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Science Advisory Report 2009/042

ASSESSMENT OF NAFO DIVISION 3O AND SUBDIVISION 3PS ATLANTIC HAGFISH (*MYXINE GLUTINOSA*)

Atlantic hagfish (Myxine glutinosa)

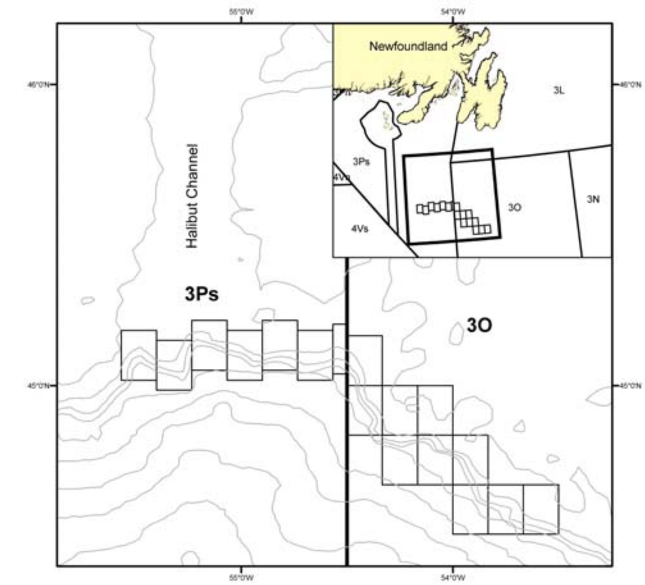

Figure 1: Map showing Atlantic hagfish research survey and commercial fishing areas in Division 3O and Subdivision 3Ps.

Context:

The Atlantic hagfish (Myxine glutinosa) is found only in the North Atlantic Ocean. Populations off Newfoundland and Labrador occur on muddy bottoms in deep water channels and on the continental slope. Low fecundity and high susceptibility to over-exploitation has been well documented for this species (AHWG 2003; Martini 1998; Grant 2006).

In 2004, an Atlantic hagfish fishery was established in an area of interest in Division 3O with a total allocation of 181 t (Fig 1). A similar fishery was established in Subdivision 3Ps in 2005 (Fig. 1). As part of the New Emerging Fisheries Policy two fishing enterprises entered into five year Joint Project Agreements (JPA) with DFO and the Marine Institute of Memorial University to conduct a resource assessment survey starting in 2004 in Div.3O and 2005 in Subdiv. 3Ps. At the conclusion of the JPA for Div. 3O, a science review was requested by Fisheries and Aquaculture Management to provide current information on the status of the Atlantic Hagfish resource in NAFO Div. 3O and Subdiv. 3Ps. The final year of the JPA for Subdiv. 3Ps is planned for 2009.

A meeting of the Regional Advisory Process was held May 12-13 and May 26, 2009 in St. John's, NL to assess the status of Atlantic Hagfish in Div. 3O and Subdiv. 3Ps, for the first time. Participants included DFO scientists & fisheries managers, and representatives from the Newfoundland and Labrador Department of Fisheries & Aquaculture (DFA), industry, and Memorial University.

SUMMARY

- The baited trap fishery was initiated in 2004 (Div. 3O) and 2005 (Subdiv. 3Ps) with an annual allocation of 181 t for each NAFO area. The catch averaged 121 t in Div. 3O (2004-08) and 176 t in Subdiv. 3Ps (2005-08).

- Annual pre-fishery research surveys and fishery data indicate Atlantic hagfish are concentrated on the continental slope in muddy substrate at depths of 125-400 m where bottom water temperatures are highest (5.8-9.0 ºC). The smallest juvenile fish captured were found primarily in depths of 300-500 m.

- Survey catch rates in baited traps declined in heavily fished areas, spanning the locations surveyed in Div. 3O and a localized survey unit in Subdiv. 3Ps. Several factors can influence catch rates; change in population abundance is one of them. Nevertheless, trends in catch rates in areas of highest fishing effort are consistent with what might be expected in the development of a fishery on a virgin stock.

- Trap volume and escape hole diameter were important factors influencing the catch of juvenile Atlantic hagfish. Large (220 L) barrel traps captured fewer juveniles than small (25 L) bucket traps. Large traps with 15.1 mm escape holes captured significantly fewer juveniles than traps with 14.3 mm escape holes. Discard mortality rates estimated from short-term (1-7 days) experiments were highly variable (0-100%). Mortality over the longer term is unknown. Conservation would be maximized and spoilage minimized at soak times of 12-36 h.

- Growth rate, age at sexual maturity, and longevity are unknown as there is no known method of aging Atlantic hagfish. However, size-at-maturity indicates large proportions of juvenile fish are caught in this fishery.

- There is a concern that Atlantic hagfish are susceptible to overexploitation due to their life history traits, catchability, and the predominance of females in the catch.

