an assisted gill ventilation treatment did not provide a survival advantage for Atlantic wolffish that were held out of the water for 1.5 hours. Method of gill ventilation may have influenced mortality as the water hose was periodically placed directly in the mouth of wolffish, which may have damaged the gills or removed protective mucus that lines the gill lamellae. Studies on coho salmon (*Oncorhynchus kisutch*) have demonstrated that even fish that appear dead may quickly recover after placement in a recovery box with a high current flow (Farrell et al. 2001) and Atlantic wolffish in the current study appeared to recover for a short period of time after 2 to 5 minutes in the assisted gill ventilation treatment. Trawl captured Atlantic wolffish also survived well during a preliminary gill ventilation experiment conducted in late autumn (November) of 2003 (S. Grant, unpublished data). In 2003, three Atlantic wolffish that were held out of the water for 60-90 minutes and exposed to an assisted gill ventilation treatment until they resumed an upright orientation (5-10 minutes) survived well in holding tanks for 6-12 hours, before they were released. During the preliminary experiment the hose was not placed directly in the mouth of wolffish. Although results from this study indicate sluggish Atlantic wolffish that spend 1.5-2 hours out of the water in spring and early winter do not require ventilatory assistance, some of the wolffish that died after over 2 hours exposure to air may have benefited from a recovery tank that assists gill ventilation. It is notable, that the post-capture survival of the spotted and northern wolffish are currently unknown and all possible aids to recovery, including assisted gill ventilation, should be considered for these threatened species. Unfortunately, weather conditions in December precluded further evaluation of the influence of gill ventilation on recovery and survival. Current results suggest future gill ventilation experiments may have greater success if they are less aggressive in the method of ventilation and limit the exposure duration until wolffish exhibit signs of recovery.

Many species of fish captured incidentally in trawl fisheries exhibit a relatively high resistance to air exposure, however a 1.5-2 hour resistance by Atlantic wolffish is unprecedented. Many stressful and damaging factors could have acted independently or interacted to cause the mortalities observed in the current study, yet mortalities were not observed until Atlantic wolffish were out of the water for 40 minutes in December and overall survival in December was high among wolffish that were exposed to air for up to 2 hours. Further, all Atlantic wolffish exposed to air for 1-1.5 hours and subjected to the unassisted gill ventilation treatment survived in June. Most surprising was the lack of an increase in mortality with an increase in air exposure duration to 1.5 hours in June and 0.5-2 hours in December suggesting some other factor or combination of factors was largely responsible for the observed mortalities. Winter flounder (*Pleuronectes americanus*) was also found to be relatively resistant to exposure to air not showing effects after capture by trawl until 45 minutes and mortality was low (10%) to 60 minutes (Ross and Hokenson 1997). Sablefish (*Anoplopoma fimbria*) and lingcod (*Ophiodon elongates*) were resistant to air exposure not showing mortalities until 45 minutes with or without laboratory simulations of towing for four hours prior to air exposure (Olla et al. 1998; Davis and Olla 2002). One of the current authors has also observed a high (55-60 minute) resistance to air exposure in American plaice captured on the Newfoundland Grand Bank, with little to no mortality in fish that were captured in 1-3 hour commercial trawls and exposed to a 5-6ºC thermocline during capture (S. Grant, in preparation).

To maximize survival, all incidental fisheries bycatch should be returned to the water as soon as practicably possible. This study has demonstrated that even when Atlantic wolffish are out of the water for up to two hours there is still a good chance they will survive when returned to the ocean. This is an important finding because trawl fishermen have concerns over the practicality and urgency of releasing wolffish that have been out of the water for extended periods of time, particularly when they appear dead. In the current study, several of the sluggish Atlantic wolffish encountered in the holding ramp or on the processing conveyor were flaccid and unresponsive and may have been considered to be dead by fishermen, but recovered while in holding tanks on board a commercial vessel or when returned to the ocean floor.

This study has demonstrated that a 5.8ºC increase in water temperature above an *in situ* acclimation temperature of 2.1ºC is within the threshold of temperature tolerance for Atlantic wolffish occurring on the Newfoundland Grand Bank. Assessment of the upper threshold of temperature tolerance for Atlantic wolffish was beyond the scope of this study. However, a preliminary survivorship study indicated that Atlantic wolffish could not tolerate an 11-12ºC increase in water temperature (S. Grant, unpublished data). In early October 2003, survival was assessed for five Atlantic wolffish captured incidentally in the Grand Bank yellowtail flounder otter trawl fishery. All Atlantic wolffish appeared to have experienced thermal shock after passing through an 11-12ºC thermocline during haul back. Bottom water temperature at the capture sites ranged from 3.9-4.1ºC and air temperature in the holding ramp ranged from 18-20ºC. All Atlantic wolffish were exposed to air for a relatively short period of time, 9-15 minutes. Although they were quickly removed from the holding ramp, four Atlantic wolffish were categorized as dead when they were encountered and the remaining wolffish died within 10-15 minutes of being placed in a holding tank containing 16ºC seawater.

It has been suggested that suffocation and crushing during net entrainment influences post-capture survival of discards when they are captured early in the trawl and the total catch weight is high (Neilson et al. 1989). There is however no way of assessing at what point fish were actually captured in the trawl. Tow durations therefore represent the maximum time which fish were enclosed by the net, when in fact they could have spent considerably less time within the trawl (Neilson et al. 1989). A comparison of the health status and injuries of Atlantic wolffish from tows with high total catch weights provides only circumstantial evidence of suffocation by a single wolffish during net entrainment. An Atlantic wolffish with a superficial head wound exhibited a lively health status after spending relatively little time (38 minutes) out of the water and maintained a lively health status throughout the monitoring period, which included 3.5 hours in a holding tank at a relatively low stocking density (2.5 fish/m^2) and close to two days on the ocean floor. The health status of this wolffish emphasizes the superficial nature of the head injury and suggests suffocation and crushing during net entrainment were not important. An Atlantic wolffish with a superficial wound on the base of a pectoral fin was sluggish after having spent 96 minutes out of the water, and although it survived, this wolffish remained sluggish after 8.5 hours in a holding tank at the highest stocking density (5 fish/m^2) and close to two days on the ocean floor. The nature of the pectoral fin injury implies meshing during net entrainment, a condition that is likely to lead to suffocation. Further, *in situ* recovery to a lively health status by a non-injured wolffish of similar size that was captured in the same tow as the wolffish with the pectoral fin injury and subjected to the same on board holding conditions, including 95 minutes exposure to air, suggests suffocation during net entrainment may have hindered the recovery of this injured wolffish. However, overall there were no mortalities among Atlantic wolffish from the catches with the highest total catch weights and evidence of suffocation was limited to a single individual suggesting the deleterious effects commonly associated with high total catch weights have little impact on Atlantic wolffish. Indeed, all of the mortalities observed in this study occurred among wolffish from catches with relatively low total catch weights.

Interactions of stressors make it difficult to determine which stressor has the greatest influence on post-capture recovery. For example, water quality during recovery is important and reduced oxygen levels in holding tanks at high stocking densities combined with increased oxygen demands during repayment of the oxygen debt would most certainly delay metabolic recovery from exhaustion, a critical stage in the recovery process (Black 1958; Beamish 1966; Peltonen 1969). In the current study, Atlantic wolffish held at the highest stocking density (5 fish/m^2) were less likely to recover to a lively health status while in the holding tanks and others exhibited a decline in health status. This leads us to conclude that overcrowded conditions in the holding tank also contributed to the prolonged poor health status of the Atlantic wolffish with a pectoral fin injury.

Overall, results of this study suggest 5 fish/m^2 represents the critical stocking density at the seawater retention times and temperatures Atlantic wolffish experienced while recovering from trawl induced exhaustion and stress. Moreover, high survival in the unassisted gill ventilation treatments at low stocking densities and ≤2 hours exposure to air in both June and December as well as evidence of increased levels of activity after 2-3.75 days on the ocean floor suggests survival may be improved by bypassing holding tanks and rapidly transferring wolffish back to the ocean once they are encountered. Furthermore, increased oxygen demands placed on fish when they are transferred to holding tanks receiving even warmer surface waters in summer and early autumn (Beamish 1964) would magnify the negative effects of overcrowding at even lower stocking densities. Holding tanks on commercial vessels are currently designed to receive water from the surface of the ocean and advantages of chilling the seawater in holding tanks when ocean surface temperatures are high are unclear as there is a risk of thermal shock when wolffish are released back into warm surface waters. The same is true when one considers lowering the temperatures in the holding ramp by pumping in chilled seawater. An important piece of missing information with regard to survival of trawl captured wolffish under varying temperature regimes is the effect of repeated rising and lowing of the ambient temperature.

The accuracy of the current Atlantic wolffish survival estimates depends on the assumption that no additional mortality due to capture, handling, and release occurs beyond a 1-4.75 day monitoring period and that mortality in the holding tanks and cages reflects that which the wolffish would have experienced had they been released. Survival studies have shown that mortality in fish due to hyperactivity during capture usually occurs within 24 hours of being caught (Black 1958; Beamish 1966; Peltonen 1969). When delayed mortality was monitored for 30-60 days following laboratory simulations of capture by otter trawl, which included towing in a net, changes in water temperature, and exposure to air it was found that all mortality may indeed occur within 1-3 days in some species (i.e., sablefish and lingcod) while in others (i.e., Pacific halibut [*Hippoglossus stenolepis*] and walleye pollock [*Theragra chalcogramma*]) delayed mortality may occur 14-30 days after treatment (Olla et al. 1997; 1998; Davis and Olla 2001; 2002). While it cannot be denied that controlled laboratory studies provide valuable insights into factors influencing mortality of fishes, laboratory survival estimates can suffer from uncertainty as to the factors that cause mortality, particularly when fish are held for extended periods of time. Even seemingly benign factors inherent to laboratory studies can magnify stress over time and influence mortality such that long-term laboratory survival experiments may be demonstrating which species of fish or individuals within a species can tolerate the added stress associated with the experiments. In fact, many laboratories are attempting to isolate and breed fish that are most resistant to laboratory handling and holding conditions (D. Boyce, personal communications, Logy Bay Ocean Sciences Centre, NL). Mortalities in laboratory studies can result directly or indirectly from added stress associated with overcrowding, social hierarchies, disease, parasites, and lighting conditions to name a few and interactions of factors can magnify stress over extended periods of time. Ultimately, the most defendable method of addressing long-term post-capture survival would be through the use of *in situ* studies involving either acoustic telemetry, capture-mark-recapture reward programs, or simulated release into cages. Unfortunately, acoustic telemetry and capture-mark-recapture studies are expensive and these kinds of *in situ* studies are also prone to bias when assumptions are not met.

We suspect that the recovery to high activity levels by Atlantic wolffish in holding tanks at the lower stocking densities and by all but one of the Atlantic wolffish returned to the ocean floor in cages was sufficient to largely prevent delayed mortalities after a 1-4.75 day monitoring period. In the current study, all mortalities occurred within 24 hours, suggesting mortality may in part at least be attributed to hyperactivity during capture and handling (Black 1958; Beamish 1966; Peltonen 1969). However, interactions of several factors causing stress and detectable and undetectable injury during commercial trawling make it unlikely that mortality can be attributed to any single factor. Nevertheless, knowledge of the factors or combination of factors that result in mortality (Olla et al. 1998; Davis and Olla 2002) may make it easier to reconcile an appropriate monitoring period to assess post-capture delayed mortality. For example, visibly injured fish should be monitored until their wounds begin to heal or until they exhibit metabolic recovery to pre-capture status. In the current study, neither of the two Atlantic wolffish that exhibited external wounds died during the 2.3 day monitoring period. The health status of one injured wolffish appeared largely unaffected while the other remained sluggish throughout the monitoring period suggesting 2.3 days was a sufficient monitoring period for one but not the other. There were no visible external wounds on Atlantic wolffish that died during this study. However, all fish fell at least 1-1.5 m when the catch was dumped to the holding ramp and in trawl bycatch survival studies of American plaice internal injuries in the form of bruising have been observed when fish fall directly on to the holding ramp (S. Grant, in preparation). Invariably all American plaice that exhibited excessive bruising died within 6-12 hours. Atlantic wolffish have been observed striking the holding ramp when the catch is dumped and because of their large head they typically land headfirst. Unfortunately, the thick skin and skin coloration makes it difficult to confirm or disconfirm bruising in Atlantic wolffish. Neilson et al. (1989) suggested that high total catch weights could provide a cushioning effect that reduces injury to fish when the catch is dumped and in the current study, all mortalities occurred in Atlantic wolffish from catches with relatively low (<1,600 kg) total catch weights. Indeed, none of the wolffish from catches with relatively high (>2,800 kg) total catch weights died suggesting a cushioning effect. We speculate that dropping of Atlantic wolffish onto hard surfaces contributed to the mortalities observed in this study and that internal injuries resulting from the impact causes mortalities to occur within 24 hours, similar to findings for American plaice.

The physiology and morphology of the Atlantic wolffish make it a good candidate for reduction of bycatch mortality. Temperature controls virtually all physiological functions and this study has demonstrated that the Atlantic wolffish can tolerate at least a 5.8ºC increase in water temperature and resists extended periods of exposure to moderate air temperatures. The high resistance to air exposure was a surprising outcome and suggests the possibility that wolffish possess respiratory adaptations yet to be identified. For example, in some fishes a small amount of aquatic gas exchange takes place in areas besides the gills and cutaneous respiration or diffusion of gas through a well vascularized skin may allow wolffish to use the atmosphere for respiration, similar to the American eel (*Anguilla anguilla*), longnose gar (*Lepisosteus osseus*), and Antarctic icefish (*Chaenocephalus* sp.) (Berg and Steen 1965; Holton 1976). Modified gills of the walking catfish (*Clarias batrachus*) represents another adaptation for aerial respiration (Jordan 1976). In short, respiratory adaptations for aerial respiration in fish are not uncommon and given their high resistance to extended periods of exposure to air it is conceivable that similar adaptations could have evolved in ancestors of wolffish and warrants further investigation. For example, ancestors of wolffish may have been intertidal and relied partially on aerial respiration during low tide. Wolffish do not possess a swim bladder, therefore respiratory adaptations of this organ can be ruled out. However, absence of a swim bladder means changes in pressure associated with the ascent through the water column during haul back or descent to the ocean floor during release are unlikely to influence survival. Further, wolffish have no scales to lose and possess a thick skin that is resistant to abrasion and therefore likely minimizes osmotic imbalances that can lead to stress and mortality. Leather products are made from the skin of spotted wolffish and further demonstrate the durability of wolffish skin. However, care should be taken during handling to avoid loss of protective mucus that covers the skin and gills as this could lead to secondary infections and delayed mortality. There were no visible signs of secondary infections in wolffish in the current study suggesting commercial handling and holding protocols limit mucus loss.

Techniques for safe handling and live release of wolffish were identified during this study and are outlined below. Fishermen should avoid lifting, sliding, or other forms of handling that involve touching the gills or gill cover of wolffish. Gaffes or other sharp edged tools must not be used as they may damage wolffish. When lifting a wolffish it should be cradled under the head and pelvic region or the pectoral fins can be used to support the weight of the animal. The tail can be grasped to quickly orient the wolffish for lifting, but should not be used to support the entire weight of the animal, as the intensity of any grip required to lift wolffish solely by the tail will result in mucus loss and possibly bruising. Use of rubber or vinyl gloves is recommended to avoid removal of the protective mucus on the skin of wolffish. This mucus protects the wolffish from bacterial and fungal infections.

The trawling industry should reduce handling where practicable by allowing wolffish to pass quickly and unimpeded along conveyor systems that deposit them back into the ocean. A weighing system may be installed within the path of a discard conveyor to reduce handling, however these weighing systems would have to be quite sophisticated and therefore costly if they are to operate on the high seas. In the current study, survival was high even when wolffish experienced what may be interpreted as extreme handling conditions while they were measured for length, health status assessed, and tagged. This suggests routine length and weight measurements made quickly by fishermen or observers will have little impact on survival. However, industry may wish to further pursue the suitability of this type of equipment if the objective is to avoid the time that one or more fishermen would have to dedicate to collecting this information.

The stainless steel and high density plastic used in the construction of the holding ramp and conveyor systems on board the CFV *Cape Ballard* are resistant to corrosion and pitting. These nonabrasive materials are unlikely to cause injury to wolffish by removing protective mucus or by damaging the skin. Unfortunately, there is no apparent modification or handling method that can be incorporated into commercial trawlers working on the high seas that will eliminate dropping of the catch from the trawl deck to the holding ramp. However, the design of the holding ramps on FPIs stern trawlers should provide a survival advantage to discards. For example, the holding ramp on the *Cape Ballard* is closed and air temperatures in a closed ramp are typically cooler than an open ramp, which not only serves to improve product quality, but should also provide a survival advantage for discards. When air temperatures are high, periodically spraying cooler subsurface seawater into the holding ramp will also help to establish a more suitable environment for discards. The angled floor of the holding ramp reduces the movement of the catch in a forward and aft direction, while narrowing the compartments in the ramp reduces the side-to-side sloshing effect. Less movement of the catch reduces damaging impacts of fish with the walls of the ramp as well as mucus and scale loss or external injuries caused by fish rubbing against one another. Apart from the CFV *Penneysmart*, all FPI stern trawlers in the Newfoundland and Labrador region are equipped with closed stainless steel holding ramps with narrow compartments and all conveyors are constructed of high density plastic or stainless steel (Derek Fudge, personal communication, FPI Marystown, NL).

In the current study, both small and large Atlantic wolffish were observed falling back from one compartment to the other at the inclined region of the discard conveyor on board the CFV *Cape Ballard* and in some cases wolffish fell back repeatedly, requiring 2-4 lifts before they were returned to the ocean. The CFV *Cape Beaver*, a stern trawler in FPIs yellowtail flounder fishing fleet on the Grand Bank, has an identical discard system to the *Cape Ballard*. To minimize injury to wolffish any incline within a conveyor system should be at a grade that reduces the likelihood that wolffish fall back among the compartments. Alternatively, flights that demarcate the compartments should be of a suitable height to accommodate the largest wolffish. It is notable that the northern wolffish has a much more robust body and broader head then that of the Atlantic wolffish which may result in an even greater likelihood of this species falling back between compartments of a conveyor with a high angle of inclination.

Summer wolffish distributions derived from an industry vessel survey of the Grand Bank yellowtail flounder fishing grounds corroborate distributions obtained from DFO fall research vessel surveys during the period 1980-2001 (Simpson and Kulka 2002). Both the spotted and northern wolffish were rarely encountered on the southern Grand Bank during the summer survey which corresponds to the sparse and patchy distributions illustrated by DFO surveys. DFO research vessel surveys identified an aggregation of Atlantic wolffish, which has occurred west of the southeast shoal from year to year and is centered at about 44ºN latitude (Simpson and Kulka 2002). The aggregate distribution plot derived from the summer industry vessel survey is consistent with the aggregate distribution plots obtained from DFO research vessel surveys. Comparable distributions in summer and fall suggest there is little seasonal migration of Atlantic wolffish on the southern Grand Bank which aligns well with previous tagging studies in Placentia Bay, Newfoundland that demonstrated limited movements (3.2-8 km) of Atlantic wolffish over a 5-7 year period (Templeman 1984).

