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Proceedings of a Workshop on Canadian Science and Management Strategies for Atlantic Hagfish

Compte rendu d'un atelier sur les stratégies canadiennes en matière d'étude scientifique et de gestion de la myxine du nord

22–23 October 2007
Bedford Institute of Oceanography
Dartmouth, Nova Scotia

Le 22–23 Octobre 2007
Institut océanographique de Bedford
Dartmouth (Nouvelle-Écosse)

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May 2009

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Foreword

The purpose of these Proceedings is to document the activities and key discussions of the meeting. The Proceedings include research recommendations, uncertainties, and the rationale for decisions made by the meeting. Proceedings also document when data, analyses or interpretations were reviewed and rejected on scientific grounds, including the reason(s) for rejection. As such, interpretations and opinions presented in this report individually may be factually incorrect or misleading, but are included to record as faithfully as possible what was considered at the meeting. No statements are to be taken as reflecting the conclusions of the meeting unless they are clearly identified as such. Moreover, further review may result in a change of conclusions where additional information was identified as relevant to the topics being considered, but not available in the timeframe of the meeting. In the rare case when there are formal dissenting views, these are also archived as Annexes to the Proceedings.

This workshop was not carried out as a formal Fisheries and Oceans Canada (DFO) Science Advisory process; however, it is being documented in the Canadian Science Advisory Secretariat's (CSAS) Proceedings series as it presents some topics of interest related to the advisory process.

Avant-propos

Le présent compte rendu a pour but de documenter les principales activités et discussions qui ont eu lieu au cours de la réunion. Il contient des recommandations sur les recherches à effectuer, traite des incertitudes et expose les motifs ayant mené à la prise de décisions pendant la réunion. En outre, il fait état de données, d'analyses ou d'interprétations passées en revue et rejetées pour des raisons scientifiques, en donnant la raison du rejet. Bien que les interprétations et les opinions contenus dans le présent rapport puissent être inexacts ou propres à induire en erreur, ils sont quand même reproduits aussi fidèlement que possible afin de refléter les échanges tenus au cours de la réunion. Ainsi, aucune partie de ce rapport ne doit être considéré en tant que reflet des conclusions de la réunion, à moins d'indication précise en ce sens. De plus, un examen ultérieur de la question pourrait entraîner des changements aux conclusions, notamment si l'information supplémentaire pertinente, non disponible au moment de la réunion, est fournie par la suite. Finalement, dans les rares cas où des opinions divergentes sont exprimées officiellement, celles-ci sont également consignées dans les annexes du compte rendu.

Le présent atelier n'a pas été tenu dans le cadre officiel du processus des avis scientifiques du ministère des Pêches et des Océans (MPO). Celui-ci est toutefois documenté dans la série des comptes rendus du Secrétariat canadien de consultation scientifique (SCCS), car il couvre certains sujets en lien avec le processus des avis.

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SUMMARY

Atlantic hagfish (*Myxine glutinosa*) is widely distributed along both coasts of the North Atlantic. There has been a directed fishery for hagfish off Nova Scotia since the late 1980s. At present, there are 7 fishers authorized to harvest hagfish in the Scotia-Fundy portion of Nova Scotia. Exploratory fishing activities have also been ongoing in the Newfoundland region since the 1990s. While the hagfish fishery is primarily an emerging fishery in Atlantic Canada, Fisheries and Oceans Canada has recognized that a requirement exists to develop a comprehensive fisheries management plan governing activities of current and future license holders. Although there is little biological information available from the Maritimes, other regions (e.g., Newfoundland) and countries (e.g., USA, Japan) have undertaken scientific studies on this and related species (e.g., Pacific hagfish (*Eptatretus stoutii*)). In this regard, there is a need to develop an understanding of the information that exists to assist management, the approaches that could be used for management, and future information needs. These Proceedings document discussions held during 22 – 23 October 2007 on these issues.