- Only three species constituted by-catch (sea lamprey, *Petromyzon marinus;* slatjaw cutthroat eel, *Synaphobranchus kaupi*; and snubnose eel, *Simenchelys parasiticus*); comprising <0.1 % of the landings in the fishery.

- Impacts of the fishing gear on bottom habitat are presumed to be low. The importance of Atlantic hagfish in the benthic community is unknown.

- Given the uncertainties with this species there is currently no scientific basis for determining a sustainable harvest level.

BACKGROUND

<u>Species Biology</u>

The Atlantic hagfish is found only in the North Atlantic Ocean. Atlantic hagfish are distributed off all coasts in Atlantic Canada and in the Gulf of St. Lawrence. Limiting factors that determine the distribution of Atlantic hagfish are salinity (>32 ppt), temperature (0-12ºC), depth (30-1200 m), and substrate type (mud). Atlantic hagfish occupy temporary burrows in soft sediments where current velocities are low (<0.15 m/s) and exhibit low tolerance to abrupt changes in temperature and salinity. Distributions are typically described as patchy and distribution and abundance can vary over time in response to a number of factors, including: changes in the local ecosystem, substrate alteration, fishing pressure, and availability of supplemental food sources. Tagging studies in other areas of the species range indicate some site fidelity and a home range of at least 2 km. These results, along with changing trends in relative abundance observed in some fisheries suggest that once an area is fished out it may take some time for Atlantic hagfish to re-populate the area (Martini 1998).

Atlantic hagfish are not functional hermaphrodites, but sexually mature individuals possess rudimentary or degenerated gonadal tissue of the opposite sex. An unequal sex ratio of far more females than males is common in Atlantic hagfish populations. Reasons for the unequal sex ratio (99:1) are unclear but may be related to the primary form of capture, that being baited traps (Martini 1998; Patzner 1998; Grant 2006).

Atlantic hagfish may reproduce every one or more years. Fertilization is external and time to hatching of the large (14-25 mm) ovoid eggs exceeds six months. Low fecundity (1-38 eggs) has been established and is largely independent of body size. Atlantic hagfish do not exhibit a definite spawning season; rather they appear capable of spawning throughout the year. Although uncommon, fertilized eggs have been collected in bottom trawls over mud, clay, or sand bottom (Patzner 1998; Grant 2006).

The most basic aspects of Atlantic hagfish life history, including growth rate, age at sexual maturity, and longevity remains a mystery as there is no known method of aging hagfish. In the Newfoundland region, Atlantic hagfish do not attain as great a maximum length as individuals from southern regions (e.g., Gulf of Maine) but are heavier at length. A reduction in size-at-maturity with a reduction in average body size has been demonstrated at large (Newfoundland vs. Gulf of Maine) geographical scales (Martini 1998; Grant 2006).

The Atlantic hagfish is jawless but possess an eversible tongue that is studded with rows of keratinous teeth. It has a reputation for consuming longlined and netted fish such as monkfish. Although Atlantic hagfish are often considered scavengers, it is unlikely their observed densities in continental shelf waters could be supported by scavenging alone. Atlantic hagfish consume polychaetes and other burrowing invertebrates, molluscs, northern shrimp, lobster, hagfish eggs, bird and mammal remains, and various finfish including, Atlantic cod, haddock, Atlantic mackerel, porbeagle, and spiny dogfish (Martini 1998).

Eggs and small Atlantic hagfish are eaten by Atlantic cod, white hake, and Atlantic halibut. All species of hagfish secrete copious amounts of slime when they are threatened and secretion of slime may generally discourage finfish from preying upon hagfishes. High frequencies of occurrence (10-60%) of various species of hagfish in the diet of marine mammals (i.e., peale's dolphin, harbor seal, and elephant seal), suggest they are a major predator (Martini 1998).

The Fishery

The fishery was initiated in 2004 (Div. 3O) and 2005 (Subdiv. 3Ps) with an annual allocation of 181 t for a single vessel in each NAFO area which was prosecuted from September to December. The catch averaged 121 t in Div. 3O (2004-08) and 176 t in Subdiv. 3Ps (2005-08).

The fishery was concentrated along the slope edges at depths of 100-200 m in Div. 3O and 100-400 m in Subdiv. 3Ps.

Strings (fleets) of barrel-type baited traps (220 L) were used to prosecute the fishery. Escape holes of 14.3 mm and 15.1 mm diameter were most common. In Div. 3O in 2004, an experimental trap with 13.5 mm escape holes was abandoned after the first commercial trip due to a high percentage of juveniles in the catch. In 2004, the majority (91%) of traps had 14.3 mm escape holes. In subsequent years, a 40/60 trap fleet split was introduced where 40% of the effort was with traps with 14.3 mm escape holes and 60% of the effort was with traps with 15.1 mm escape holes. In Subdiv. 3Ps, traps with 14.3 mm (84%) and 15.1 mm (16%) escape holes were used in 2005, with a split of 40/60 occurring in subsequent years.