In an effort to mitigate the capture of wolffish while directing for yellowtail flounder and augment traditional ecological knowledge an aggregate distribution map of all three species of wolffish has been distributed among FPI skippers. A concerted effort by FPI skippers to avoid areas where Atlantic wolffish are concentrated will not only reduce the likelihood of incidental capture, but also undetected mortalities from gear encounters and potential damaging and disruptive impacts on wolffish habitat. For example, there were no wolffish captured during the June fishing trip when industry targeted the region north of the wolffish grounds, while Atlantic wolffish occurred in 80.6% of the tows conducted on wolffish grounds during December when this area was targeted in an effort to capture sufficient quantities of wolffish for post-capture survival experiments.

Overall, results of this study suggest the yellowtail flounder otter trawl fishery is unlikely to prevent the recovery of wolffish on the Newfoundland Grand Bank. This study corroborates DFO research vessel survey findings on the sparse and patchy distribution of spotted and northern wolffish on the southern Grand Bank, a condition that not only minimizes undetected mortality from gear encounters, but also post-capture mortality while directing for yellowtail flounder. This study confirmed the presence of a concentration of Atlantic wolffish in the southern and western region of the yellowtail flounder fishing grounds and hence their vulnerability to capture by otter trawl. However, this study also demonstrated that post-capture survival is high when the difference between the surface and bottom water temperatures at wolffish capture sites are within 5.8ºC and air temperatures in the holding ramp of commercial vessels are <13ºC. These temperature conditions typically prevail on the southern Grand Bank for at least a 7.5 month period from November to mid-June when the yellowtail flounder fishery closes for 1.5 months during the spawning season. Thus, for up to about 70% of the fishing season (7.5 month/10.5 months) the mortality risk to Atlantic wolffish posed by the Grand Bank yellowtail flounder otter trawl fishery should be substantially reduced since the introduction of DFOs mandatory wolffish live release program in 2004.

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Table 1. Otter trawl tow details from a directed yellowtail flounder trip of the CFV *Atlantic Claire* on the Newfoundland Grand Bank in June 2004. Catch values are reported in kilograms. Both the weight and number of individuals captured (in parenthesis) are reported for Atlantic wolffish. See text for trawl description.

Tow No.	Date	Time start	Duration (hr:min)	Latitude	Longitude	depth (m)	Atlantic Wolffish	Yellowtail	Plaice	Cod	Witch	Haddock	Skate	Sculpin	Crab	**Total**
1	6/12/04	15:55	2:00	44 41.35	50 31.44	56.7	91 (9)	486	68	0	2	1	114	27	0	790
2	6/12/04	23:20	2:00	45 22.41	50 02.03	58.5	0	1,545	68	0	0	0	45	5	0	1,664
3	6/13/04	1:50	2:00	45 25.26	50 08.03	58.5	0	1,809	191	0	0	0	55	0	0	2,055
4	6/13/04	4:20	2:00	45 22.52	50 01.64	60.4	0	1,727	364	0	0	0	45	5	0	2,141
5	6/13/04	7:45	2:00	45 33.78	50 03.04	67.7	0	505	205	11	0	0	23	2	0	745
6	6/13/04	10:20	2:00	45 41.02	50 10.17	71.3	0	2,386	364	14	0	0	45	5	0	2,814
7	6/13/04	12:50	2:05	45 45.57	50 07.70	71.3	0	2,300	364	14	0	0	36	5	0	2,718
8	6/13/04	15:25	2:10	45 41.74	50 09.40	71.3	0	1,705	341	23	0	0	45	5	0	2,118
9	6/13/04	20:00	2:00	45 46.67	50 23.81	80.5	0	2,555	364	14	0	0	36	5	0	2,973
10	6/13/04	22:30	2:00	45 52.67	50 22.21	80.5	0	2,409	364	0	0	0	34	9	0	2,816
11	6/14/04	1:20	2:00	45 46.60	50 23.69	75.0	0	3,818	291	45	0	0	45	5	5	4,209
12	6/14/04	4:00	2:10	45 52.39	50 22.26	80.5	0	2,300	477	55	0	0	36	0	5	2,873
13	6/14/04	7:55	2:00	45 45.70	50 23.88	78.6	0	1,734	255	23	0	0	27	0	2	2,041
14	6/14/04	10:30	2:00	45 51.73	50 22.52	78.6	0	2,105	382	14	5	0	27	0	2	2,534
15	6/14/04	13:00	2:15	45 47.46	50 24.39	76.8	0	2,655	445	68	5	0	23	0	5	3,200
16	6/14/04	15:45	2:15	45 53.21	50 22.09	78.6	0	2,618	445	14	0	0	23	0	2	3,102
17	6/14/04	19:25	2:20	45 45.63	50 23.85	80.5	0	2,991	436	9	0	0	9	0	2	3,448
18	6/14/04	23:20	2:00	45 49.41	50 24.19	80.5	0	3,189	255	0	0	0	23	0	2	3,468
19	6/15/04	2:55	2:00	45 52.35	50 22.02	80.5	0	2,814	382	45	0	0	23	0	2	3,266
20	6/15/04	5:50	2:15	45 46.82	50 23.70	78.6	0	2,300	445	45	0	0	9	0	2	2,802
21	6/15/04	9:25	2:10	45 54.76	50 07.94	76.8	0	2,041	191	18	0	0	9	5	2	2,266

Table 1. Cont'd.

Tow No.	Date	Time start	Duration (hr:min)	Latitude	Longitude	depth (m)	Atlantic Wolffish	Yellowtail	Plaice	Cod	Witch	Haddock	Skate	Sculpin	Crab	**Total**
22	6/15/04	12:15	2:00	45 57.72	50 01.22	73.2	0	1,655	218	14	0	0	18	5	5	1,914
23	6/15/04	14:45	2:00	45 50.68	50 05.88	73.2	0	3,227	255	0	0	0	18	5	2	3,507
24	6/15/04	17:15	2:05	45 44.26	50 09.93	73.2	0	2,491	409	32	0	0	9	5	5	2,950
25	6/15/04	23:50	1:40	45 14.36	49 47.80	56.7	0	1,068	127	5	9	0	23	0	2	1,234
26	6/16/04	2:00	2:00	45 12.10	49 41.22	60.4	0	1,355	127	0	0	0	45	0	2	1,530
27	6/16/04	5:15	2:00	45 21.97	50 00.30	60.4	0	1,273	511	0	0	0	18	0	5	1,807
28	6/16/04	7:50	1:45	45 23.73	50 06.18	65.8	0	732	136	5	5	0	36	5	2	920
29	6/16/04	12:00	2:00	45 45.19	50 23.86	80.5	0	2,159	545	14	0	2	23	5	2	2,750
30	6/16/04	14:30	2:00	45 50.80	50 22.64	78.6	0	1,795	307	9	0	0	18	5	2	2,136
31	6/16/04	16:55	2:15	45 45.15	50 24.02	78.6	0	1,977	477	159	0	0	23	5	2	2,643
32	6/16/04	20:25	2:10	45 51.94	50 21.81	80.5	0	2,909	477	0	0	0	45	9	5	3,445
33	6/17/04	0:30	1:45	45 46.67	50 23.53	78.6	0	3,845	182	0	0	0	45	9	5	4,086
34	6/17/04	3:55	1:40	45 51.33	50 22.59	78.6	0	1,955	375	27	0	2	14	5	2	2,380
35	6/17/04	7:15	2:00	45 47.44	50 23.50	80.5	0	1,686	443	23	0	0	9	5	2	2,168
36	6/17/04	9:45	2:10	45 53.26	50 21.76	78.6	0	2,495	443	23	5	0	14	5	2	2,986
37	6/17/04	15:05	2:00	45 47.12	50 23.83	80.5	0	2,236	443	36	0	0	27	5	2	2,750
38	6/17/04	18:10	2:05	45 51.19	50 22.84	80.5	0	2,527	545	45	5	0	5	32	2	3,161
39	6/17/04	20:45	2:15	45 46.00	50 24.17	80.5	0	3,755	400	0	0	0	9	9	2	4,175
40	6/18/04	1:00	2:00	45 52.90	50 22.09	80.5	0	5,000	273	34	0	0	9	0	0	5,316
41	6/18/04	6:25	1:25	45 46.69	50 23.96	80.5	0	989	170	45	0	0	18	0	0	1,223
42	6/18/04	8:30	2:15	45 53.00	50 21.85	80.5	0	2,495	341	23	0	0	14	5	0	2,877
43	6/18/04	11:15	2:25	45 46.82	50 23.78	80.5	0	2,495	443	18	5	0	18	5	0	2,984

Table 1. Cont'd.

Tow No.	Date	Time start	Duration (hr:min)	Latitude	Longitude	depth (m)	Atlantic Wolffish	Yellowtail	Plaice	Cod	Witch	Haddock	Skate	Sculpin	Crab	**Total**
44	6/18/04	14:00	2:30	45 53.22	50 22.15	78.6	0	2,009	307	9	0	0	14	2	0	2,341
45	6/18/04	21:25	2:05	45 46.75	50 23.65	80.5	0	3,618	236	0	0	0	23	5	0	3,882
46	6/19/04	0:00	2:00	45 52.89	50 23.09	80.5	0	3,682	291	5	0	0	23	9	0	4,009
47	6/19/04	4:40	2:20	45 46.55	50 23.86	78.6	0	2,982	307	45	5	0	23	2	2	3,366
48	6/19/04	7:45	2:20	45 53.18	50 22.06	80.5	0	2,982	375	14	5	0	18	2	2	3,398
49	6/19/04	10:50	2:25	45 46.10	50 23.90	80.5	0	3,209	273	23	5	0	36	0	0	3,545
50	6/19/04	15:45	1:15	45 52.90	50 22.28	80.5	0	1,545	591	109	9	0	23	0	2	2,280
						Totals	91 (9)	116,139	16,725	1,127	61	5	1,352	214	91	135,805

Table 2. Summary of Atlantic wolffish health status (L=lively and S=sluggish) after capture by otter trawl and exposure to two gill ventilation and air exposure duration treatments in June 2004.

Gill Ventilation	Air Exposure Duration (hr:min)	Body Length (cm)	Health Status When Placed in Holding Tank	Duration In Holding Tank	Holding Tank Stocking Density (No. fish/m^2)	Health Status When Placed in Cage	Duration In Cage (hr:min)	Post-caging Health Status
Unassisted	1:00	95	L	23:45	2.7	L	90:10	L
Unassisted	1:00	90	L	23:45	2.7	L	90:10	L
Unassisted	1:00	101	L	23:45	2.7	L	90:10	L
Unassisted	1:30	100	L	23:15	2.7	L	90:10	L
Unassisted	1:30	108	S	23:15	2.7	L	90:10	L
Unassisted	1:30	89	S	23:15	2.7	L	90:10	L
Assisted	1:30	106	S	6:00*	1.4			
Assisted	1:30	75	S	6:00*	1.4			
Assisted	1:30	126	S	3:00*	1.4			

* Dead

Table 3. Otter trawl tow details from a directed yellowtail flounder trip of the CFV *Cape Ballard* on the Newfoundland Grand Bank in December 2004. All catch values are reported in kilograms unless otherwise stated. See text for trawl description.

Tow No.	Date	Time start	Duration (hr:min)	Latitude	Longitude	depth (m)	No. of Atlantic Wolffish	Atlantic Wolffish	Yellowtail	Plaice	Cod	Halibut	Skate	Sculpin	**Total**
1	12/8/04	15:00	2:00	44 40.79	50 32.27	53.0	0	0	1,795	114	0	0	0	9	1,918
2	12/8/04	17:25	2:00	44 34.12	50 32.33	54.9	0	0	1,523	45	0	0	34	11	1,614
3	12/8/04	23:15	2:00	44 17.95	50 05.23	49.4	8	68	2,818	182	0	0	227	91	3,386
4	12/9/04	1:45	2:00	44 11.70	50 02.95	49.4	4	34	4,545	159	57	0	182	80	5,057
5	12/9/04	4:25	2:15	44 17.56	50 04.34	47.6	6	45	3,818	68	0	0	136	57	4,125
6	12/9/04	8:00	2:30	44 08.06	50 02.93	49.4	7	73	909	295	23	0	227	45	1,573
7	12/9/04	12:35	2:15	44 18.24	50 05.48	47.6	5	45	1,136	182	0	0	68	68	1,500
8	12/9/04	15:35	2:30	44 10.98	50 02.70	47.6	4	34	2,750	91	34	0	159	114	3,182
9	12/9/04	20:10	2:15	44 17.76	50 01.21	47.6	5	45	2,091	250	68	0	273	91	2,818
10	12/9/04	23:30	2:30	44 10.52	49.56.75	45.7	0	0	1,091	409	57	0	295	114	1,966
11	12/10/04	4:00	2:30	44 11.84	49 58.39	45.7	0	0	2,284	318	23	0	91	68	2,784
12	12/10/04	8:00	2:30	44 11.21	50 02.02	47.6	1	11	920	182	0	0	227	91	1,432
13	12/10/04	11:05	2:30	44 17.80	50 04.80	47.6	6	80	909	45	45	0	68	45	1,193
14	12/10/04	14:10	2:30	44 10.12	50 02.62	45.7	2	23	1,602	57	0	18	159	68	1,927
15	12/10/04	17:30	2:00	44 17.46	50 04.86	47.6	2	23	2,273	261	0	0	182	114	2,852
16	12/10/04	20:00	2:10	44 12.00	50 00.73	47.6	0	0	2,568	68	91	0	193	102	3,023
17	12/10/04	22:40	2:00	44 17.64	50 04.74	47.6	2	23	3,659	159	23	0	341	114	4,318
18	12/11/04	1:15	2:00	44 17.76	50 01.15	45.7	1	11	3,045	136	11	0	193	80	3,477
19	12/11/04	4:35	2:20	44 18.05	50 05.20	45.7	0	0	3,205	136	0	0	95	57	3,493
20	12/11/04	10:35	2:30	44 17.90	50 05.05	47.6	4	34	1,136	45	0	0	118	64	1,398
21	12/11/04	14:00	2:30	44 17.65	50 04.16	47.6	4	34	1,102	455	0	0	68	91	1,750

Table 3. Cont'd.

Tow No.	Date	Time start	Duration (hr:min)	Latitude	Longitude	depth (m)	No. of Atlantic Wolffish	Atlantic Wolffish	Yellowtail	Plaice	Cod	Halibut	Skate	Sculpin	**Total**
22	12/11/04	16:50	2:10	44 12.21	50 00.30	47.6	5	45	4,727	318	0	0	57	45	5,193
23	12/11/04	19:40	2:00	44 18.60	50 05.12	47.6	1	11	3,068	68	0	0	80	34	3,261
24	12/11/04	23:10	2:00	44 10.60	50 00.60	47.6	3	34	3,159	295	0	0	34	34	3,557
25	12/12/04	2:10	2:15	44 17.90	50 04.33	45.7	2	23	2,568	45	0	0	57	45	2,739
26	12/12/04	5:00	2:30	44 10.98	50 00.19	45.7	0	0	2,591	318	0	0	68	45	3,023
27	12/12/04	8:00	2:30	44 18.08	50 04.70	45.7	5	45	2,977	300	0	0	45	68	3,436
28	12/12/04	11:05	2:30	44 10.30	50 02.78	45.7	5	45	1,500	91	0	0	68	45	1,750
29	12/12/04	14:10	2:30	44 18.02	50 04.65	45.7	7	80	1,295	91	0	0	45	45	1,557
30	12/12/04	17:05	2:00	44 11.81	50 02.22	45.7	2	23	3,432	273	0	0	45	114	3,886
31	12/12/04	21:00	2:00	44 18.52	50 05.19	45.7	1	11	4,239	182	0	0	57	80	4,568
32	12/12/04	23:40	2:00	44 12.24	50 00.53	45.7	3	45	2,216	273	34	0	57	68	2,693
33	12/13/04	2:45	1:30	44 18.17	50 04.56	45.7	0	0	2,102	91	0	0	34	68	2,295
						Totals	95	948	79,057	6,005	466	18	3,986	2,266	92,745

Table 4. Summary of health status (L=lively and S= sluggish) of Atlantic wolffish following capture by otter trawl and exposure to air for less than 30 minutes in December 2004. Wolffish from Tows 3, 4, and 5 were transferred to cages and lowered to the ocean floor.

Tow No.	Tow Duration (hr:min)	Body Length (cm)	Air Exposure Duration (hr:min)	Health Status When Placed in Holding Tank	Duration In Holding Tank	Holding Tank Stocking Density (No. fish/m^2)	Health Status When Removed From Holding Tank	Duration In Cage (hr:min)	Post-caging Health Status
7	2:30	107	0:24	L	24:00	4.4	L		
13	2:30	95	0:25	L	24:00	4.4	L		
3	2:00	107	0:14	L	9:56	5	S	46:00	L
3	2:00	108	0:15	L	9:55	5	S	46:00	L
3	2:00	98	0:16	L	9:54	5	L	46:00	L
3	2:00	78	0:26	L	9:44	5	L	46:00	L
4	2:00	106	0:25	L	7:23	2.5	L	46:43	L
5	2:15	115	0:15	S	3:55	3.8	L	46:50	L
5	2:15	102	0:16	L	3:54	3.8	L	46:10	L
Means	2:10	101.8	0:20					46:20	

Table 5. Summary of health status (L=lively and S= sluggish) of Atlantic wolffish following capture by otter trawl and exposure to air for 31-60 minutes in December 2004. Wolffish from Tows 3, 4, and 5 were transferred to cages and lowered to the ocean floor.

Tow No.	Tow Duration (hr:min)	Body Length (cm)	Air Exposure Duration (hr:min)	Health Status When Placed in Holding Tank	Duration In Holding Tank	Holding Tank Stocking Density (No. fish/m^2)	Health Status When Removed From Holding Tank	Duration In Cage (hr:min)	Post-caging Health Status
9	2:15	77	0:35	L	36:00	3.8	L		
9	2:15	89	0:37	L	36:00	3.8	L		
9	2:15	78	0:39	L	36:00	3.8	L		
9	2:15	77	0:45	L	36:00	3.8	L		
9	2:15	100	0:51	L	36:00	3.8	L		
13	2:30	94	0:54	S	6:00	4.4	DEAD		
13	2:30	105	0:35	L	24:00	4.4	L		
13	2:30	96	0:37	L	24:00	4.4	L		
13	2:30	86	0:40	S	24:00	4.4	DEAD		
13	2:30	112	0:42	S	24:00	4.4	L		
3	2:00	100	0:54	L	9:06	5	S	45:50	L
4	2:00	88	0:31	L	7:17	2.5	L	46:13	L
4	2:00	111*	0:38	L	7:10	2.5	L	46:13	L
5	2:15	95	0:35	L	3:35	3.8	L	46:10	L
5	2:15	92	0:59	S	3:11	3.8	L	46:10	L
5	2:15	106	0:60	S	3:10	3.8	L	46:10	L
Means	2:16	95.1	0:43					46:08	

*one fresh wound was found on the back of the head

Table 6. Summary of health status (L=lively and S= sluggish) of Atlantic wolffish following capture by otter trawl and exposure to air for 61-90 minutes in December 2004.