SOMMAIRE

La myxine du nord (*Myxine glutinosa*) est largement répartie le long des deux côtes de l’Atlantique Nord. Elle fait l’objet d’une pêche dirigée au large de la Nouvelle-Écosse depuis la fin des années 1980. Actuellement, sept pêcheurs sont autorisés à la capturer dans la partie néo-écossaise de Scotia-Fundy. Une pêche exploratoire de la myxine est pratiquée dans la Région de Terre-Neuve depuis les années 1990. Bien que la pêche de la myxine soit essentiellement une nouvelle pêche au Canada atlantique, Pêches et Océans Canada est conscient de la nécessité d’élaborer un plan de pêche exhaustif régissant les activités des titulaires de permis actuels et futurs. La Région des Maritimes a produit peu d’information biologique sur l’espèce, mais d’autres Régions (p. ex. celle de Terre-Neuve) et d’autres pays (p. ex. les États-Unis et le Japon) ont entrepris des études scientifiques sur la myxine et sur les espèces qui lui sont apparentées (p. ex. la myxine brune [*Eptatretus stoutii*]). Il importe de savoir de quelle information on dispose pour aider à la gestion de cette ressource, quelles sont les approches de gestion qui pourraient être adoptées et quels sont les besoins futurs en matière d’information. Le présent compte rendu relate les discussions tenues les 22 et 23 octobre 2007 à ce sujet.

INTRODUCTION

Atlantic hagfish (*Myxine glutinosa*) is widely distributed along both coasts of the North Atlantic. There has been a directed fishery for hagfish off Nova Scotia since the late 1980s. At present, there are 7 fishers authorized to harvest hagfish in the Scotia-Fundy portion of Nova Scotia. Of these fishers, 2 were granted permanent commercial access in 1997, 4 remain at the exploratory stage, and the remaining 1 received experimental access in 2005. Exploratory fishing activities have also been ongoing in the Newfoundland region since the 1990s.

While the hagfish fishery is primarily an emerging fishery in Atlantic Canada, Department of Fisheries and Oceans (DFO) Canada has recognized that a requirement exists to develop a comprehensive fisheries management plan governing activities of current and future license holders. Although there is little biological information available from the Maritimes, other regions (e.g., Newfoundland) and countries (e.g., USA, Japan) have undertaken scientific studies on this and related species (e.g., Pacific hagfish (*Eptatretus stoutii*)). In this regard, there is a need to develop an understanding of the information that exists to assist management, the approaches that could be used for management, and future information needs.

A workshop was therefore convened in the George Needler Boardroom at the Bedford Institute of Oceanography, Dartmouth, NS, during 22–23 October 2007, to address the Terms of Reference (Appendix 1), which had been developed jointly by DFO Fisheries and Aquaculture Management (FAM) and Science branches. The Chair, Robert O'Boyle, opened the meeting by welcoming the participants (Appendix 2), which included experts from other parts of Atlantic Canada and the USA. The Chair then reviewed the Terms of Reference, which included the Workshop's context and objectives. He noted that the main product of the workshop was to be these Proceedings. The Agenda (Appendix 3) was then reviewed. The Chair noted that the first day was to be devoted to presentations and discussion on hagfish biology and fisheries, while the second day would be devoted to the science needs of potential management approaches and priorities. Lastly, he noted that the agenda was deliberately designed to allow lots of time for discussion.

PRESENTATIONS

Overview of Hagfish Ecology
F. Martini

Presentation Highlights

Hagfish are found worldwide in benthic habitats shallower than 3500 m and between 66 ºN and 62 ºS (at temperatures usually <12 ºC and salinities approaching 'full seawater'). Seventy-three species are currently recognized, but many of those are based on very few specimens. There is no clear pattern known across species for size/sex distribution. Most species prefer, but are not restricted to, areas with soft substrates and low current velocities.

Myxine glutinosa is distributed in the North Atlantic from Florida to Davis Strait, around southern Greenland and Icelandic waters, and from the Mediterranean Sea to Murmansk, including the North Sea and the waters around the UK. They are found in depths <1200 m, in temperatures <14 ºC, and in salinities >32 ppt. They occupy temporary burrows that collapse upon their emergence. Burrowing is a slow process that can take 4-11 minutes. Because they live as infaunal residents of soft, flocculent sediments, they are seldom detected by visual surveys in the absence of bait or some form of substrate disturbance. This lifestyle accounts for their low frequency of occurrence in trawl surveys (approximately 7%), even when trawls are done in areas known to support large populations.