Annual landings in NAFO Div. 3O ranged from 186 t in 2005 to 26 t in 2008 (Fig. 2). Failure to achieve the allocation in 2007 and 2008 was due in part to mechanical problems with the fishing vessel. Trap effort focused on areas of highest concentration identified in annual surveys, peaking in 2005 (Figure 2). Landings in Subdiv. 3Ps totaled 171-176 t each year, with effort peaking in 2006 (Fig. 2).

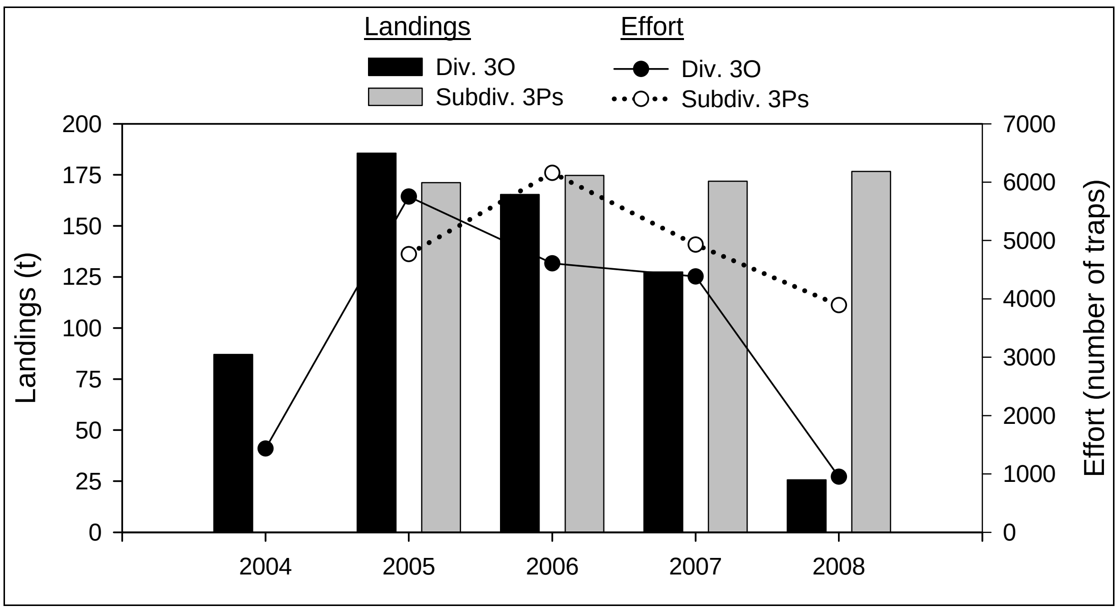

Figure 2: Atlantic Hagfish landings (t) and effort for Div. 3O and Subdiv. 3Ps, 2004-08.

ASSESSMENT

Resource status was evaluated based on annual pre-fishery research surveys and biological sampling conducted in late summer (August-September) as well as CPUE data collected during the fishery (Grant et al., In prep a, b, c). All sources of information indicate Atlantic hagfish are concentrated at the highest bottom water temperatures (5.8-9.0ºC) on the continental slope which occur within depths of 125-400 m. The smallest juvenile fish captured were found primarily in depths of 300-500 m.

Commercial Fishery

Catch Rates

In Div. 3O, commercial CPUE (kg/trap) in the 101-200 m depth interval was highest in 2004 but was confounded by a higher percentage of traps with 14.3 mm escape holes fished than in other years. Catch rates declined in 2005 and remained stable from 2005-08 (Fig. 3).

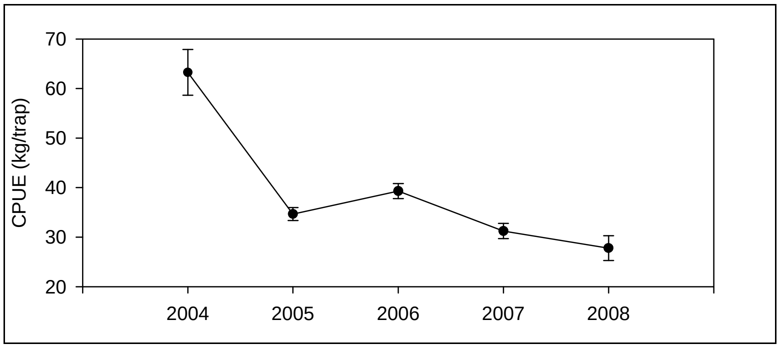

Figure 3: Trends in Div. 3O commercial CPUE (kg/trap) within the 101-200 m depth interval, 2004-08 (bars indicate ±1 SE).

In Subdiv. 3Ps, CPUE in the 101-200 m depth interval declined from 2005-06 but increased back to the 2005 level in 2007-08 (Fig. 4). In the 201-300 m depth interval, CPUE remained stable from 2005-07 before increasing in 2008. In the greatest depths fished (301-400 m) CPUE was unchanged from 2005-08.