Tow No.	Tow Duration (hr:min)	Body Length (cm)	Air Exposure Duration (hr:min)	Health Status When Placed in Holding Tank	Duration In Holding Tank	Holding Tank Stocking Density (No. fish/m^2)	Health Status When Removed From Holding Tank	Duration In Cage (hr:min)	Post-caging Health Status
3	2:00	99	1:04	S	8:56	5	S	45:50	L
5	2:15	98	1:10	S	3:00	3.8	L	46:10	L
Means	2:08	98.5	1:07		5:58			46:00	

Table 7. Summary of health status (L=lively and S= sluggish) of Atlantic wolffish following capture by otter trawl and exposure to air for 91-120 minutes in December. Wolffish from Tows 3 and 4 were transferred to cages and lowered to the ocean floor.

Tow No.	Tow Duration (hr:min)	Body Length (cm)	Air Exposure Duration (hr:min)	Health Status When Placed in Holding Tank	Duration In Holding Tank	Holding Tank Stocking Density (No. fish/m^2)	Health Status When Removed From Holding Tank	Duration In Cage (hr:min)	Post-caging Health Status
6	2:30	109	1:48	S	24:00	4.4	L		
6	2:30	73	1:50	S	24:00	4.4	DEAD		
6	2:30	111	1:53	S	24:00	4.4	L		
6	2:30	98	1:59	S	24:00	4.4	L		
7	2:15	65	1:33	S	48:00	1.9	L		
7	2:15	106	2:00	S	48:00	1.9	L		
7	2:30	108	2:00	S	24:00	4.4	L		
3	2:00	102	1:35	S	8:25	5	S	45:50	L
3	2:00	103*	1:36	S	8:24	5	S	45:50	S
4	2:00	102	1:46	L	7:02	2.5	L	46:13	L
Means	2:00	97.7	1:48					45:58	

* one fresh wound was found on the proximal region of the left pectoral fin

Table 8. Summary of the health status (L=lively and S= sluggish) of Atlantic wolffish following capture by otter trawl and exposure to air for over 120 minutes in December.

Tow No.	Tow Duration (hr:min)	Body Length (cm)	Air Exposure Duration (hr:min)	Health Status When Placed in Holding Tank	Duration In Holding Tank	Holding Tank Stocking Density (No. fish/m^2)	Health Status When Removed From Holding Tank
6	2:30	108	2:15	S	24:00	4.4	DEAD
6	2:30	92	2:19	S	24:00	4.4	DEAD
6	2:30	93	2:25	S	24:00	4.4	DEAD
7	2:15	99	2:10	S	24:00	1.9	DEAD
Means	2:21	98.0	2:17				

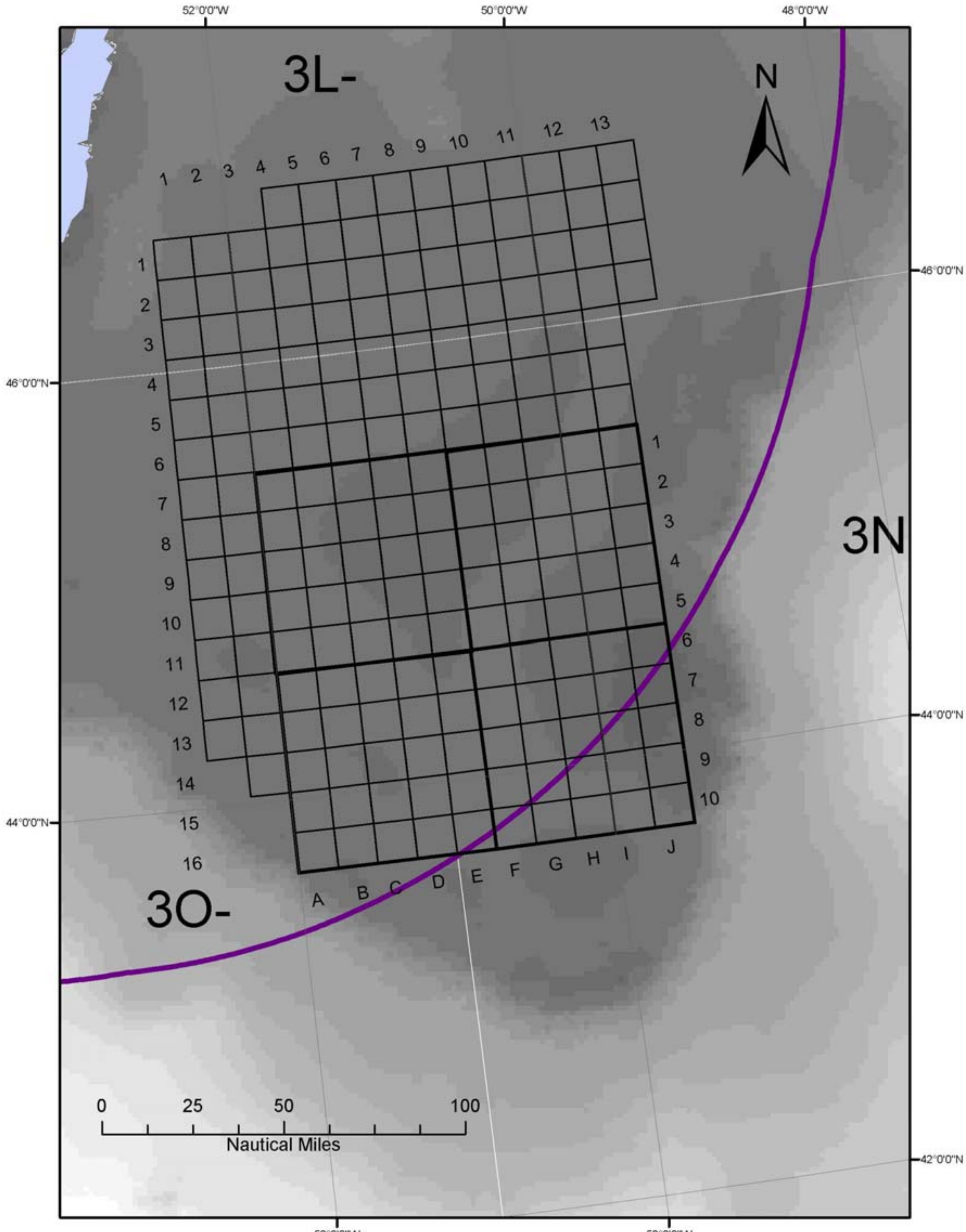

Figure 1. Map of the Newfoundland Grand Bank illustrating the bulk of the yellowtail flounder distribution in the 1990's (bolded grid sections in southeast quadrant) and expanded grid areas of interest to the west and north in 2000 and beyond. The Canadian Exclusive Economic Zone and NAFO Subdivisions are also shown.

Figure 2. Dumping the contents of the codend from the trawl deck to the holding ramp in the hold of the vessel (CFV *Atlantic Claire*).

Figure 3. Contents of codend falling into the holding ramp within the hold of the vessel (CFV *Atlantic Claire*)

Figure 4. Holding ramp on board the CFV *Atlantic Claire*.

Figure 5. Hatchway access to holding ramp on board the CFV *Cape Ballard*.

Figure 6. Processing conveyor on board the CFV *Atlantic Claire*.

Figure 7. Processing conveyor on board the CFV *Cape Ballard*.

Figure 8. Photograph of research team member transferring a wolffish from a holding tank to the discard conveyor. The chute from the processing conveyor to the discard conveyor is also visible in the left-hand region of the photograph.

Figure 9. Discard conveyor rising to the discard chute.

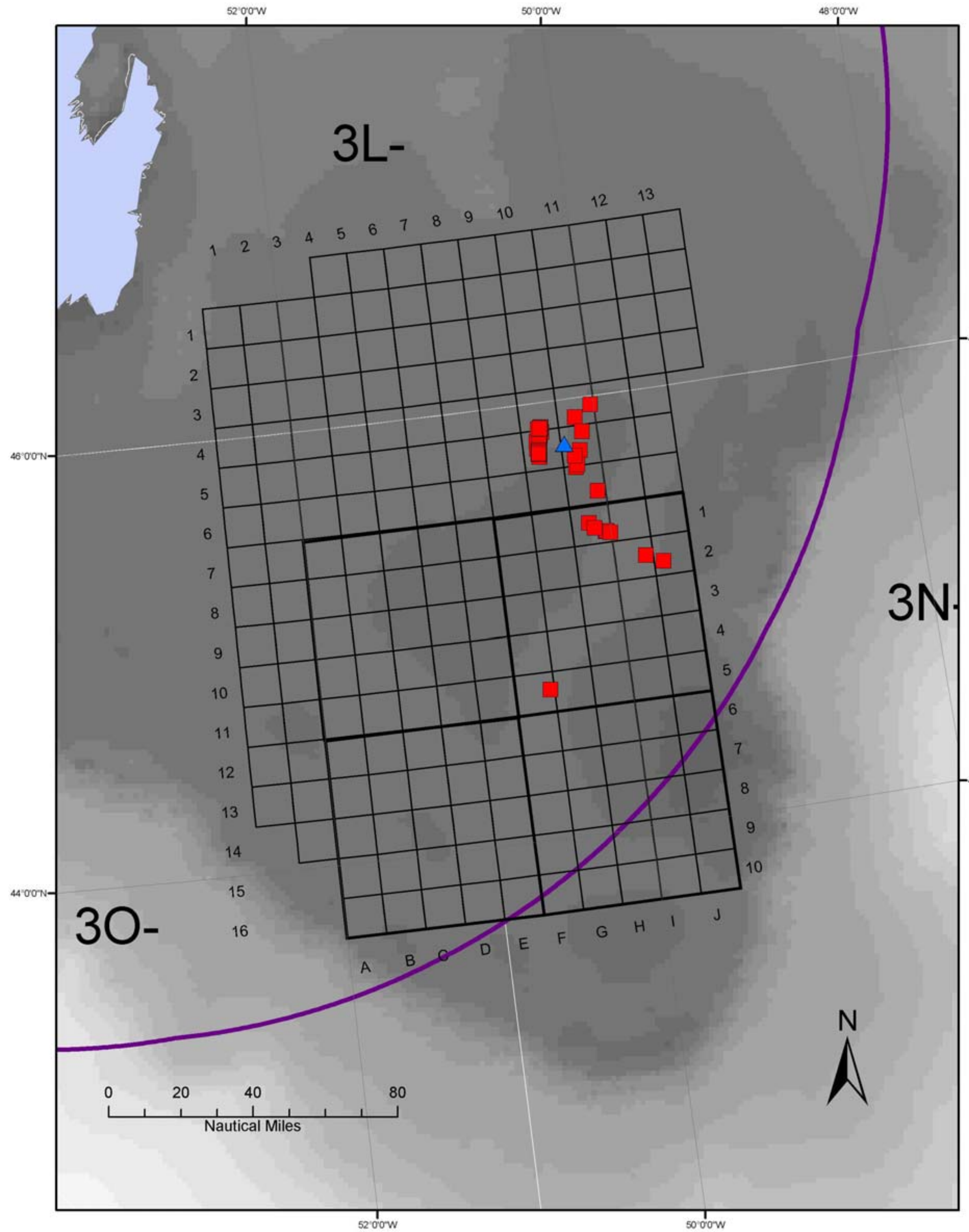

Figure 10. Map of the Newfoundland Grand Bank illustrating the fishing locations (square symbols) and wolffish caging site (triangle symbol) during a directed yellowtail flounder trip in June 2004.

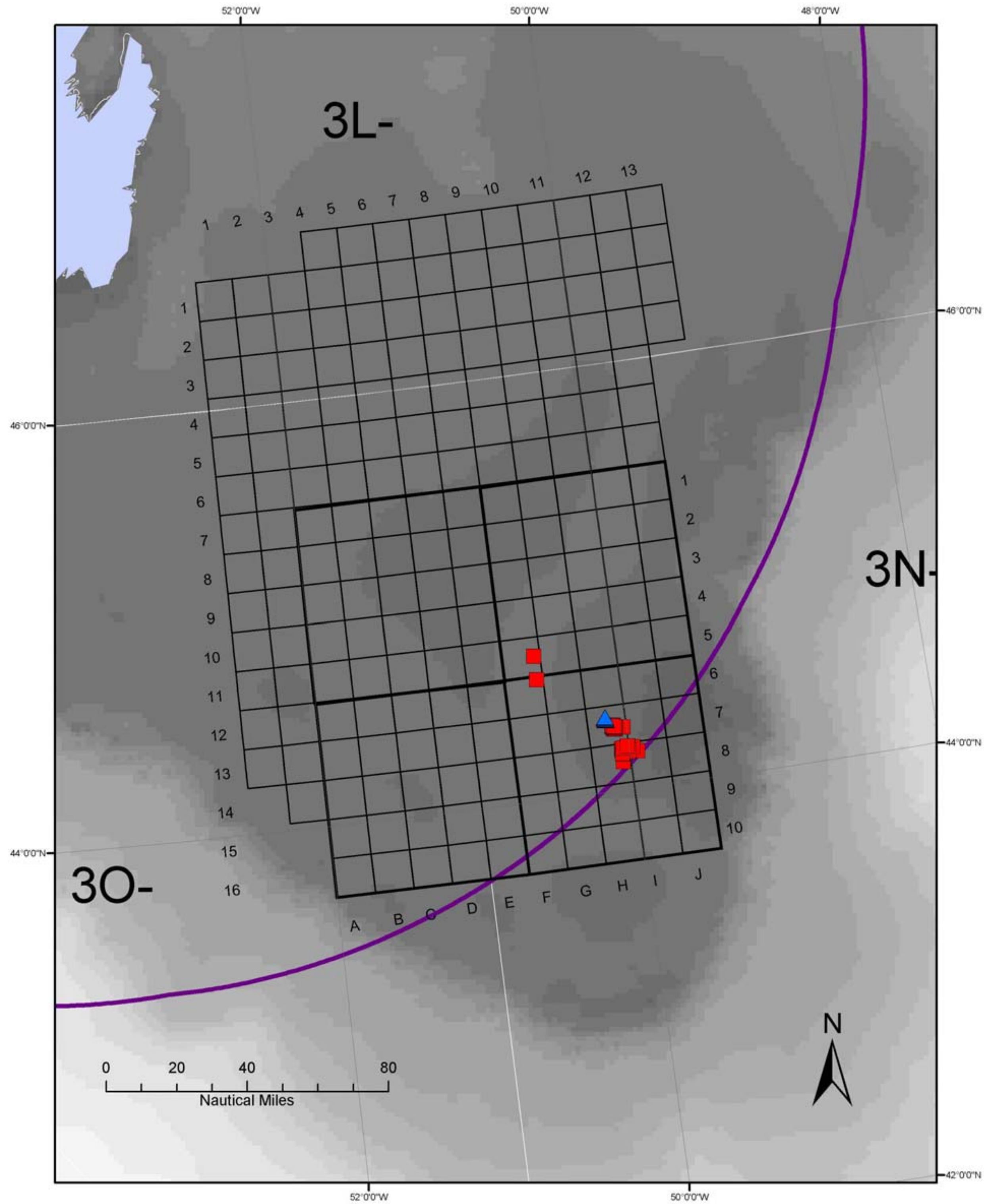

Figure 11. Map of the Newfoundland Grand Bank illustrating the fishing locations (square symbols) and wolffish caging site (triangle symbol) during a directed yellowtail flounder trip in December 2004.

Figure 12. Aluminum holding tank on board the CFV *Atlantic Claire*.

Figure 13. Holding tanks on board the CFV *Cape Ballard*. Fresh seawater inlet lines are visible at the lower left of each tank.

Figure 14. Two compartment PVC coated wire mesh cage. The left compartment contains the haul line.

Figure 15. Transferring an Atlantic wolffish by the cradle method.

Figure 16. Transferring an Atlantic wolffish by using the pectoral fins to support its weight.

Figure 17. Atlantic wolffish in a perforated plastic basket.

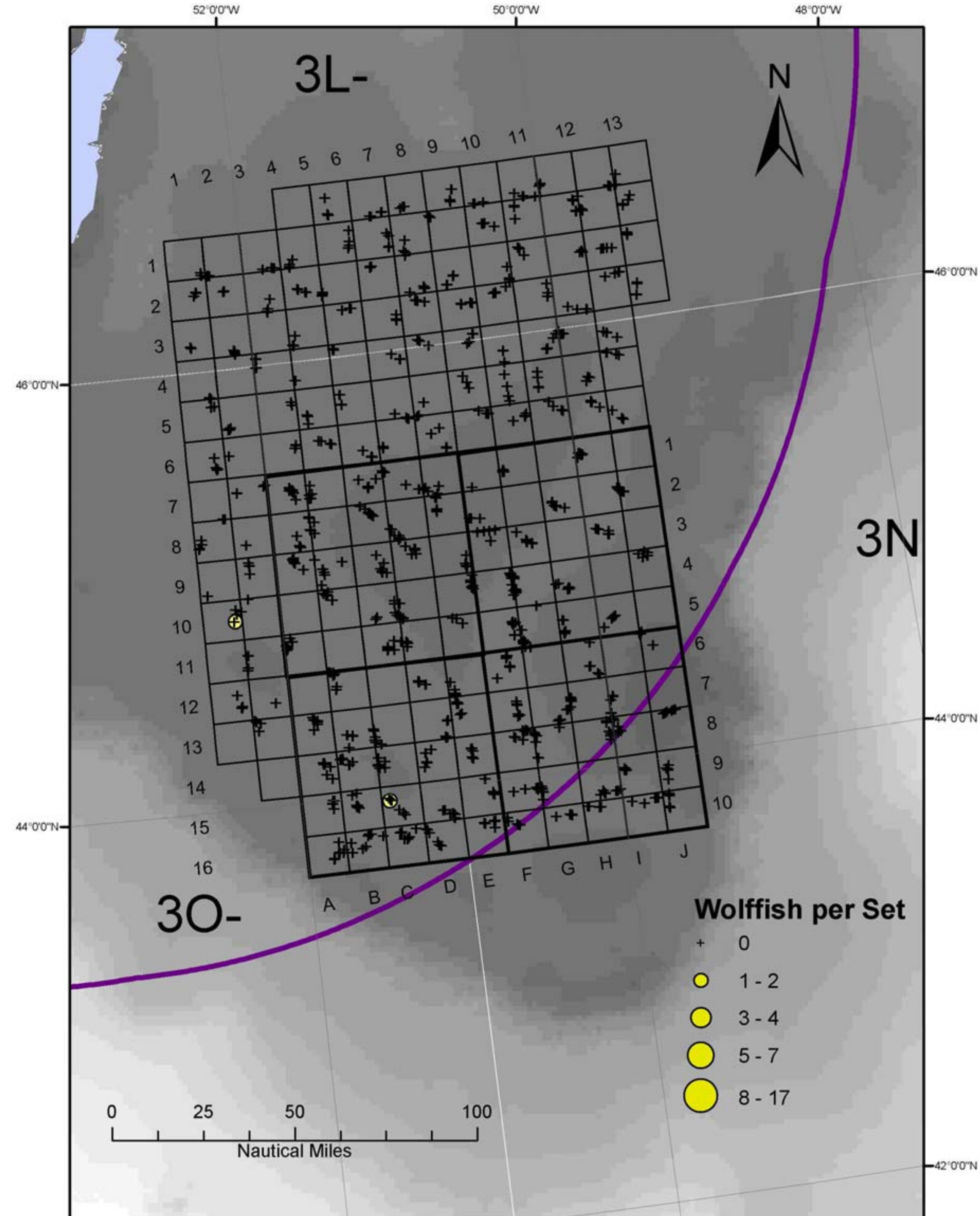

Figure 18. Aggregate distribution of northern wolffish during a summer survey of the Grand Bank yellowtail flounder fishing grounds for the time period 1996-2003.