No practical methods of tagging have been developed for *M. glutinosa,* although coded wire tags have been used successfully for other, more robust species. Successful tagging may require facilities for transporting and releasing tagged animals at the locations (depths) where they were captured. The few tagging studies done on hagfishes have all shown that growth is indeterminate and individuals may grow longer or shorter between samplings. This makes standard age and growth estimates impossible. Unfortunately, there is presently no method to determine the age of hagfish (e.g., no otoliths, vertebrae, stataconia, etc.). One small scale tagging study suggested that *M. glutinosa* may have a home range of ≥2 km and some site fidelity. The results of tagging studies and patterns observed in some fisheries suggest that once an area is fished out, it may take some time for hagfish to re-populate the area.

Because in-situ observation is difficult, population and biomass estimates are limited in scope. In one study, peak densities were estimated to be approximately 500,000/km^2, comparable to those reported for *Eptatretus deani* off California.

M. glutinosa in the western North Atlantic cannot generally be distinguished from those in the eastern North Atlantic on the basis of standard morphometric characters. However, individuals collected in the inner portion of the Gulf of Maine (and perhaps along the continental shelf break south and east of Georges Bank) reach a larger maximum size and reach sexual maturity at a larger size than individuals in other populations.

Reproduction is known to be synchronous in only 1 species of hagfish, *Eptatretus burgeri*. Circumstantial evidence indicates that *M. glutinosa* reproduces asynchronously and recruitment occurs year-round. A significant proportion of adult hagfish populations may be either sterile or in a resting state, and many species appear to have skewed sex ratios with females outnumbering males by a large margin. Mature females produce clutches of <30 eggs that measure 20-25 mm in total length. The eggs are probably deposited in burrows. Only 3 embryos of *M. glutinosa* have ever been collected. All evidence indicates that these are slow-growing, slow-developing, long-lived animals, with a limited reproductive potential.

Hagfish, including *M. glutinosa*, are benthic predators feeding on infaunal and epifaunal invertebrates (nemerteans, polychaetes, crustaceans), and scavenging opportunistically on vertebrate or invertebrate remains. They are preyed upon by small cetaceans and pinnipeds. Despite their abundance and probable importance in the benthic ecosystem and benthopelagic coupling, they have generally been ignored in models of ecosystem energetics.

Discussion

There were several questions posed concerning the results of research on Atlantic hagfish in the Gulf of Maine and the fishery that occurred there. A participant asked if the sites surveyed in the Gulf of Maine from 1981 to 1992 were re-surveyed after that time period to determine if they had been re-populated by hagfish. Martini indicated that the sites had been re-surveyed. Another participant asked what proportion of the survey tows (i.e., bottom trawl) were actually made on good hagfish bottom. Martini responded that this is unknown because there is lack of detailed knowledge of bottom sediments in the area.

Commenting on the suggestion that hagfish may occasionally exhibit negative growth, a participant expressed skepticism about this and indicated that the phenomenon is probably a reflection of the difficulties involved in accurately measuring live (i.e., struggling) hagfish in the field. It was recommended that standardized protocols for measuring hagfish (e.g., not stretching them) be developed.

A participant questioned whether hagfish line/coat their burrows with slime. Martini responded that this is possible, but that there is currently no evidence that this occurs.

The Chair proposed an open discussion of aspects of the biology and ecology of hagfish. The following were the highlights of this discussion:

1) Population structure.

   It was noted that there is little or no information on this subject (for any species), but hagfish do not have a homogeneous distribution in the western Atlantic Ocean. There have not been any broad-scale genetic studies done on hagfish (anywhere).

   A participant asked if anyone has done a stock depletion experiment to estimate the size of a virgin hagfish population. The response given was that this has not been done. It was suggested that there may be signs of stock depletion off Newfoundland, but that this perception may be confounded by the fact that hagfish in this area are at the northern limit of their distribution. Off Newfoundland, the most important determinants of hagfish distribution appear to be temperature and possibly currents.

   Referring to the absence of information on population structure, a participant asked if there is a management structure that could be used for hagfish that would be robust to these uncertainties. No response was given to this question.