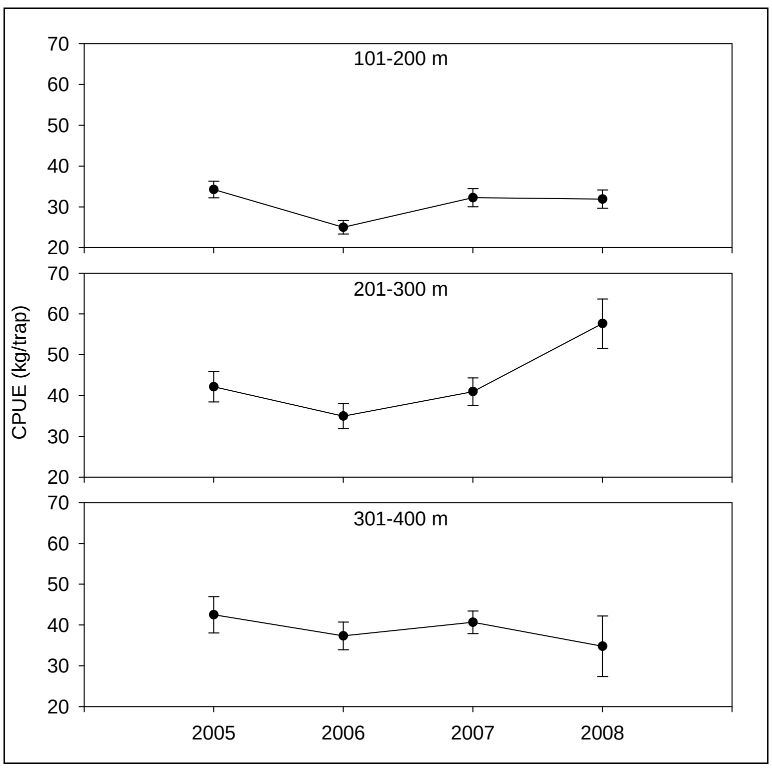

Figure 4: Trends in Subdiv. 3Ps commercial CPUE (kg/trap) within the 101-200 m, 201-300 m, and 301-400 m depth intervals, 2005-08 (bars indicate ±1 SE).

Research Survey

Catch Rates

Sampling from surveys was conducted each year in randomly selected locations within large (10' x 10') fixed blocks centered about the 183 m depth contour of the slope edge (Fig. 1). Research sampling gear was standardized for soak time and consisted of seven 220 L barrel-type baited traps with one control (3.2 mm holes) and three replicates of each experimental trap (14.3 mm and 15.1 mm escape holes) set in a string.

Survey catch rates (kg/trap) from experimental traps declined in heavily fished areas, spanning the locations surveyed in Div. 3O and a localized survey unit (2' x 2') in Subdiv. 3Ps. Several factors can influence catch rates in baited traps other than a change in population abundance. Additional factors that may be important include changes in catchability related to individual condition, female reproductive stage, satiation, and tidal mediated changes in bottom water temperature. Nevertheless, trends in catch rates in areas of highest fishing effort are consistent with what might be expected in the development of a fishery on a virgin stock.

In Div. 3O, research survey catch rates in traps with 15.1 mm escape holes decreased significantly in the 101-300 m depth intervals from 2005-07 (Fig. 5). In the 101-200 m depth interval catch rate in traps with 15.1 mm escape holes returned to the 2005 level in 2008 and in the 201-300 m depth interval, catch rate stabilized from 2007-08 (Fig. 5). Trends in catch rates from traps with 14.3 mm escape holes were consistent with those from traps with 15.1 mm escape holes.