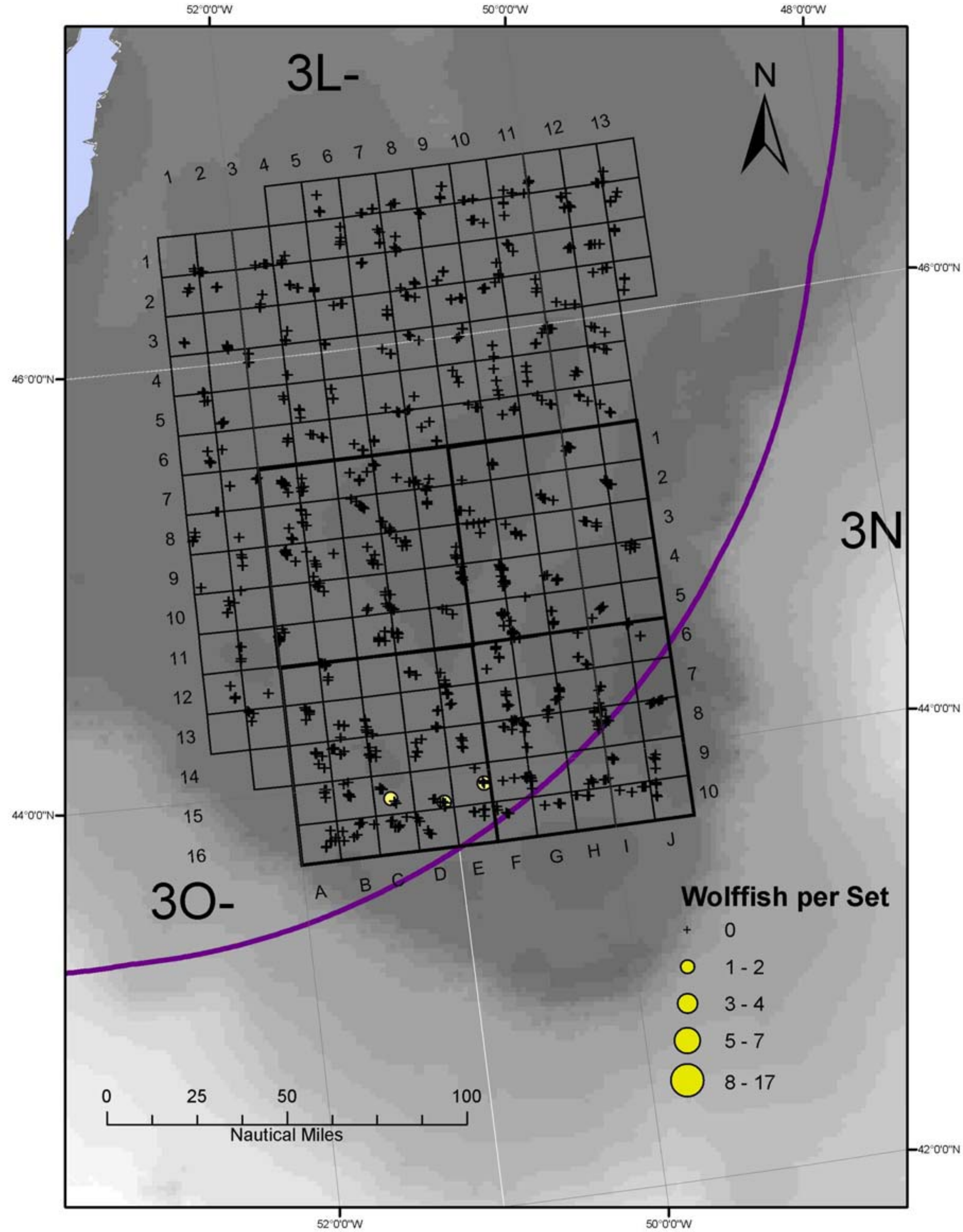

Figure 19. Aggregate distribution of spotted wolffish during a summer survey of the Grand Bank yellowtail flounder fishing grounds for the time period 1996-2003.

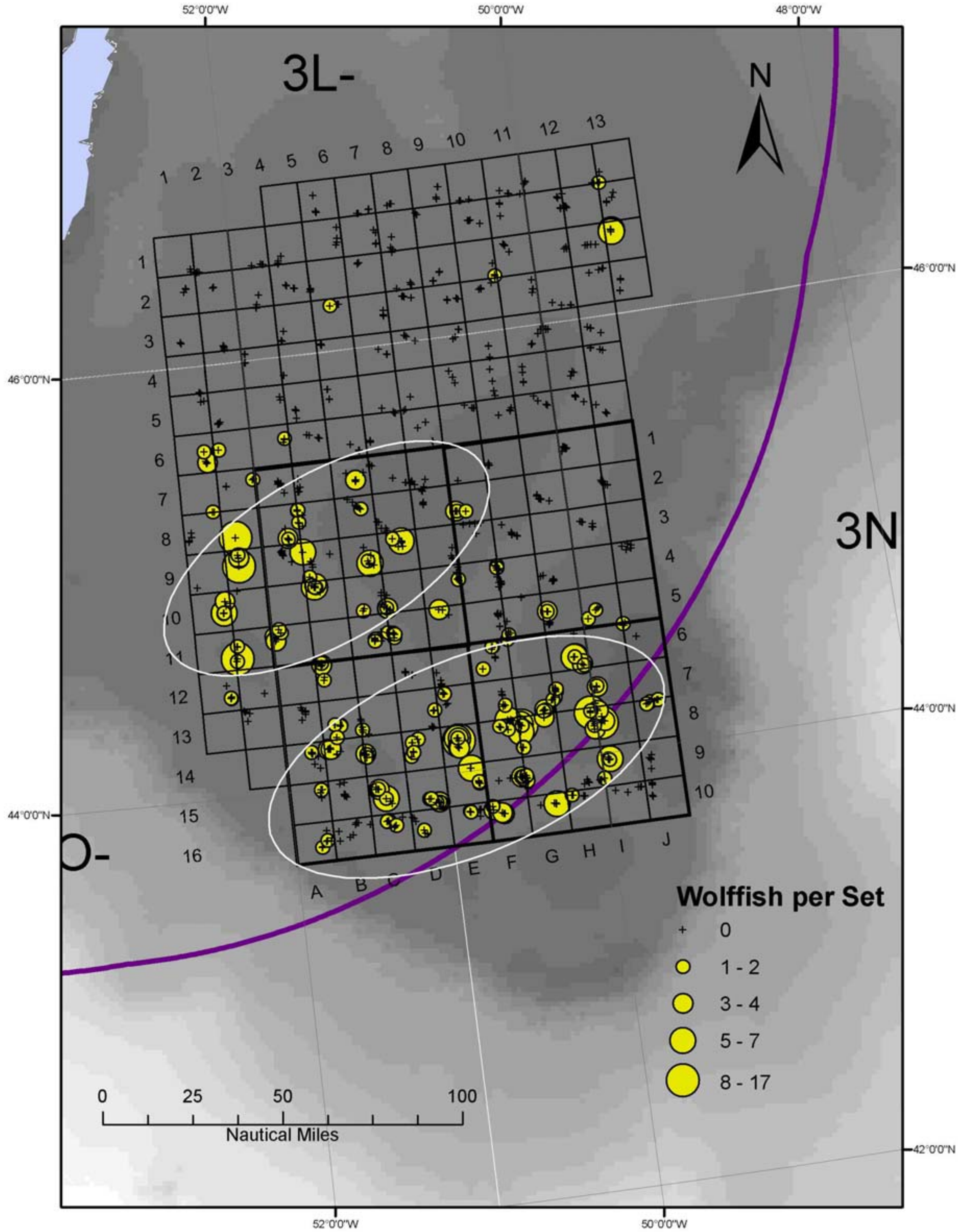

Figure 20. Aggregate distribution of Atlantic wolffish during a summer survey of the Grand Bank yellowtail flounder fishing grounds for the time period 1996-2003. Two apparent centres of distribution are also illustrated.

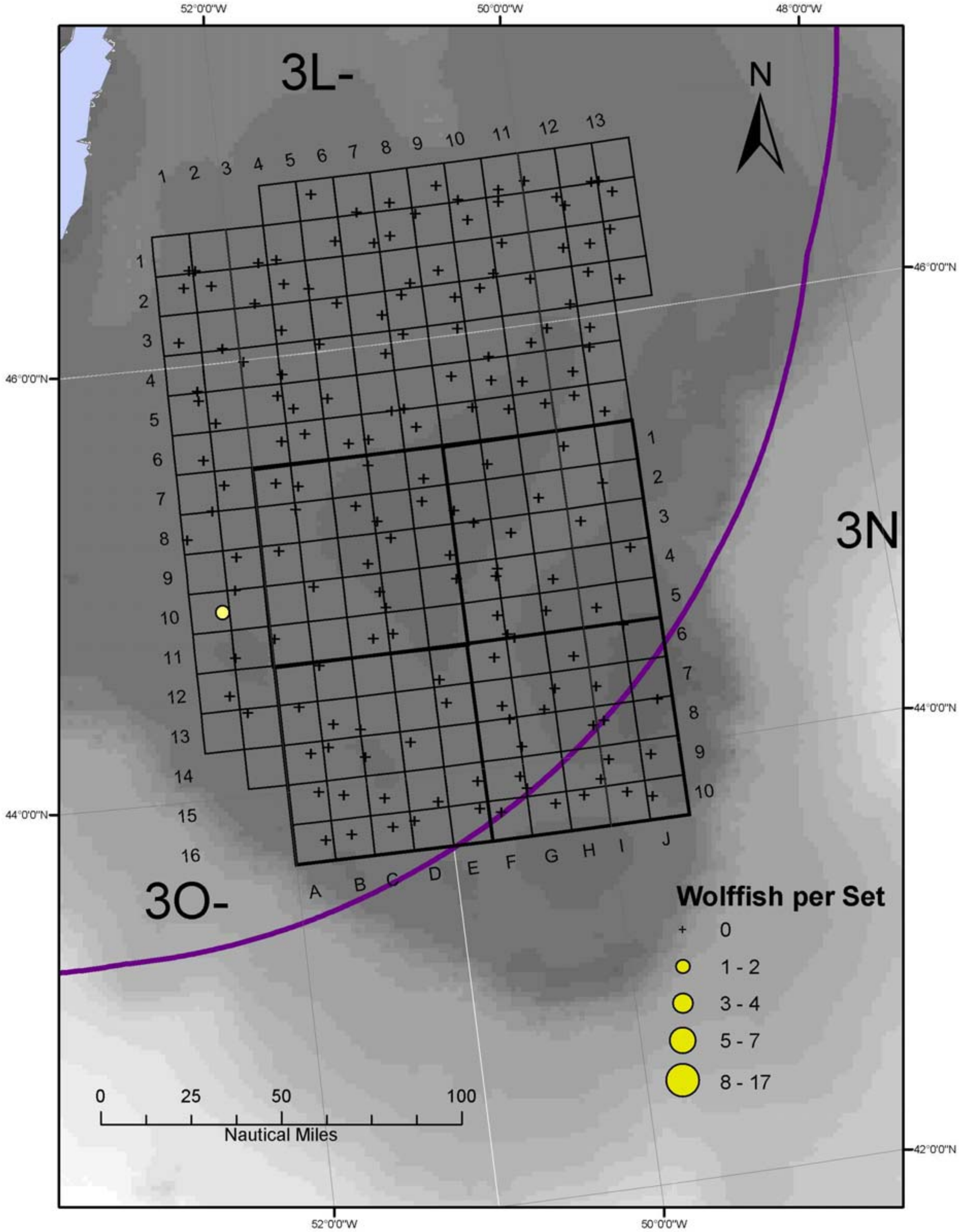

Figure 21. Distribution of northern wolffish during a summer survey of the Grand Bank yellowtail flounder fishing grounds, 2002.

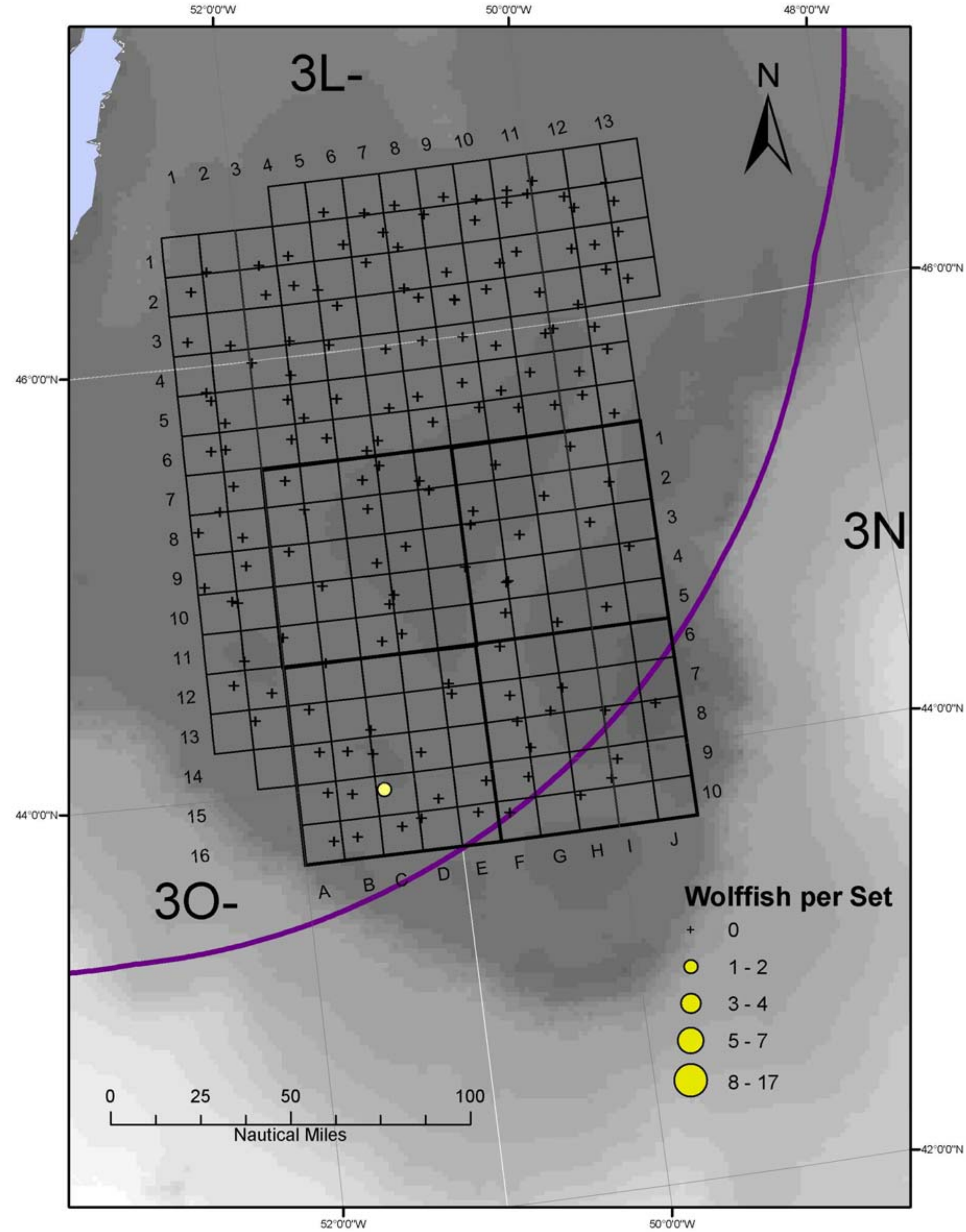

Figure 22. Distribution of northern wolffish during a summer survey of the Grand Bank yellowtail flounder fishing grounds, 2003.