2) Distribution and movements.

   It was noted that if the catchability of hagfish to survey trawls is constant, then survey data could be used to describe their distribution. Available evidence suggests very little movement of hagfish between adjacent areas.

   a) Spawning, early life history, juveniles, and adults (males versus females):
      The Chair asked what is known about spawning, early life history, and juvenile stages of hagfish. The response given was that virtually nothing is known about these issues (only 3 fertilized eggs have ever been observed).

   b) Habitat:
      It was suggested that the fertilized eggs may be stored in their burrows (anoxic) and that they may be oxygenated by some activity of the adult hagfish that laid them.

3) Production.

   a) Recruitment:
      The Chair stated that if hagfish are only reproducing every second, third, or fourth year, then this will have major implications for their intrinsic growth rate.
   b) Growth (sexual dimorphism):
      The Chair stated that a metric is needed for describing the growth rate of hagfish. It was also reiterated that a standardized protocol for measuring them is required.
   c) Carrying capacity:
      The Chair suggested that if hagfish use their gonads as an energy store and reabsorb them during times of stress, then this will have implications on their carrying capacity.

G. Black, a hagfish processor from southwestern Nova Scotia, indicated that over the course of a year, he sees hagfish eggs mature from ‘rice grain sizes’ in the spring to ‘jellybean sizes’ in the fall.

A hagfish harvester stated that he tends to have his best catches at a site, when he visits it for the second time. He also reported that he has fished in areas where he had excellent catch rates for several consecutive years and then gone back to the same site and was unable to catch a single hagfish for two years, which led him to speculate that hagfish may have a two-year spawning cycle.

Black stated that fishermen from his area voluntarily exercise ‘self regulation’ of their fishing practices in order to maintain 17-19" sizes in their catches. He stressed that this behaviour must be considered when comparing/evaluating their catch rates. Black was asked if he monitors the size composition of hagfish that he processes. He responded that they (voluntarily) measure the sizes of 2-3 samples of hagfish per day during production. He also mentioned that he feels that the average size of hagfish processed in his plant has decreased by 2-2.5 cm since he began processing them.

4) Mortality.

   a) Predators:
   Atlantic hagfish have few known predators. Available evidence suggests that cod, white hake, and halibut may prey on small hagfish. It was also suggested that harbour porpoise and bluefin tuna may prey on hagfish, but doubts were expressed by some participants about bluefin tuna (they contended that the alleged hagfish from the stomach of a bluefin tuna were incorrectly identified (deep-water eels?)). An Industry representative suggested that snow crab may also prey on hagfish, noting that snow crab have been caught in traps baited with hagfish in Northwest Atlantic Fisheries Organization (NAFO) Division 4Vn.

   b) Prey:
   Atlantic hagfish prey on a variety of benthic marine invertebrates including shrimp, polychaetes, and nemerteans.

5) Role in the ecosystem.

   Hagfish may play a significant role in the ecosystem by preying on soft-bodied invertebrates and turning over the sediments, but not much is known about them. It was also suggested that hagfish may have an important role in coupling the benthic and pelagic ecosystems.

It was agreed that Frederic Martini, Scott Grant, and Bruce Hatcher would meet to develop a conceptual biological model of hagfish for presentation on the second day.

Global Overview of Hagfish Fisheries and Resource Assessment
F. Martini

Presentation Highlights

Hagfish leather, sold as ‘eelskin’ or ‘Conger eelskin’, is a major export from China and Korea. The skin, which is loosely attached along the dorsal midline and firmly attached ventrolaterally, can be removed easily and the carcass then used for human consumption or as pet food. The skins are scraped, degreased, dried, stretched, and glued to a cloth backing to form a durable, flexible strip that can be sown to form large sheets. These sheets are used to make a variety of consumer goods, including slippers, wallets, purses, briefcases, portfolios, glasses cases, etc. The meat is consumed primarily by residents of Korea and Japan or by Korean and Japanese immigrants in other countries. Prices in Korea have risen to $40/kg over the last few years, as rumors have spread regarding the aphrodisiacal powers of hagfish meat.