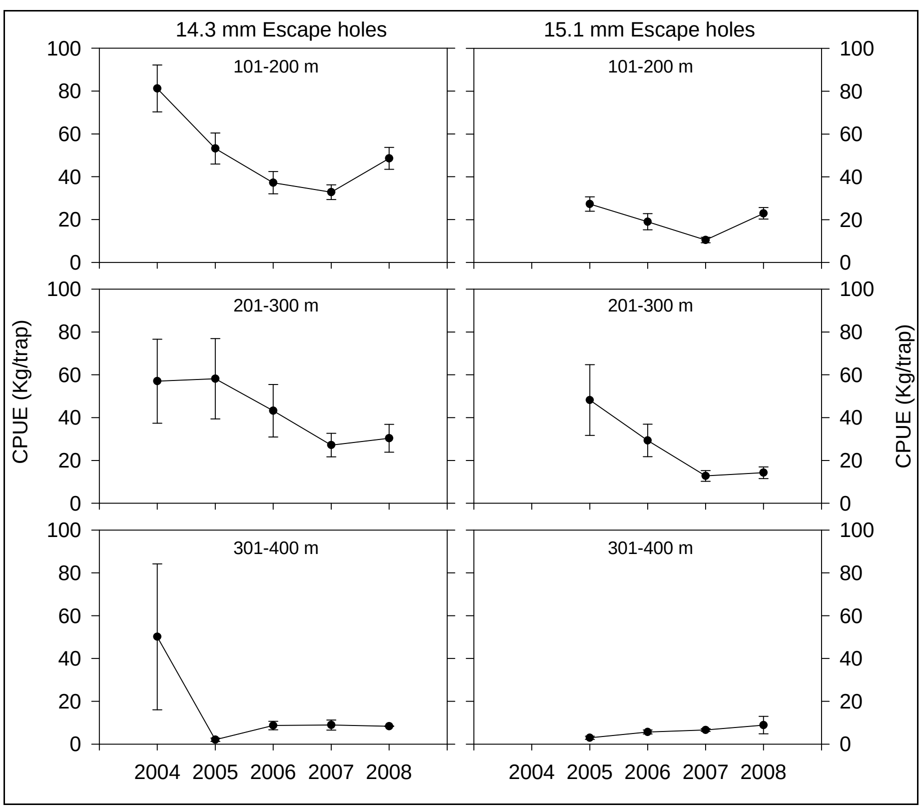

Figure 5: Trends in Div. 3O research survey CPUE (kg/trap) within the 101-200 m, 201-300 m, and 301-400 m depth intervals, 2004-08 (bars indicate ±1 SE).

In Subdiv. 3Ps, research survey CPUE was variable and trends were inconsistent across depth and year (Fig. 6). A localized survey unit in the 301-400 m depth interval in Subdiv. 3Ps was surveyed in three consecutive years. In this area, annual CPUE decreased significantly from 2005-06 in traps with both the 14.3 mm and 15.1 mm escape holes and exhibited a further decrease to 2008 (Fig. 6 bottom panel).

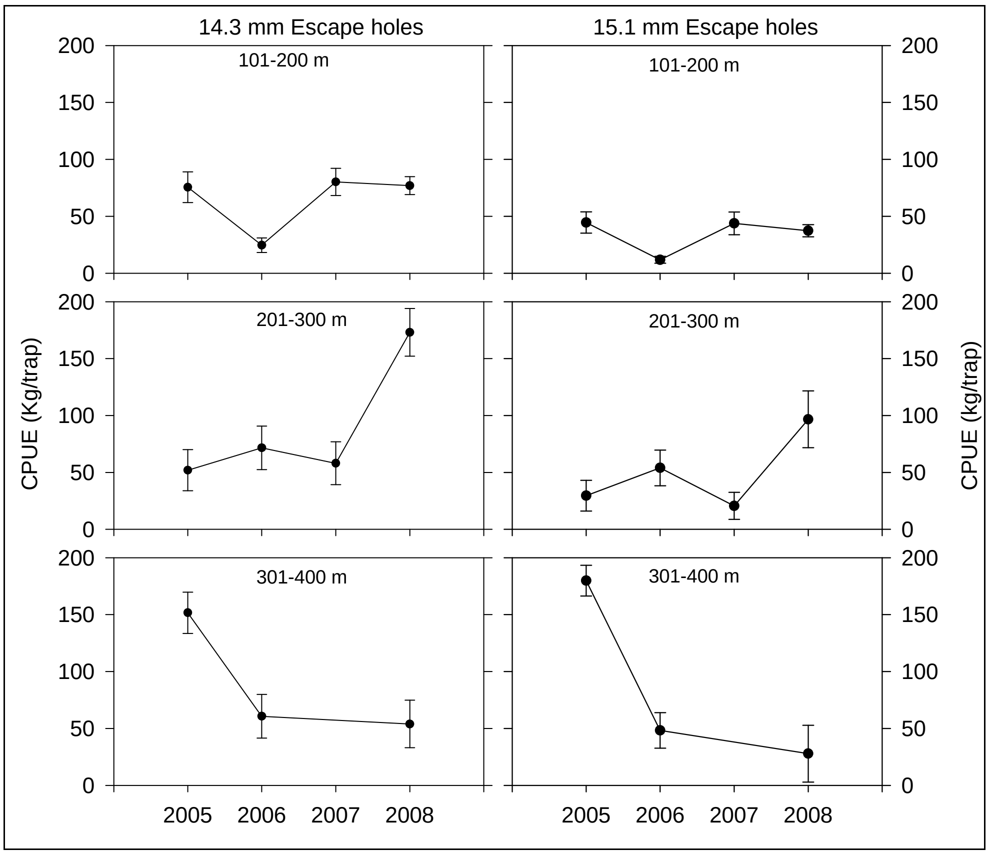

Figure 6: Trends in Subdiv. 3Ps research survey CPUE (kg/trap) within the 101-200 m, 201-300 m, and 301-400 m depth intervals, 2005-08 (bars indicate ±1 SE).

Size Composition

Standardized length-specific indices of abundance were not developed from surveys. Nevertheless, there is some evidence from length-frequency distributions of localized reduction in contribution of large individuals in traps with 14.3 mm and 15.1 mm escape holes.