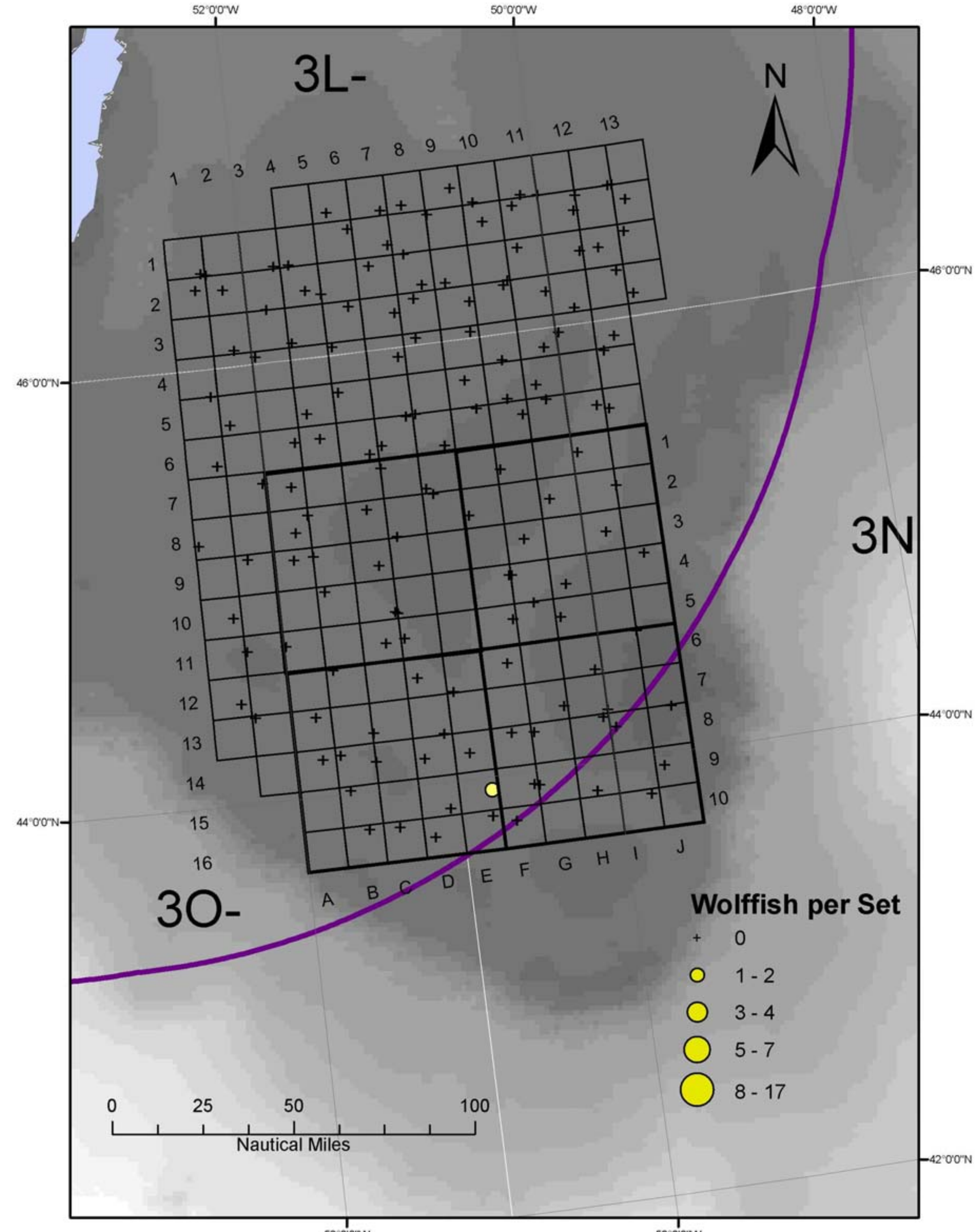

Figure 23. Distribution of spotted wolffish during a summer survey of the Grand Bank yellowtail flounder fishing grounds, 2000.

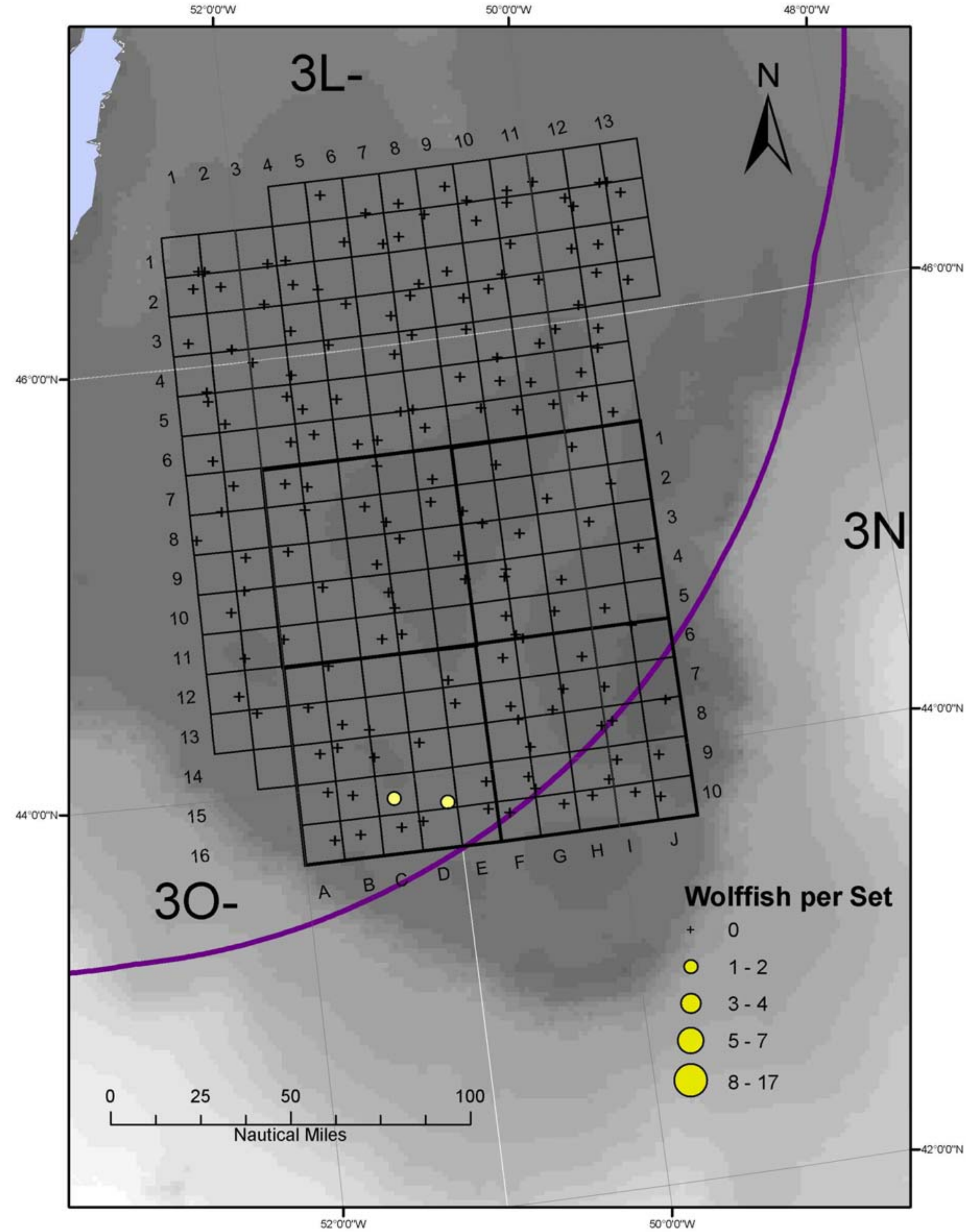

Figure 24. Distribution of spotted wolffish during a summer survey of the Grand Bank yellowtail flounder fishing grounds, 2002.

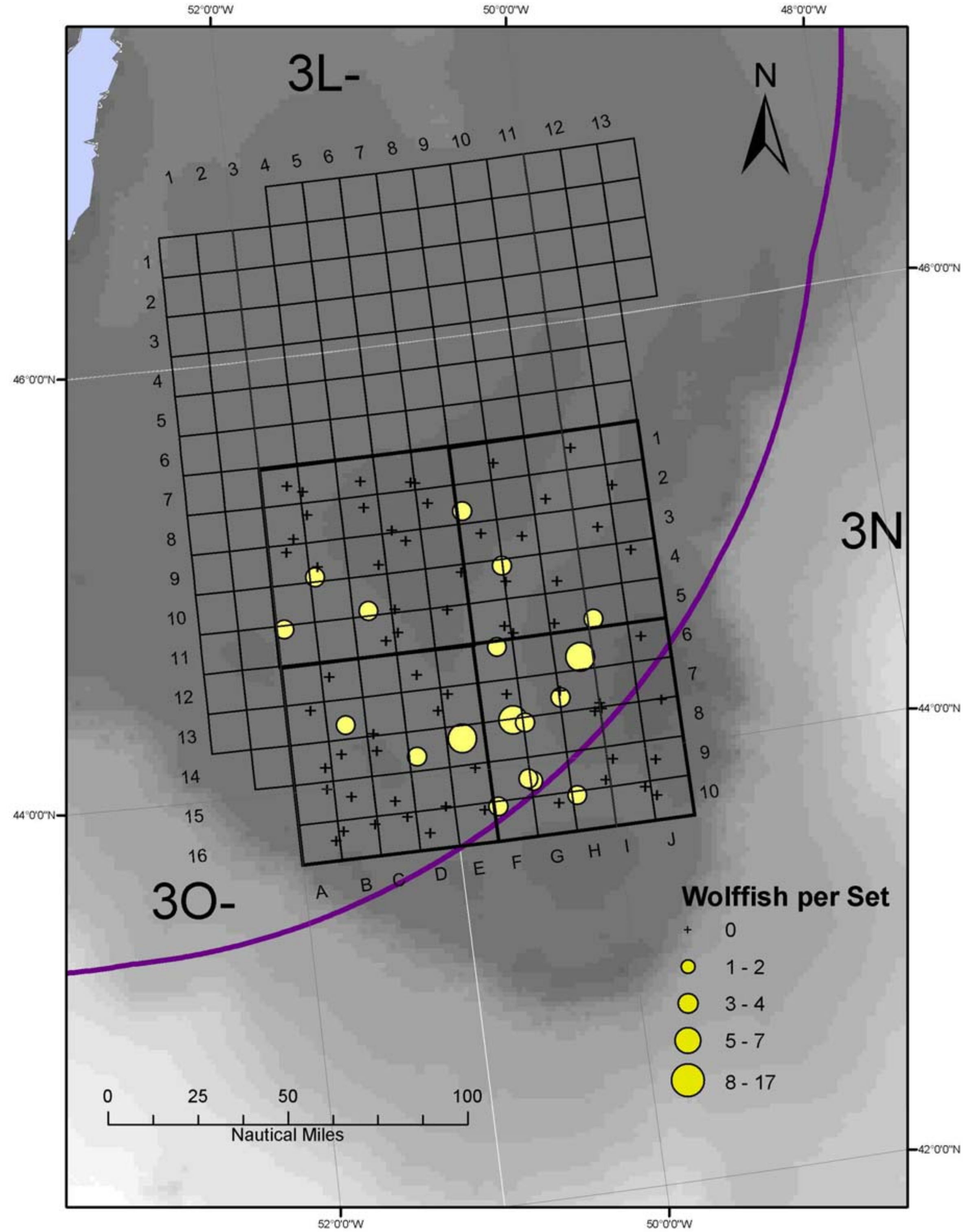

Figure 25. Distribution of Atlantic wolffish during a summer survey of the Grand Bank yellowtail flounder fishing grounds, 1996.

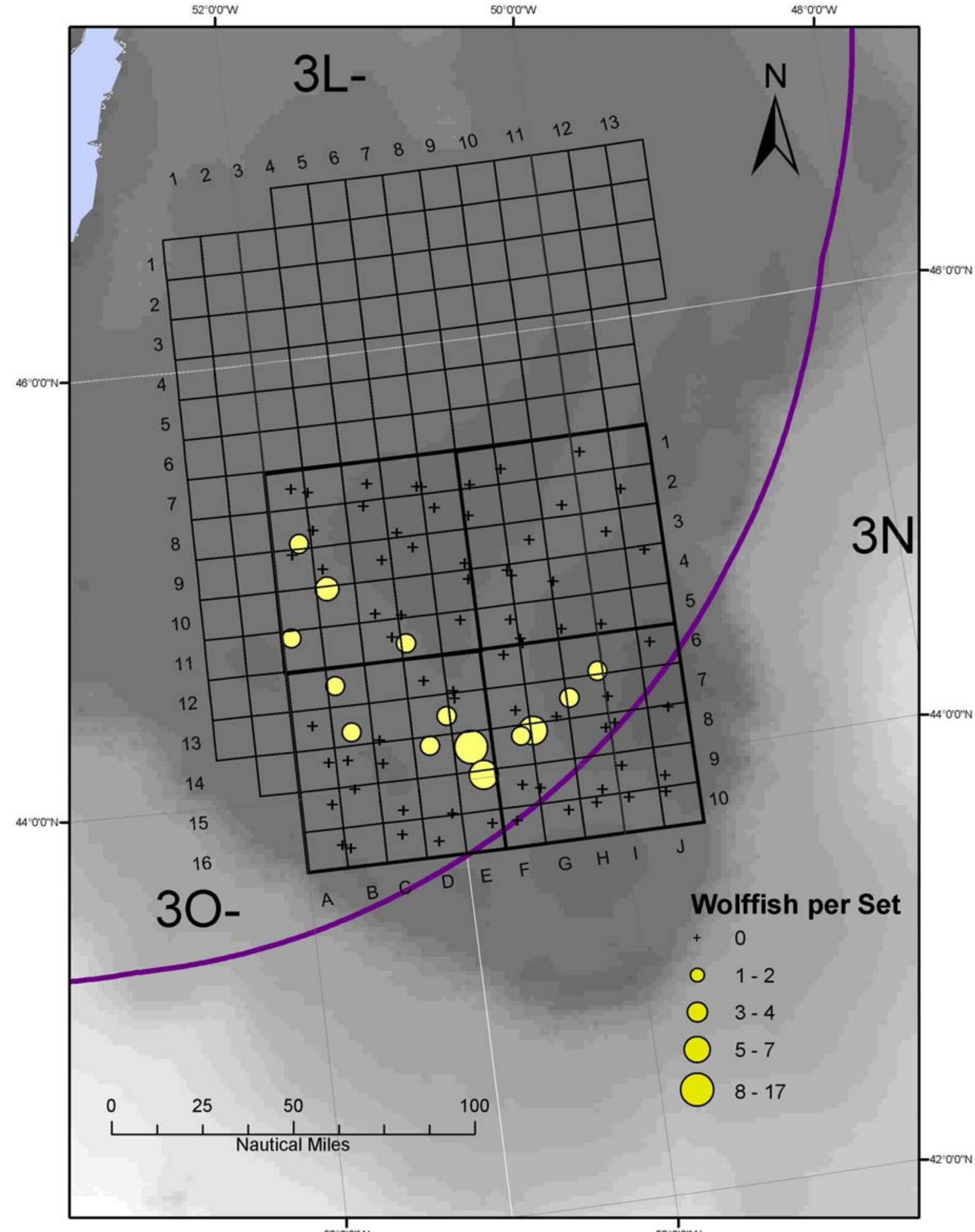

Figure 26. Distribution of Atlantic wolffish during a summer survey of the Grand Bank yellowtail flounder fishing grounds, 1997.

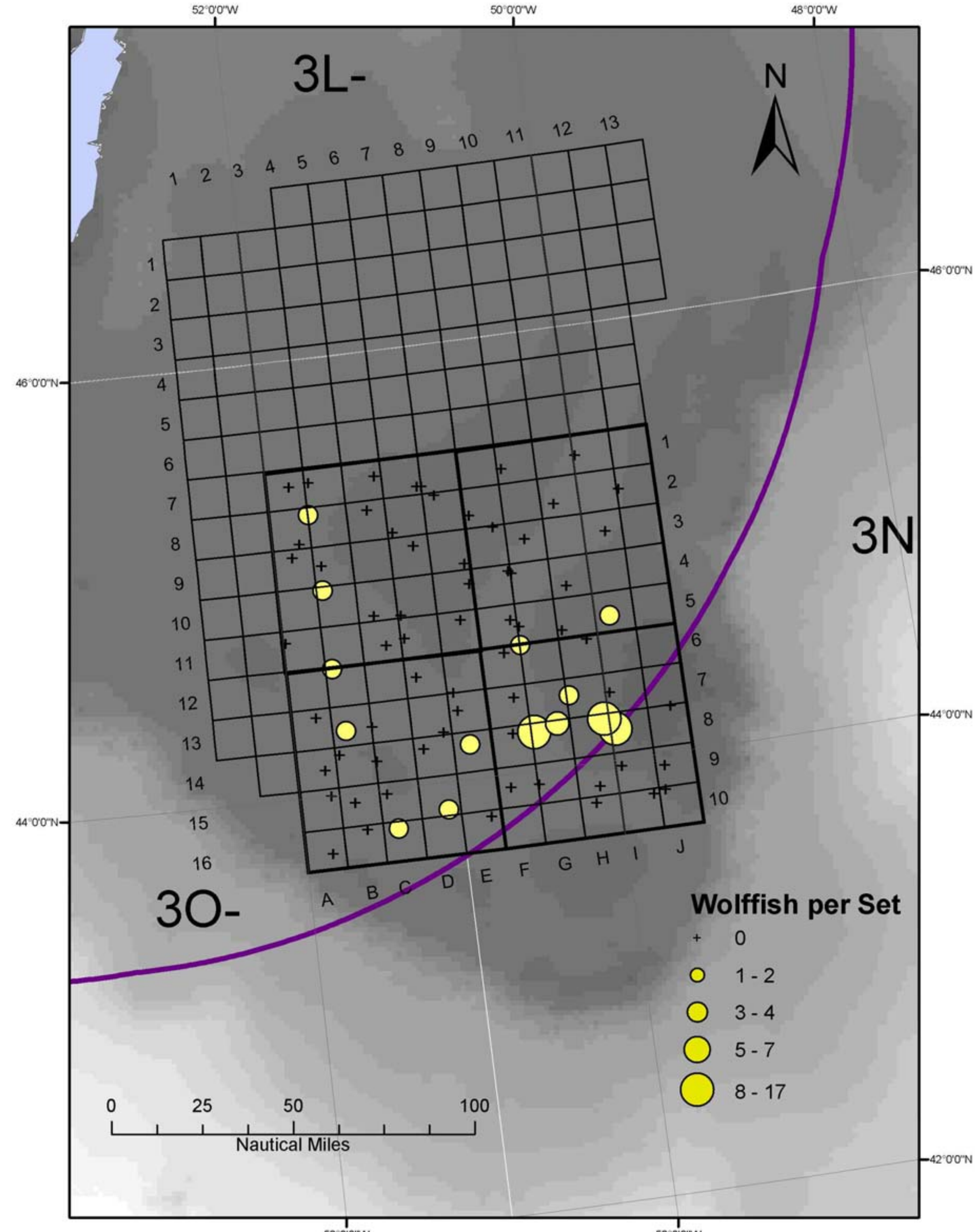

Figure 27. Distribution of Atlantic wolffish during a summer survey of the Grand Bank yellowtail flounder fishing grounds, 1998.