The commercial fishery in Asia began in the 1980s, with Korean boats targeting local species. As these species were depleted, the fishery moved to Japan, and, by 1987, there were attempts to locate hagfish resources off the west coast of the USA and Canada.

The California fishery for *Eptatretus stoutii* and *E. deani* started in 1987 as a day-boat, coastal fishery involving 81 vessels from 14 ports. Plastic, conical 'Korean traps' were used initially but as effort intensified, the fleet went to 5 gallon tubs, and then to 50 gallon drums. There were problems with skin quality and this, combined with other economic factors, led to the decline of the fishery in 1993. The Oregon fishery started in 1988 and peaked in 1992; Washington landings started and peaked in 1990. These fisheries then declined precipitously for the same reasons that depressed the California fishery. As interest in hagfish meat, rather than leather, increased, landings began rising in Oregon in 2002 and in California in 2005; the fishery has not restarted in Washington. The BC fishery was small and experimental, operating only from 1988-1992 and 2000-2001; there are currently no plans to revive that fishery. All of the west coast fisheries have long had permit systems in place and have monitored landings and mandated catch methods to limit effort and reduce juvenile mortality.

The Northeast US fishery for *Myxine glutinosa* started in 1993, peaked in 2000, and declined sharply thereafter, with landings currently at or below the levels of the west coast fishery. Until 2007, no regulatory steps were taken to limit effort, limit discards and juvenile mortality, or monitor landings; as of 2007, processors must report landings.

The general trends for commercial hagfish fisheries in all locations can be summarized as: (1) vessels gradually move farther offshore; (2) catch per unit effort (CPUE) decreases; (3) voyages are extended; (4) larger vessels, some with freezing capabilities, replace the small day-boat fleet; (5) the number of vessels engaged in the fishery decreases; (6) the total catch decreases, sometimes precipitously; and (7) the average length of the animals collected decreases.

Given the history of the fishery and the life history and ecology of hagfish, the following recommendations are made, with respect to fisheries development for hagfish in general: (1) fund basic research on the species in areas outside of the regions targeted by the fishery; (2) issue permits, limit entry, and mandate gear type, size, and numbers of traps deployed; (3) monitor the catch (landings and size/sex distribution), discards, and CPUE closely; (4) watch for regional trends in fishing effort and capitalization; (5) reduce wastage and juvenile mortality by the use of gear that is size-selective; and (6) do not permit fishing methods that disrupt the physical environment. The DFO in Canada should be commended for taking many of these steps before opening the resource to exploitation.

Discussion

A participant questioned whether a sustainable fishery is possible in Canada. Martini replied that a sustainable fishery is still possible in Canada; examples provided of what not to do were from other jurisdictions, notably the USA. In general, hagfish fisheries appear difficult to sustain. There is an artesanal fishery in Japan which sustains itself, because harvesters only fish in the bay near where they live using small boats and do so sporadically, allowing recovery. In theory, larger boats could also fish in a manner that is biologically sustainable, given the right set of circumstances (resource size and distribution, effort regulation, market conditions). In Atlantic Canada, we might best aim for a flexible, supplemental type of fishery.

Fisheries and Resource Assessment for Atlantic Hagfish in the Maritimes
S. Rowe, P. Comeau, C. Jones, P. Hurley, and S. Coffen-Smout

Presentation Highlights

Atlantic hagfish (*Myxine glutinosa*) is widely distributed along both coasts of the North Atlantic. There has been a directed fishery for hagfish off Nova Scotia since the late 1980s. At present, there are 7 fishers authorized to harvest hagfish in the Scotia-Fundy portion of Nova Scotia. Of these fishers, 2 were granted permanent commercial access in 1997, 4 remain at the exploratory stage, and the remaining 1 received experimental access in 2005. The hagfish fishery is primarily an emerging fishery in the Maritimes Region and, like many emerging fisheries, there is little biological information to assess fishery sustainability. Landings increased to a peak of approximately 1800 t in 2004, and declined steadily to approximately 1300 t in 2006. During the early years of the fishery, landings were derived almost exclusively from NAFO Division 4X. Since 2000, the fishery has expanded eastward and NAFO Division 4W has also become an important source of hagfish landings. Small-scale surveys were conducted during 2005 and 2006 in portions of NAFO divisions 4VsW with the following objectives: (1) determine hagfish distribution and relative abundance; (2) record bycatch; and (3) gather hagfish life history information. Surveys were a collaborative effort involving Louisbourg Fisheries Ltd., Cape Breton University, and Fisheries and Oceans Canada.