The smallest juvenile fish captured (100-200 mm) were concentrated and their distribution was patchy within the 301-400 m depth interval in Div. 3O and Subdiv. 3Ps. Sampling in deeper waters (to 1000 m) in Div. 3O indicates small juveniles are also concentrated in the 401-500 m depth interval.

Life History

Growth rate, age at sexual maturity, and longevity are unknown as there is no known method of aging Atlantic hagfish. Males and females mature at similar lengths while males appear to attain a greater maximum length. Size-at-maturity in females (Fig. 7) indicates large proportions of juvenile fish are caught in this fishery. Large proportions of Atlantic hagfish below the minimum weight for human consumption (80 g) are also captured. Between trap comparisons indicated traps with 15.1 mm escape holes captured significantly fewer Atlantic hagfish below the length at 50% maturity and significantly fewer below 80 g. On average, Atlantic hagfish below the length at 50% maturity accounted for 10-12% (Div. 3O vs. Subdiv. 3Ps) of the catch in traps with 14.3 mm escape holes, compared to 5-6% in traps with 15.1 mm escape holes. Atlantic hagfish below 80 g accounted for 34-41% of the catch in traps with 14.3 mm escape holes, compared to 20-24% in traps with 15.1 mm escape holes.

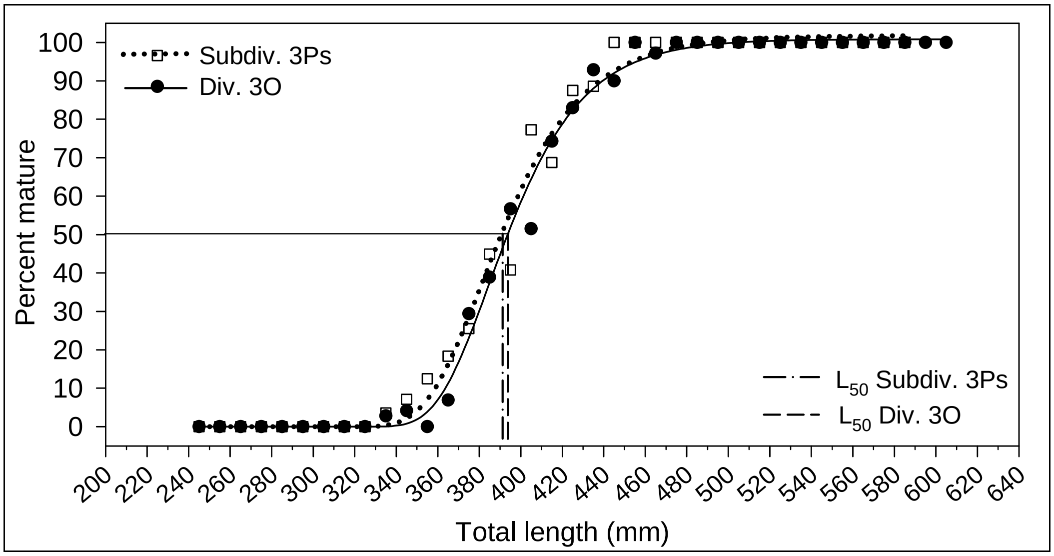

Figure 7: Length at maturity curves and length at 50% maturity (L_{50}) for female Atlantic hagfish in Div. 3O and Subdiv. 3Ps.

The sex ratio indicated predominance of females (98:1) in the catches, with few males and hermaphroditic animals captured. Atlantic hagfish exhibit low fecundity (6-42 eggs/female) and a weak to moderately strong positive relation to body length. Eggs in final stages of development are greater than or equal to 20 mm in length and 8 mm in diameter. No relation was established between size of mature eggs and that of females.

Spawning frequency and duration of the reproductive cycle are unknown. However, spawning appears to occur throughout the year as suggested by asynchronous female gonadal development. Analysis suggests the duration of the resting period between reproductive cycles is influenced by local environmental conditions.

Weight of the smallest juveniles captured in control traps (0.9-2.0 g; 98-100 mm) encompassed the weight of mature eggs suggesting these were recently hatched juveniles and absence of a larval stage in Atlantic hagfish.

Trap Selectivity and Discard Mortality

Trap volume and escape hole diameter were important factors influencing the catch of juvenile Atlantic hagfish. Large (220 L) barrel traps captured fewer juveniles than small (25 L) bucket traps. Large traps with 15.1 mm escape holes captured significantly fewer juveniles than traps with 14.3 mm escape holes.

The average length at 50% probability (Fig. 8) of Atlantic hagfish being retained in traps with 14.3 mm escape holes was 4-28 mm less (Div. 3O vs. Subdiv. 3Ps) than the length at 50%

maturity, while the average length at 50% probability of retention for traps with 15.1 mm escape holes was 5-10 mm higher (Subdiv. 3Ps vs. Div. 3O) than the length at 50% maturity.