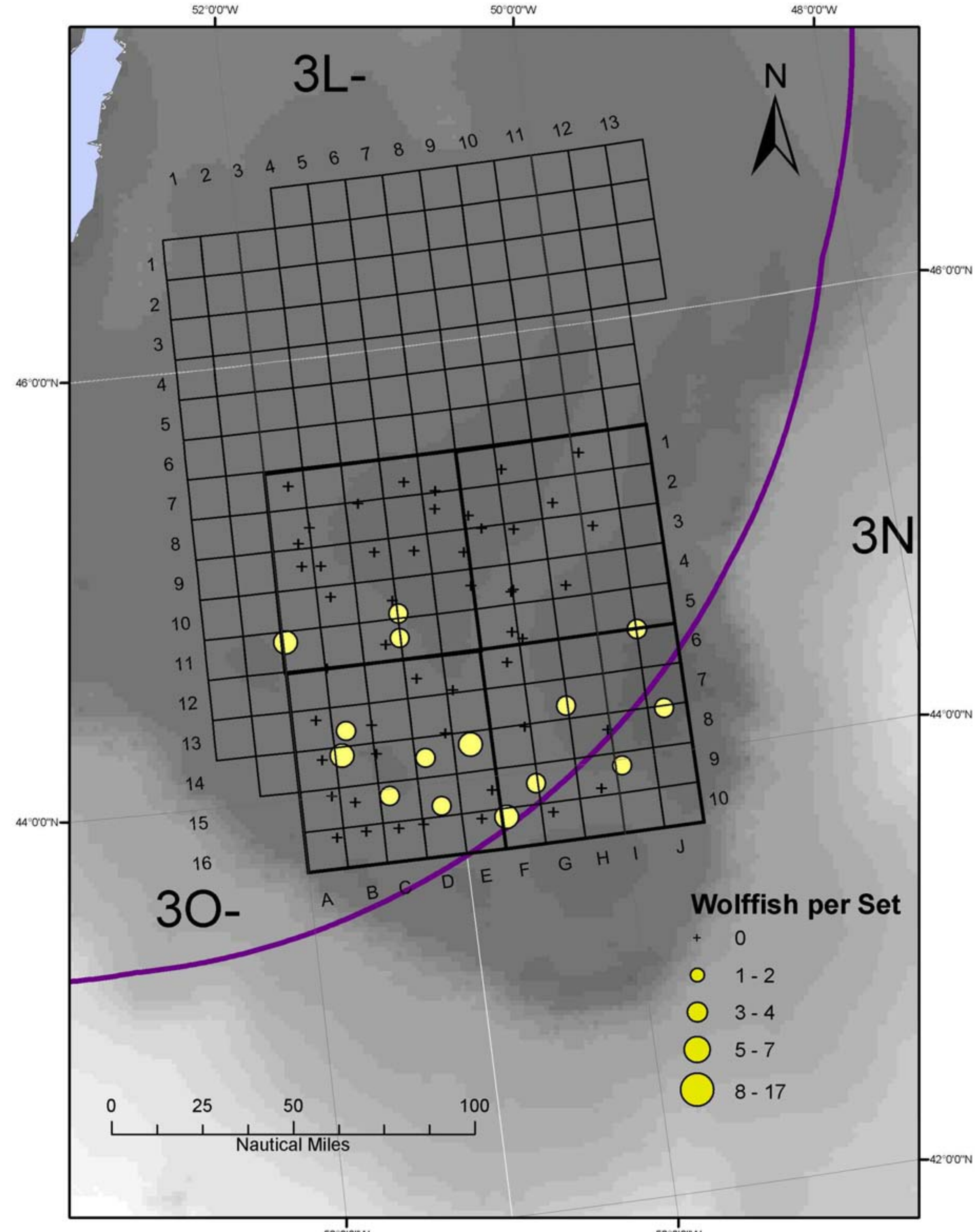

Figure 28. Distribution of Atlantic wolffish during a summer survey of the Grand Bank yellowtail flounder fishing grounds, 1999.

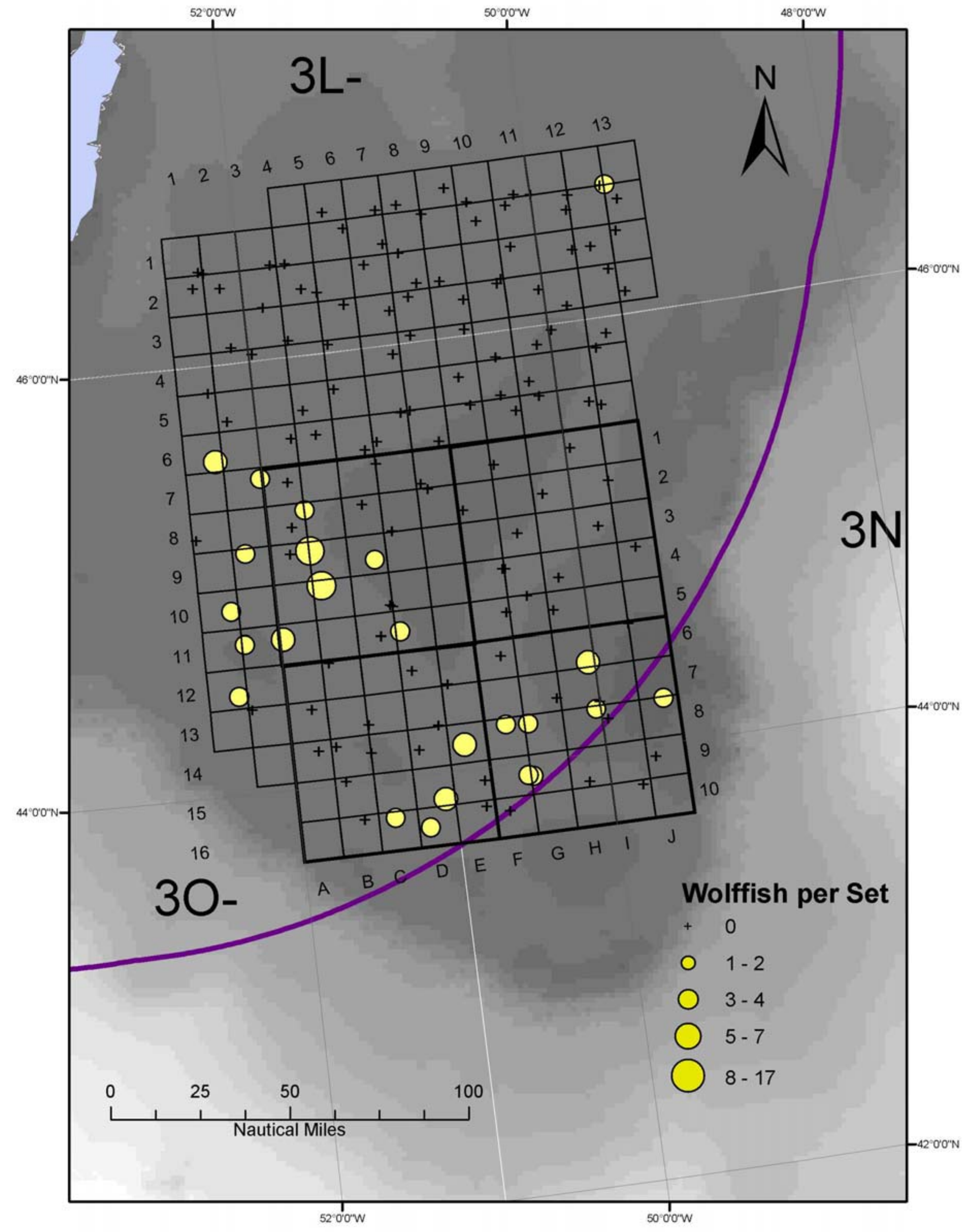

Figure 29. Distribution of Atlantic wolffish during a summer survey of the Grand Bank yellowtail flounder fishing grounds, 2000.

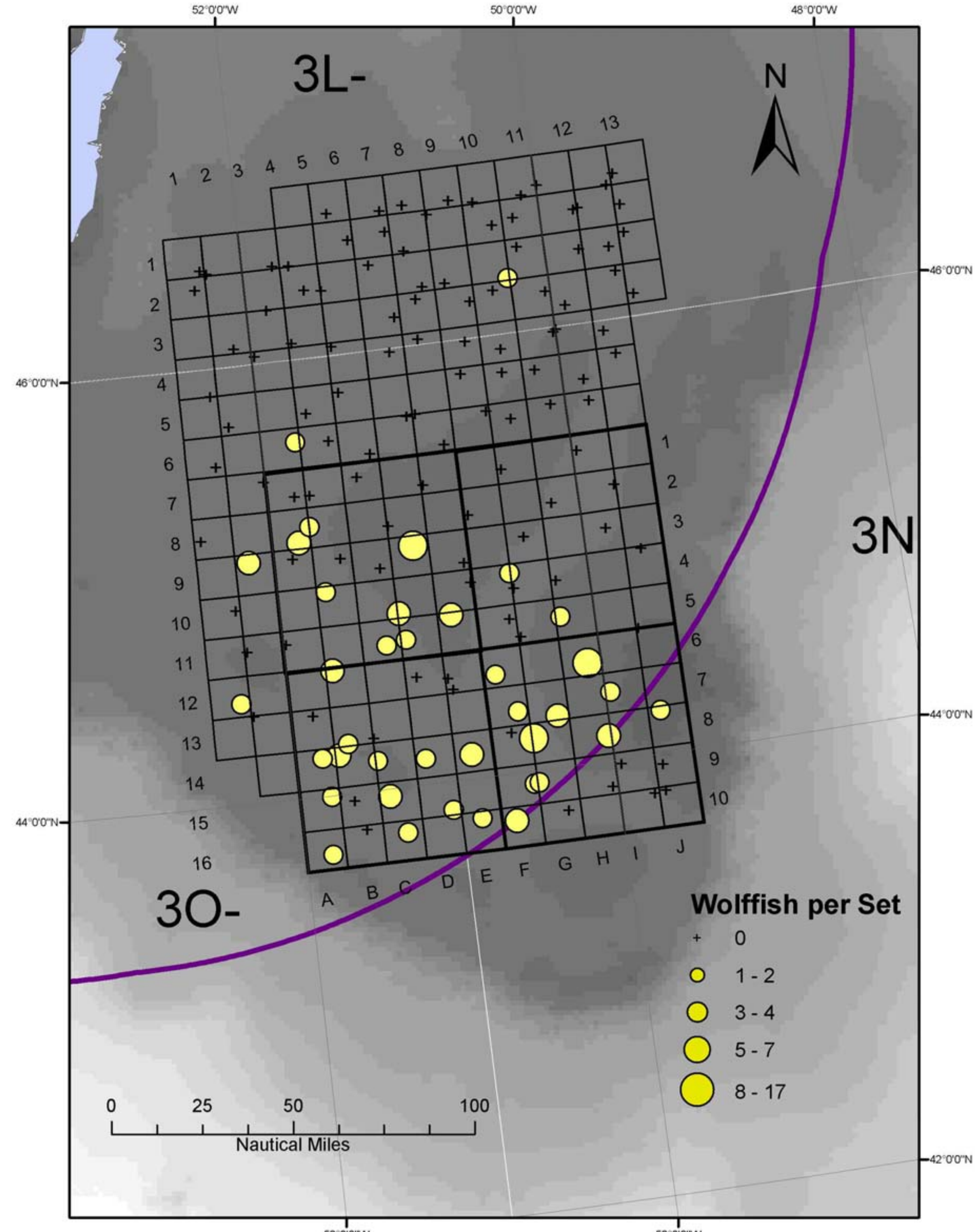

Figure 30. Distribution of Atlantic wolffish during a summer survey of the Grand Bank yellowtail flounder fishing grounds, 2001.

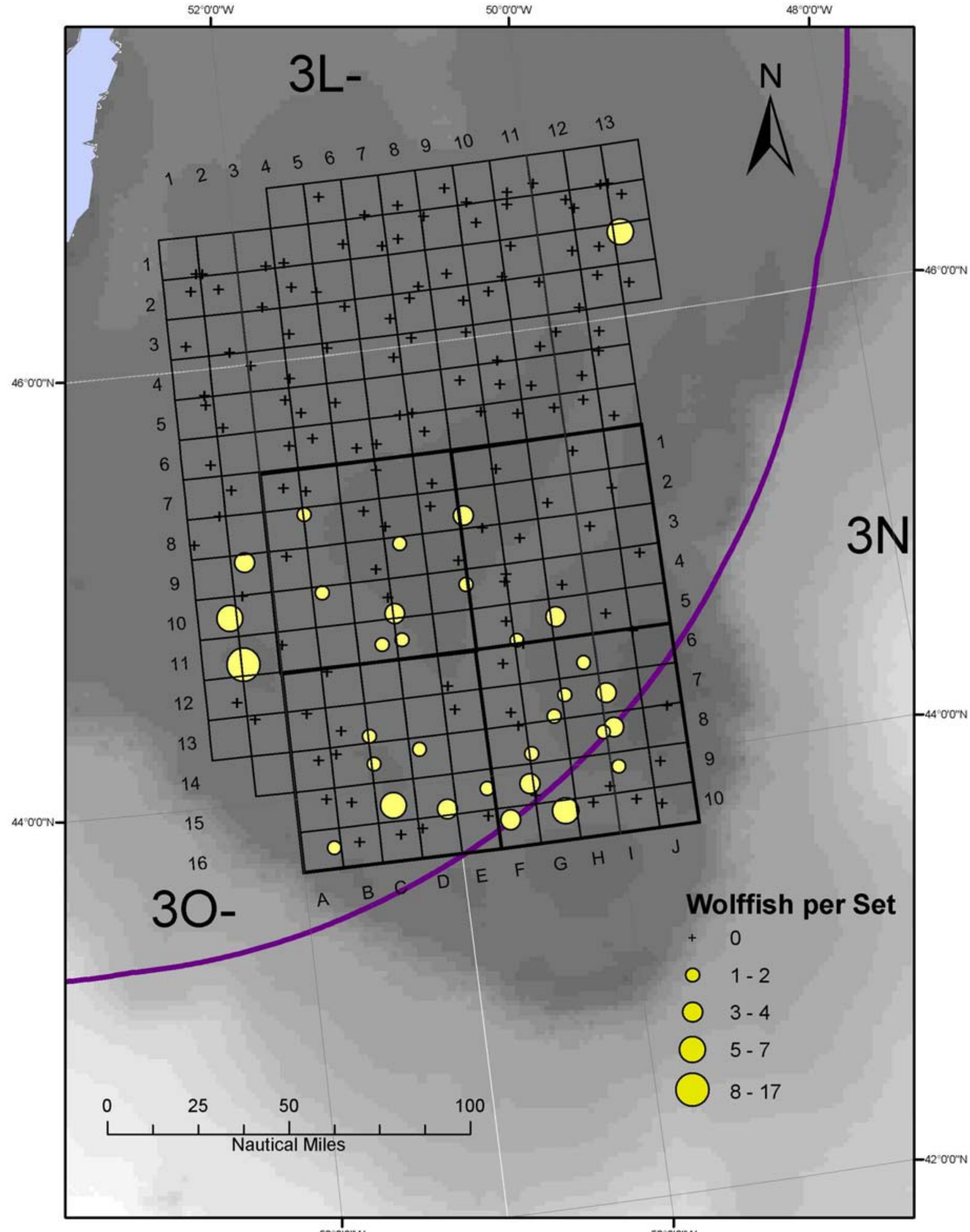

Figure 31. Distribution of Atlantic wolffish during a summer survey of the Grand Bank yellowtail flounder fishing grounds, 2002.

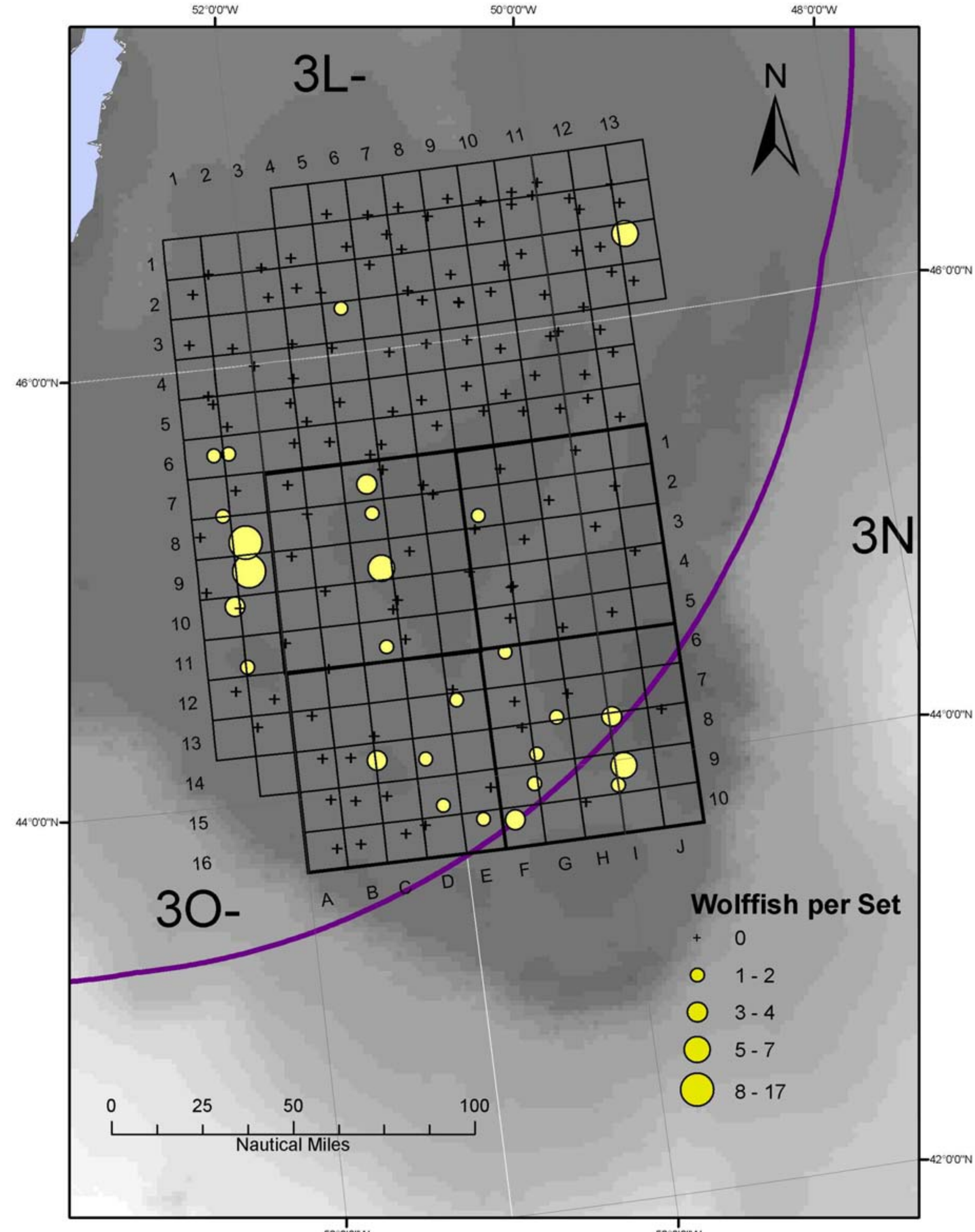

Figure 32. Distribution of Atlantic wolffish during a summer survey of the Grand Bank yellowtail flounder fishing grounds, 2003.

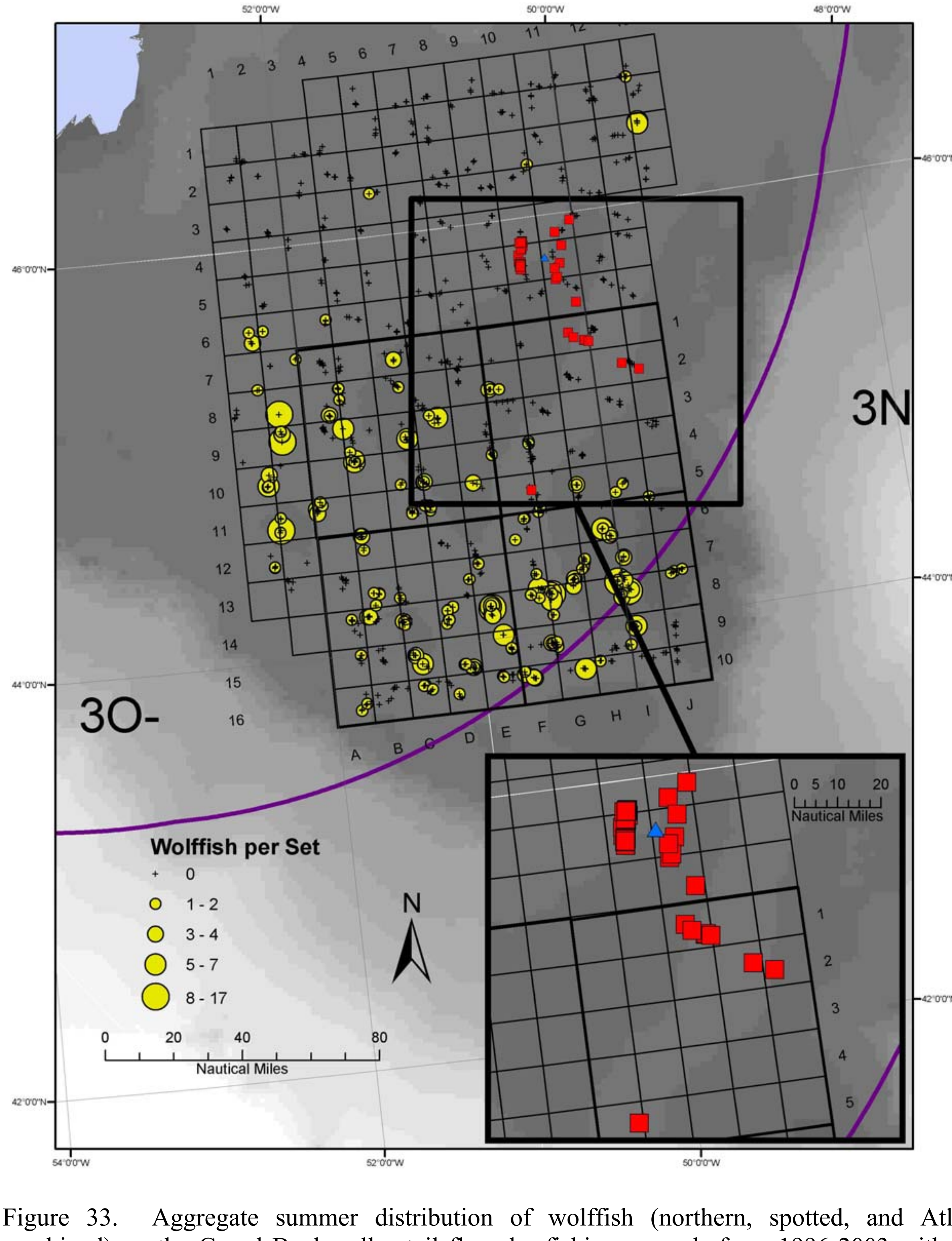

Figure 33. Aggregate summer distribution of wolffish (northern, spotted, and Atlantic combined) on the Grand Bank yellowtail flounder fishing grounds from 1996-2003 with inset illustrating commercial trawl locations (square symbols) and wolffish cage deployment sites (triangles) during the June 2004 fishing trip.

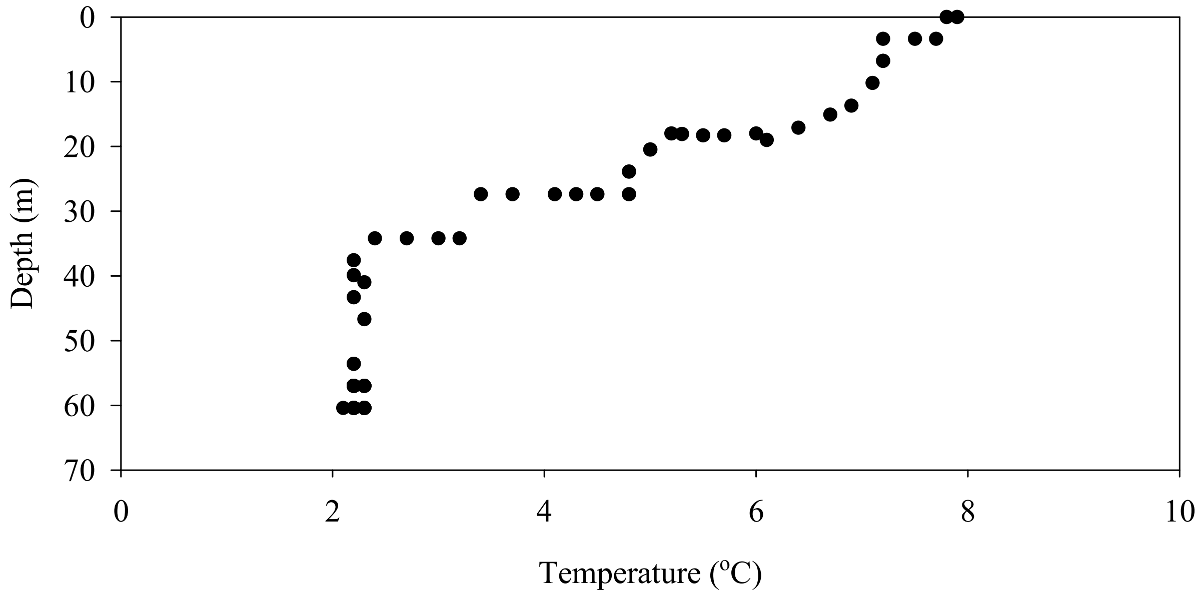

Figure 34. Depth-temperature profile on the Newfoundland Grand Bank at the wolffish capture location in June 2004 (i.e., Tow 1; Table 1).

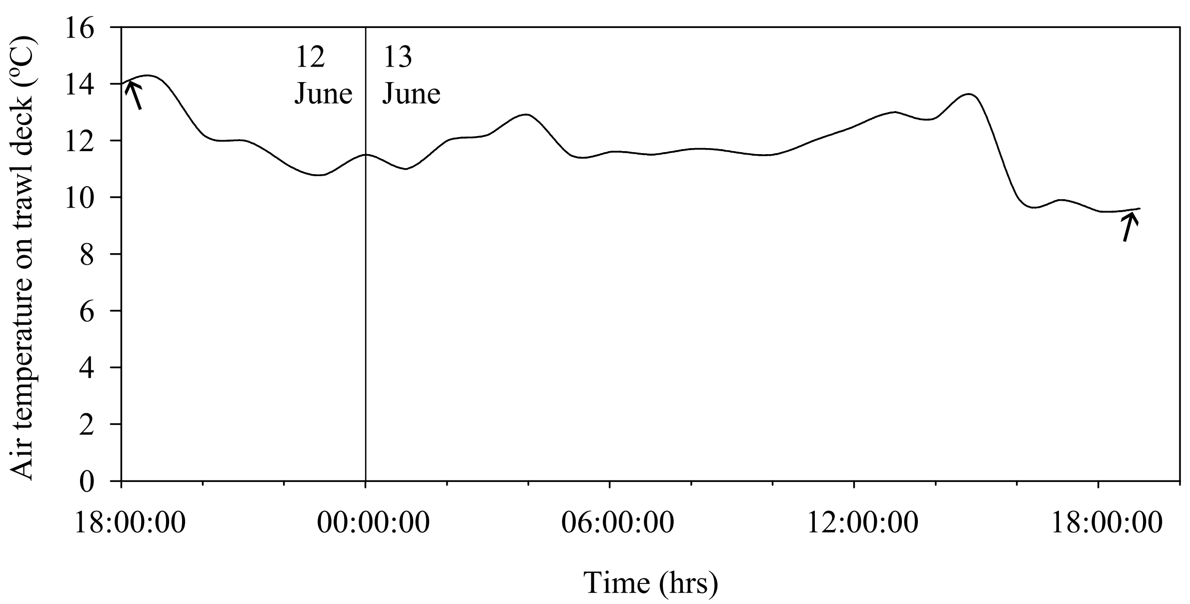

Figure 35. Variation in trawl deck air temperature on the CFV *Atlantic Claire* while fishing on the Newfoundland Grand Bank over a 24-hour period in June 2004. Arrows indicate the approximate temperature when the catch was hauled onto the trawl deck (12 June) and when a cage containing Atlantic wolffish was deployed (13 June).

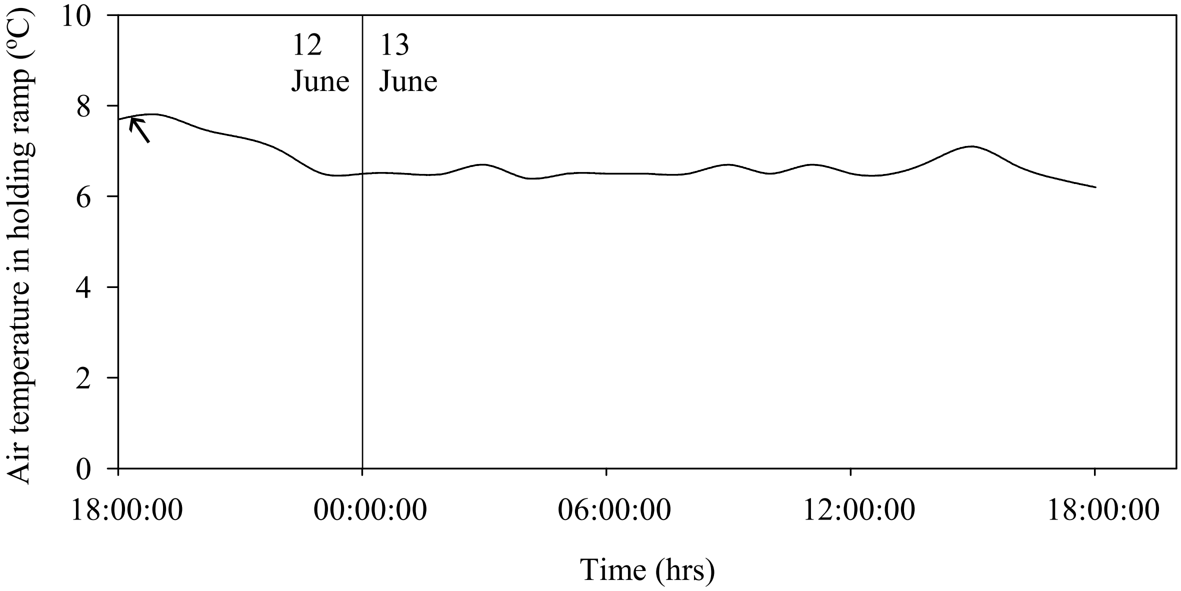

Figure 36. Variation in holding ramp air temperature on the CFV *Atlantic Claire* while fishing on the Newfoundland Grand Bank over a 24-hour period in June 2004. Arrow indicates approximate temperature when catch was dumped to the holding ramp.

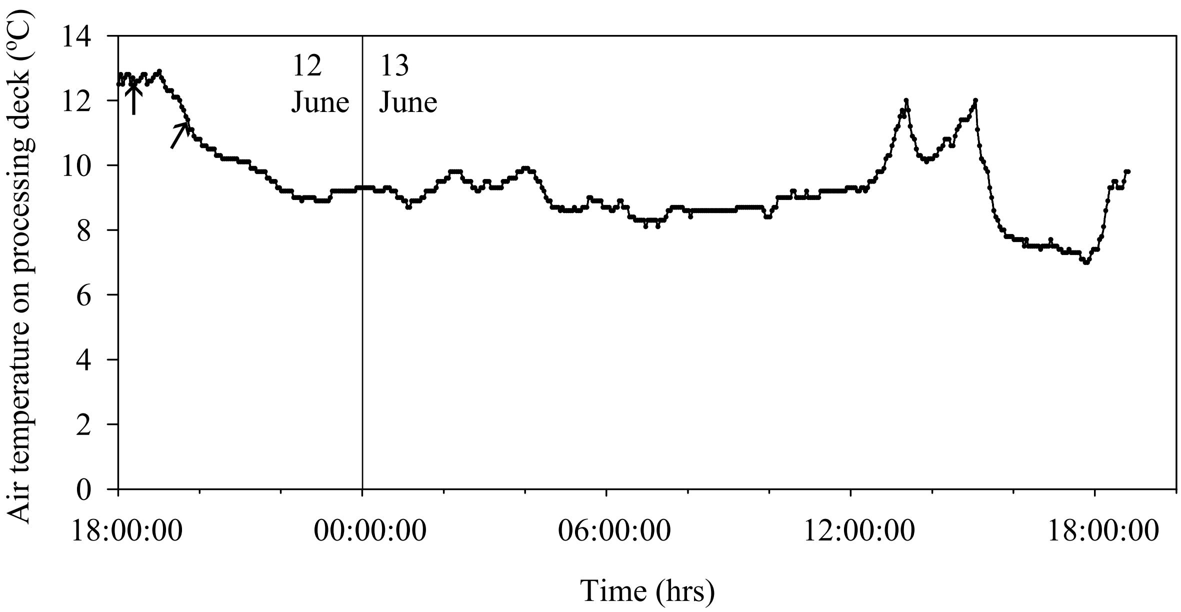

Figure 37. Variation in processing deck air temperature on the CFV *Atlantic Claire* while fishing on the Newfoundland Grand Bank over a 24-hour period in June 2004. Arrows indicate the time interval and temperature experienced by wolffish during the air exposure treatments.

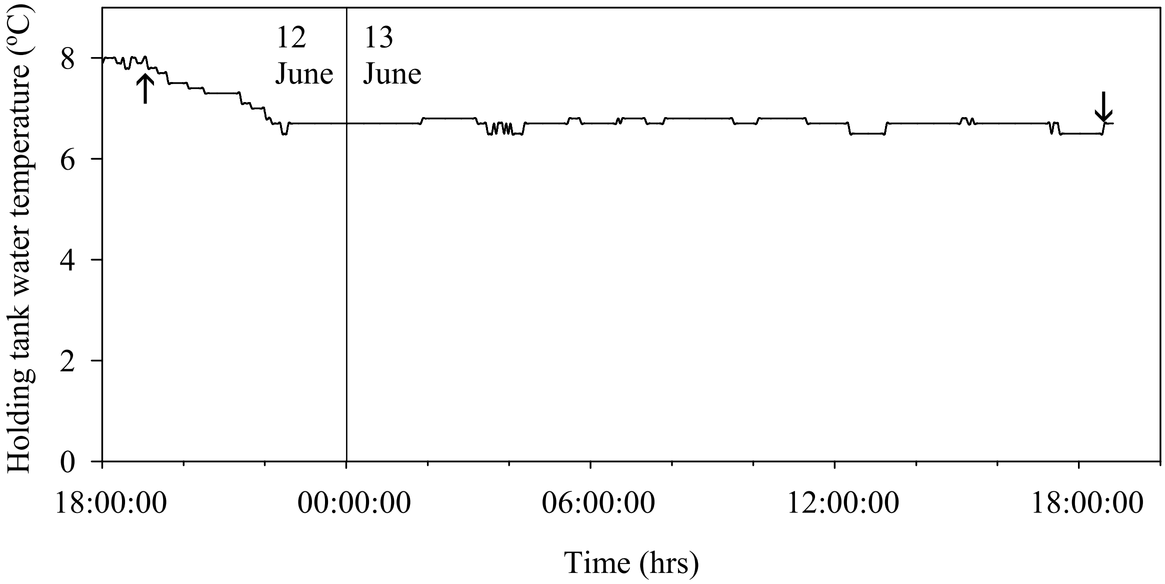

Figure 38. Variation in holding tank water temperature on the CFV *Atlantic Claire* while fishing on the Newfoundland Grand Bank over a 24-hour period in June 2004. Arrows indicate the approximate time and temperature when the first wolffish was placed in the tank (↑) and the last wolffish was removed from the tank (↓).

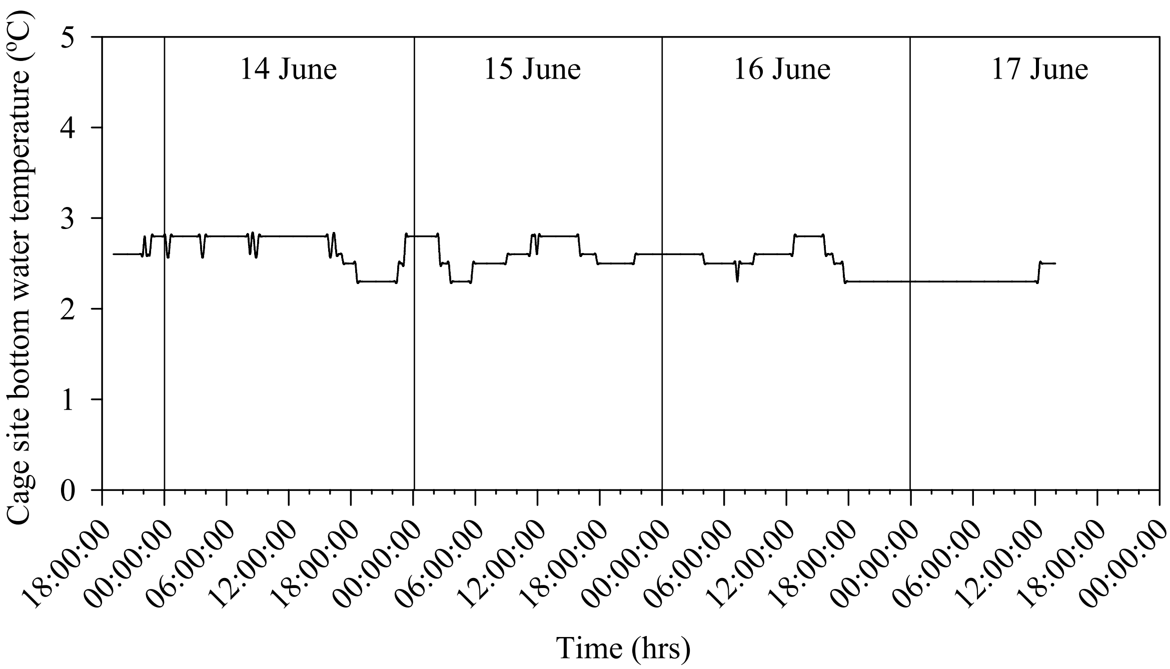

Figure 39. Bottom water temperatures experienced by wolffish at the caging site on the Newfoundland Grand Bank, June 2004.