Differences in trap selectivity among NAFO areas could suggest regional variation in size-specific maturity in Atlantic hagfish populations.

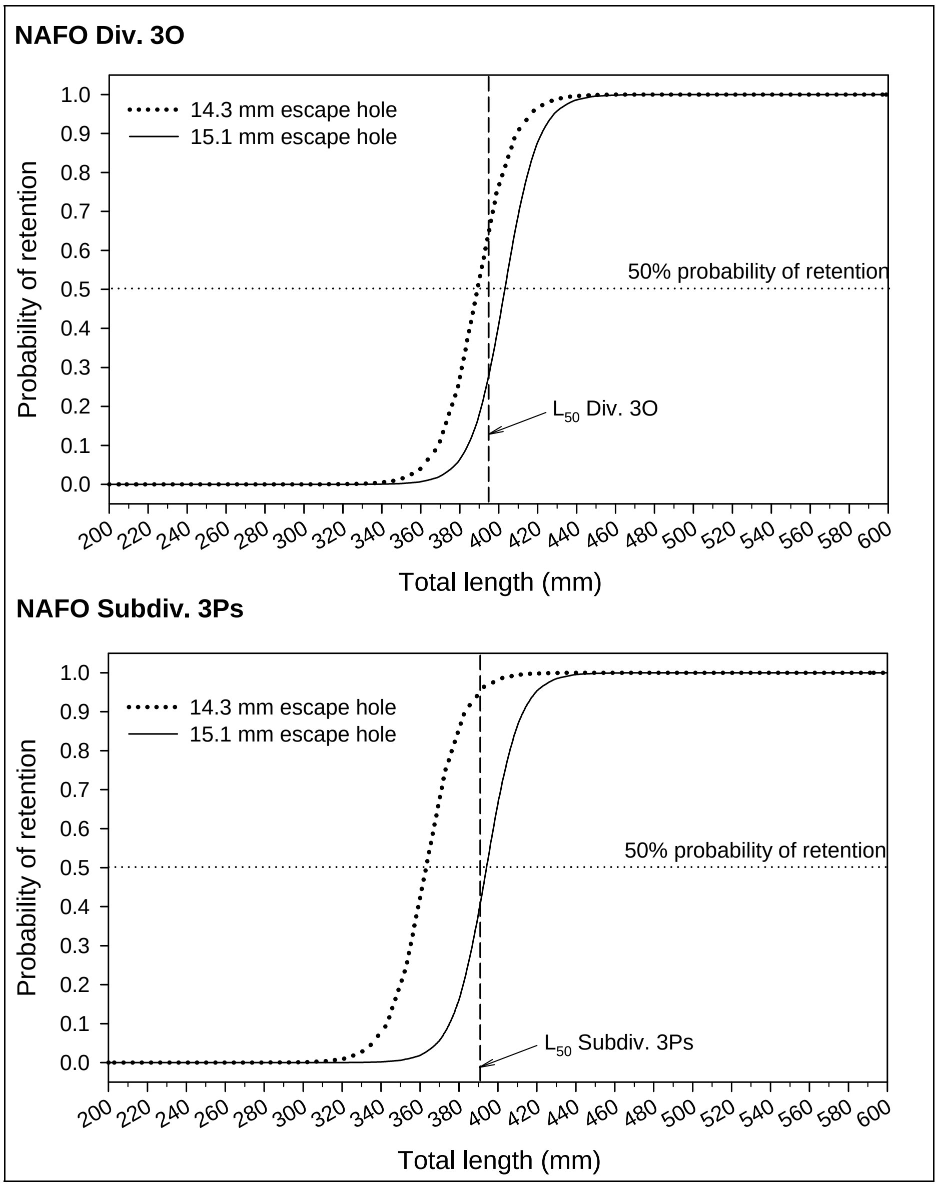

Figure 8: Atlantic hagfish selectivity curves for 220 L traps with 14.3 mm and 15.1 mm escape holes in Div. 3O and Subdiv. 3Ps. Female length at 50% maturity (L_{50}) and 50% probability of retention are also shown.

Saturation is common in traps with small escape holes and small volume, with increased proportions of juveniles in the catch. Soak times longer than 36 hours were shown to exhibit high levels of mortality when traps were saturated.

Discard mortality rates estimated from short-term (1-7 days) experiments were highly variable (0-100%); mortality over the longer term is unknown.

Ecosystem Considerations

Atlantic hagfish are predominately concentrated at highest bottom water temperatures along the slope edges of the continental shelf in muddy substrates. Where Atlantic hagfish occur in high densities their behaviour of burrowing in the sediment may be expected to play a role in structuring the physical habitat. If, as suspected, Atlantic hagfish are more predatory than initially thought, then they may also play a role from a trophic dynamics perspective. However, the importance and function of Atlantic hagfish in the benthic community is unknown.