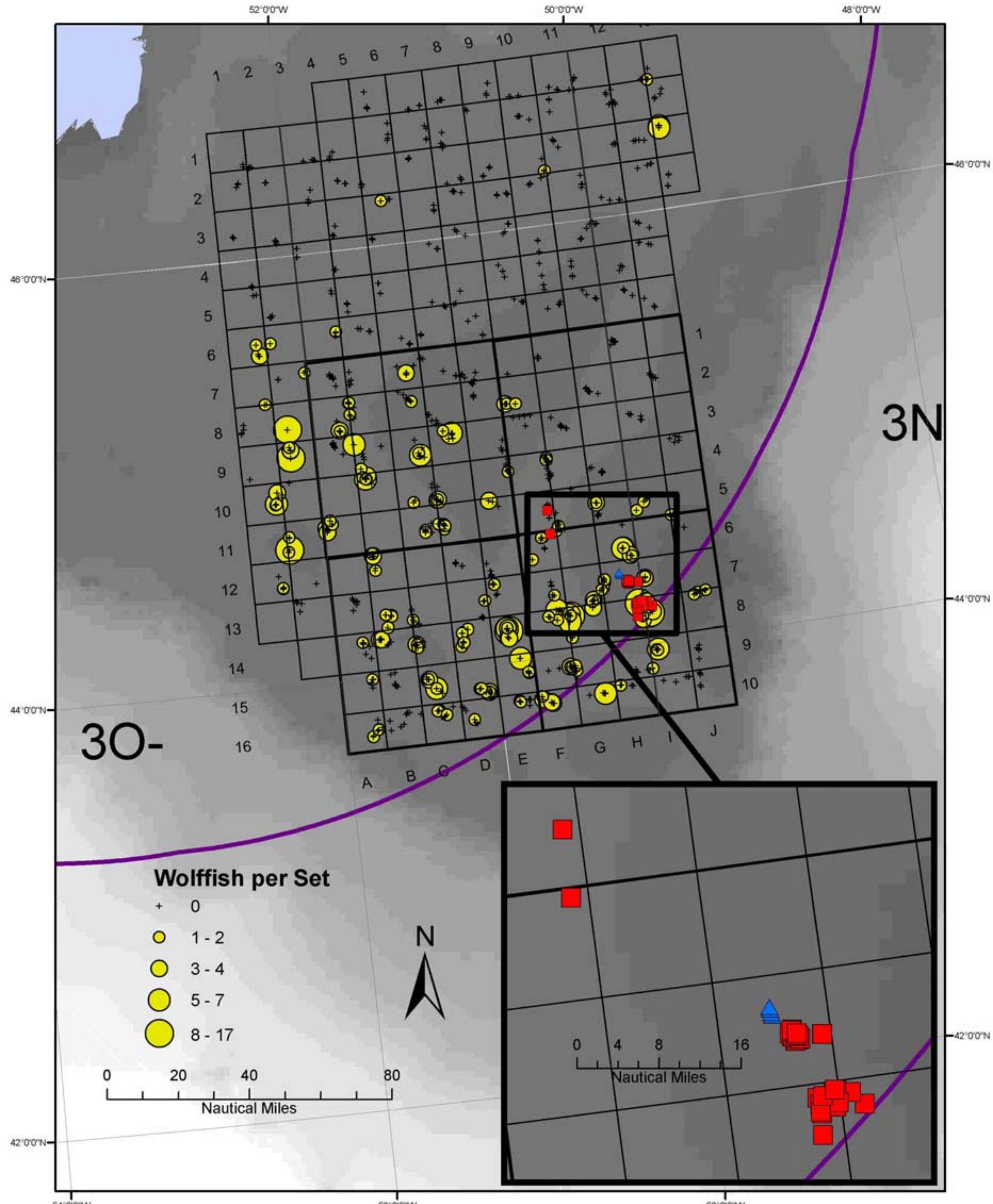

Figure 40. Aggregate summer distribution of wolffish (northern, spotted, and Atlantic combined) on the Grand Bank yellowtail flounder fishing grounds from 1996-2003 with inset illustrating commercial trawl locations (square symbols) and wolffish cage deployment sites (triangles) during the December 2004 fishing trip.

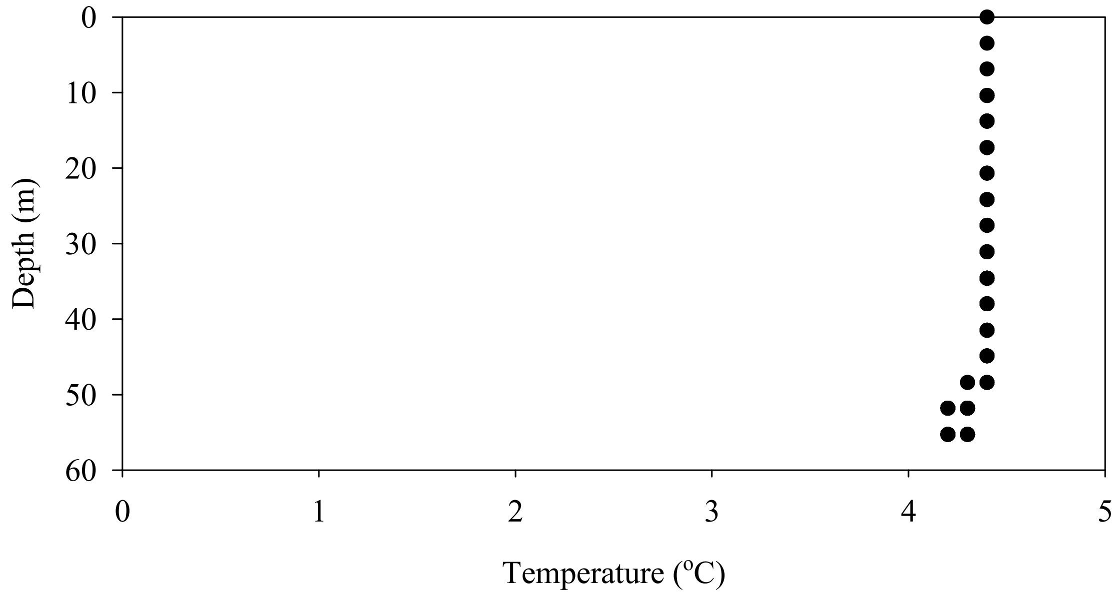

Figure 41. Typical depth-temperature profile in the southern region of the Newfoundland Grand Bank, 9-12 December 2004. See Table 3 and Figure 40 for geographic location of Tows made from 9-12 December.

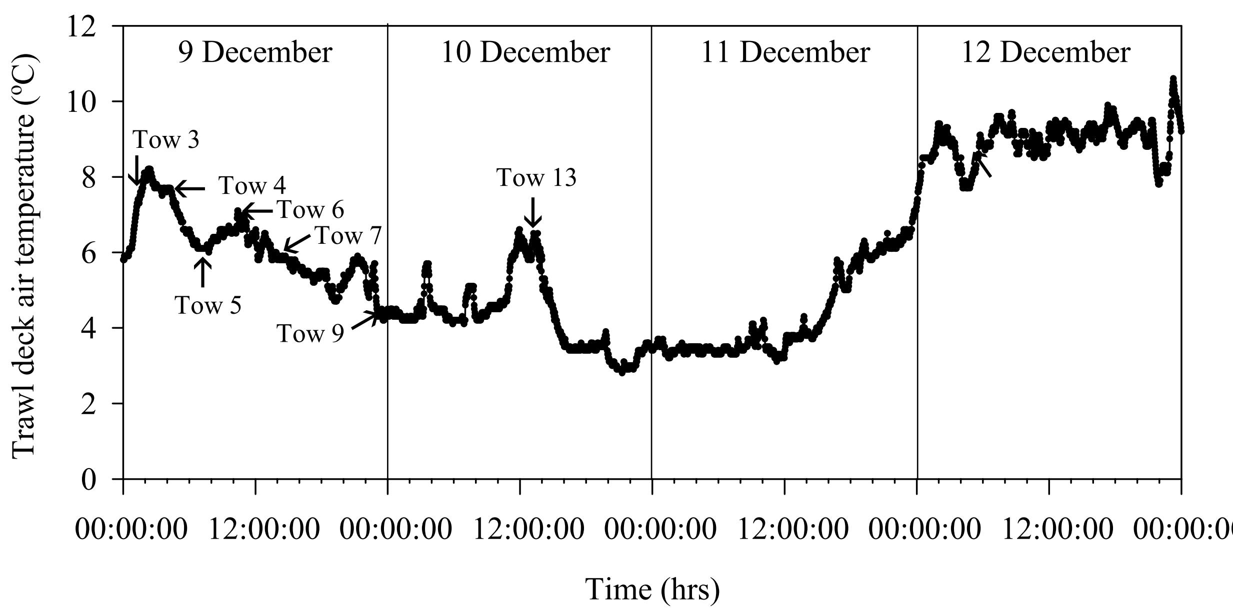

Figure 42. Variation in trawl deck air temperature on the CFV *Cape Ballard* while fishing on the Newfoundland Grand Bank in December 2004. Arrows indicate the approximate temperature when a monitored tow was hauled on deck.

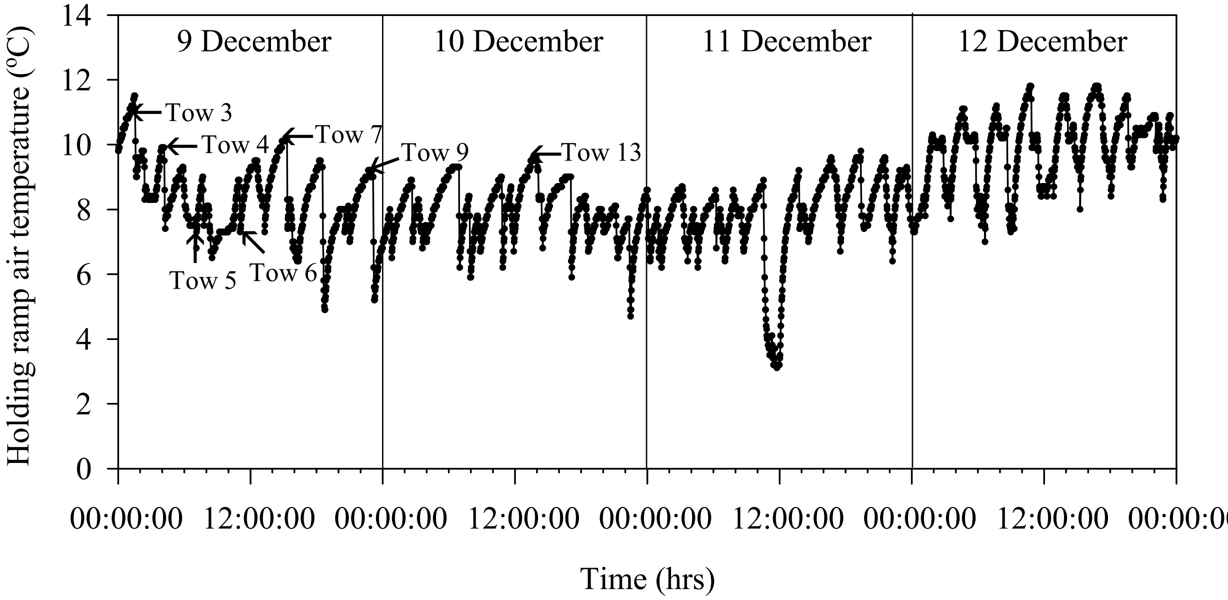

Figure 43. Variation in holding ramp air temperature on the CFV *Cape Ballard* while fishing on the Newfoundland Grand Bank in December 2004. Arrows indicate the approximate temperature when a monitored tow was dumped to the holding ramp.

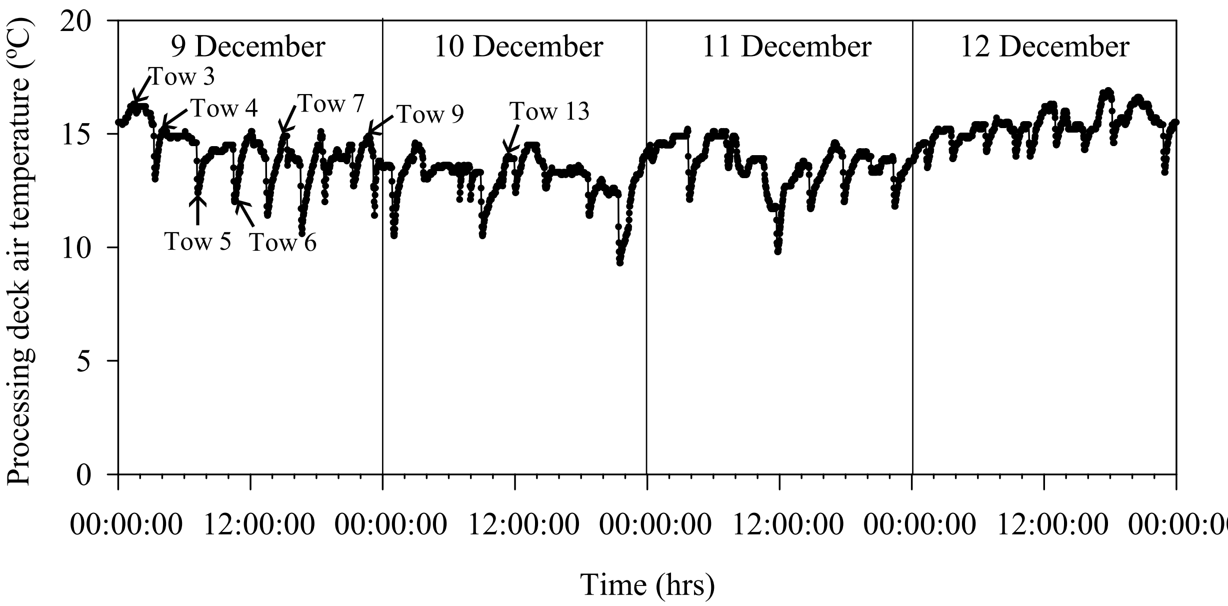

Figure 44. Variation in processing deck air temperature on the CFV *Cape Ballard* while fishing on the Newfoundland Grand Bank in December 2004. Arrows indicate the approximate temperature when a monitored tow was dumped to the holding ramp.

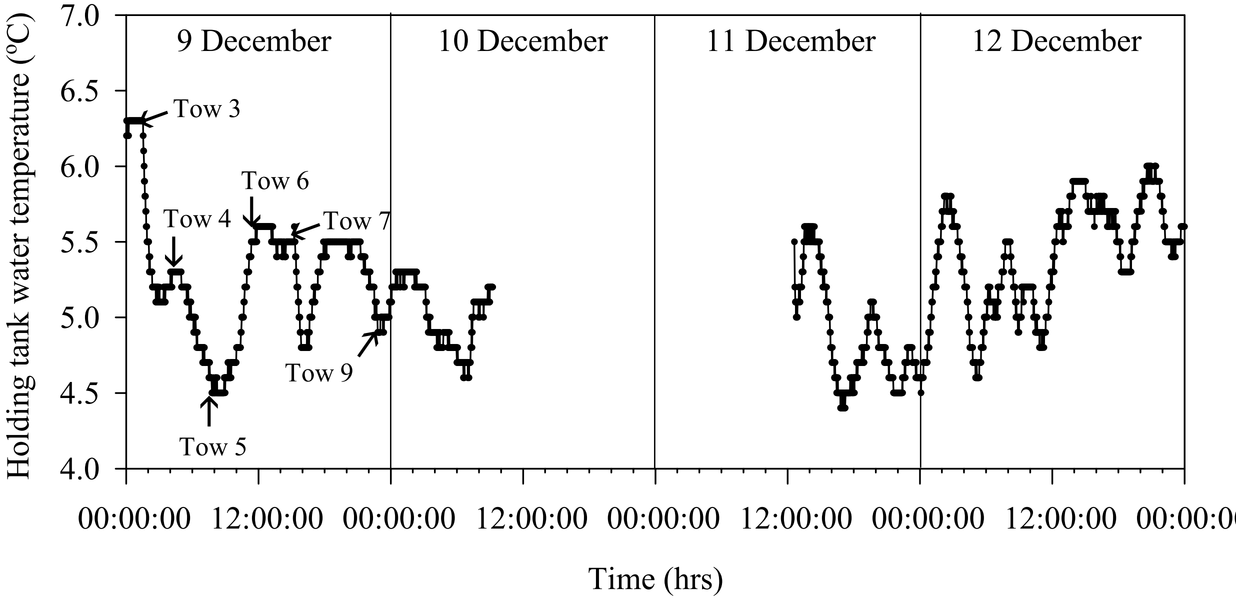

Figure 45. Variation in holding tank water temperature on the CFV *Cape Ballard* while fishing on the Newfoundland Grand Bank in December 2004. Arrows indicate the approximate temperature when a monitored tow was dumped to the holding ramp.

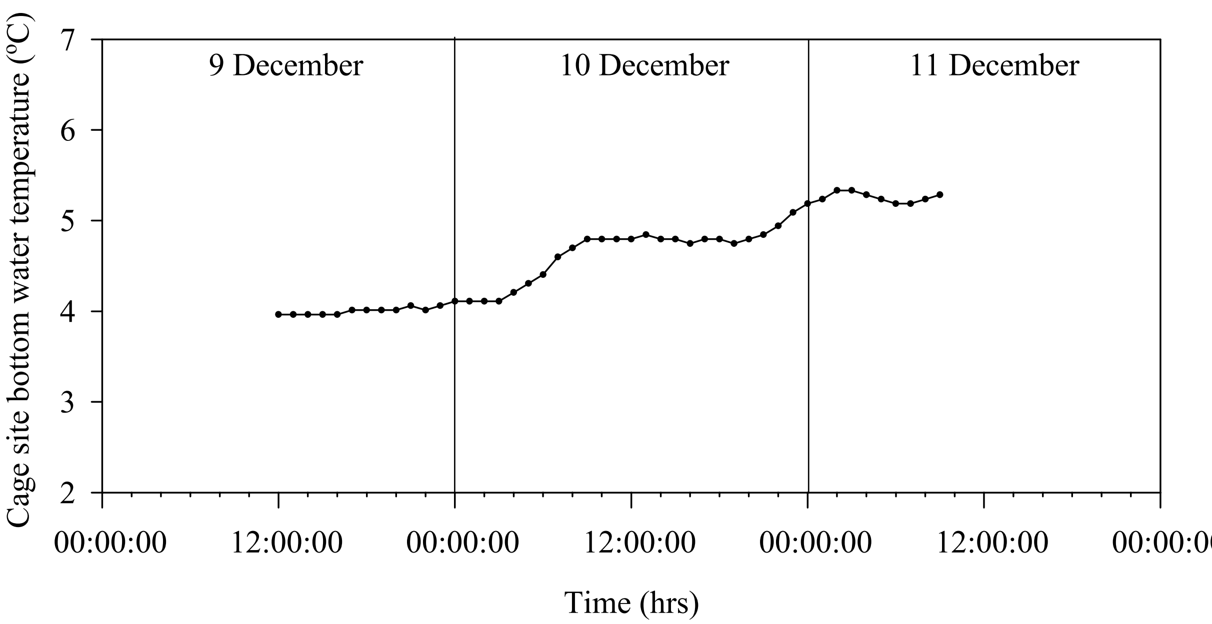

Figure 46. Bottom water temperatures experienced by wolffish at the caging site on the Newfoundland Grand Bank, December 2004.