The construction and design of the traps used in the fishery results in little risk of 1) non-targeted species being captured and 2) negative impacts on benthos and benthic habitat.

Incidental capture in the baited traps was minimal and limited to three species; sea lamprey (*Petromyzon marinus),* slatjaw cutthroat eel (*Synaphobranchus kaupi*), and snubnose eel (*Simenchelys parasiticus*) which comprised <1% of the catch in both the fishery and the survey.

Sources of Uncertainty

Given what is known about the life history characteristics and behavior of hagfish and the limitations and difficulties interpreting CPUE data, it is important to recognize that there are several key sources of uncertainty associated with the assessment data presented. These sources need to be recognized and addressed if hagfish are to be harvested sustainably in the long term.

Several factors can influence catch rates; change in population abundance is one. More research on other factors is required. In addition, alternative approaches to assessing abundance should be explored, including new analytical techniques using existing data and the development of new approaches such as tagging studies.

There is only limited information on population structure currently available and sustainable exploitation rates are unknown.

Growth rate, age at maturity, longevity, recruitment processes, and natural mortality are unknown.

Trends in relative abundance of mature and immature fish, potential recruitment, and bias in catchability of ripe females across areas are unknown. The information provided by the current analysis of research survey length frequency data was limited. A re-examination of these data according to size group by calculating survey catch rates at length may provide comprehensive results.

The long-term survival of discards returned to the water is unknown.

The consequences of removals on ecosystem structure and function are unknown.

ADDITIONAL STAKEHOLDER PERSPECTIVES

Department of Fisheries and Aquaculture (DFA)

The DFA has participated, with industry, in the development of the hagfish fishery to ensure that the fishery is developed sustainably. Good progress has been made in expanding knowledge of the life history of the hagfish through the annual pre-fishery surveys and analysis of the collected data. However, this has not lead to a point where there is enough knowledge to form a scientific foundation on which to determine a sustainable harvest level.

The expansion of the fishery is suggested to be limited and proceed slowly until more is known about the life history of hagfish, and effects of fishing mortality can be observed and quantified. The pre-fishery surveys need to continue to be used in the currently fished areas, as well as in any other areas that may be surveyed for commercial fishery potential.

Where hagfish fit into the aquatic ecosystem, and their importance, is not known at this time requiring further study. Therefore, the affects of developing a hagfish fishery on the ecosystem should be studied so the effects are kept to a minimum. DFO must include this effort as part of the hagfish management plan that they develop.

The sustainability of the fishery, once it becomes commercial, is paramount. Therefore, the DFO must continue to conduct annual resource surveys and harvesters should continue to collect data for analysis by DFO to inform fishery management decisions and plans.

CONCLUSIONS AND ADVICE

Given the limited knowledge and uncertainties with Atlantic hagfish population dynamics there is currently no scientific basis for determining a sustainable harvest level. It has been demonstrated elsewhere that hagfish populations cannot withstand heavy fishing pressure and there is a concern that Atlantic hagfish are susceptible to overexploitation due to their life history traits, catchability, and the predominance of females in the catch.

There is limited available information pertaining to distribution, abundance, and population structure of Atlantic hagfish in Div. 3O and Subdiv. 3Ps beyond the currently surveyed areas. Scientific surveys into new areas should be conducted and biological information collected before any geographical expansion of the fishery is considered.

Although several factors including a change in abundance can influence catch rates in baited traps, survey catch rates have declined in heavily fished areas which is consistent with what might be expected in the development of a fishery on a virgin stock. However, from a precautionary perspective it is not advisable to expand fishing efforts beyond current levels within the current survey areas.

MANAGEMENT CONSIDERATIONS

At this time it is not possible to determine abundance and productivity of this species in Newfoundland waters, nor whether there is a compensatory increase in production at reduced stock size. It is also not possible to determine what might be a sustainable removal level.

Consequently it is suggested management be based on size selectivity and escapement potential of the traps used and fishing effort.

Use available habitat information combined with exploratory survey work to further map the population structure and distribution of the resource in un-surveyed areas in Div. 3O and Subdiv. 3Ps.

Given the high incidence of trap saturation by juveniles and spoilage in small traps (25 L), large traps (220 L) should be considered.

In the absence of a sustainable harvest or mortality level a conservation objective would be to allow escapement to occur consistent with a length at 50% maturity. It is considered that this may be achieved with a 40/60 trap fleet split where 40% of the effort is with traps with 14.3 mm escape holes and 60% of the effort is with traps with 15.1 mm escape holes.

High susceptibility of juveniles to capture in baited traps and high concentrations of the smallest juveniles in depths of 300-500 m would suggest fisheries should avoid these depths given they may be potential spawning and rearing grounds.

Better quantitative estimates of discarding at sea are required.

Conservation would be maximized and spoilage minimized at soak times of 12-36 h.

Continue use of biodegradable escapement mechanisms.

Continue monitoring of biological parameters that showed sensitivity to fishing pressure.

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