Discussion

Industry members noted that catch levels described for the period prior to 2001 appeared to be less than the actual landings, which might relate to the lack of dockside monitoring at that time. G. Black indicated that his records may help resolve landings information from those years. In addition, industry members indicated that years with low catch levels were a result of periods of low market demand, not resource availability.

There was some discussion about the origins of the gear currently used in this fishery. Industry indicated that there was some experimentation with different gear types in the early years of the fishery, and the gear currently being used (e.g., 9/16” diameter escape holes) is a product of this experimentation.

Exploratory Fisheries and Resource Assessment of Atlantic Hagfish (*Myxine glutinosa*) in the Newfoundland and Labrador Region
S. Grant, W. Hiscock, and G. Bishop

Presentation Highlights

Interest in the Atlantic hagfish resource in the Newfoundland and Labrador Region began with exploratory fishing in NAFO Division 3Pn, which has occurred off and on since 1996, with renewed interest in the past 3 years. Recent findings in Div. 3Pn confirm the predominance of small (<80 g) hagfish in catches with small (20 L) and large (227 L) traps. In 2002, an exploratory survey and biological resource assessment of hagfish on the southwest slope of the Grand Bank (NAFO Division 3O) demonstrated the presence of large market-sized (>80 g) hagfish, predominance (100%) of females in the catches, low fecundity (11-38 eggs), size at first (354 mm), 50% (378 mm), and 100% (440 mm) sexual maturity in females, and established a trap type (i.e., 227 L barrel trap with 14.3 mm escape holes) that reduced the capture of nonmarket-sized hagfish. Absence of Atlantic hagfish in an exploratory survey on the northern Grand Bank (NAFO Division 3L) during the summer of 2006 was attributed to cold bottom temperatures (0.1-1.9 ºC). Five year exploratory fisheries were established on the southwest slope of the Grand Bank (Div. 3O) and St. Pierre Bank (NAFO Division 3Ps) in 2004 and 2005, respectively. The study area in Div. 3O encompasses ten 10' × 10' (longitude × latitude) blocks while the Div. 3Ps study area encompasses six 10' × 10' and a single 10' × 4' block. Traditional ecological knowledge (i.e., hagfish predation in the monkfish gillnet fishery) resulted in each block being centred on the 183 m (100 fathom) depth contour with peripheral block depths ranging 90-600 m in Div. 3Ps and 90-1400 m in Div. 3O. Annual provisional fishery allocations of 181,440 kg were provided to each study area to monitor the influence of the fishery on the resource. Each allocation is harvested from September to December by a single enterprise and all hagfish are frozen at-sea. Regulations in the provisional fishery include 100% observer coverage, maximum number (200) of traps fished in a 24 hour cycle, type of trap used (227 L barrel; 40% of traps with 14.3 mm and 60% with 15.1 mm escape holes), minimum spacing between traps (55 m), minimum size (>60 g) of hagfish retained, and no bulk removals (<45,360 kg) from any single block. Pre-fishery research surveys are conducted annually (September) to assess distribution, relative abundance, size (length and weight), and selectivity of hagfish captured in baited traps with 14.3 mm, 15.1 mm, and 3.2 mm escape holes, as well as provide hagfish for detailed biological analysis of key reproductive features for establishing sex and the nature of the reproductive cycle and spawning season. Recently (2007), preliminary hagfish discard survival studies were initiated.

On the southwest slope of the Grand and St. Pierre banks, hagfish are not captured in shallow sub-zero waters and appear to concentrate (greatest catches) within the warmest (5.8-9.0 ºC) available bottom waters, which occur within depths of 125-300 m. Research survey data indicate a decrease in mean CPUE with an increase in depth to 1300 m. In Div. 3O, analysis of the effect of year (2004-2007) on mean CPUE in the annual research survey indicates significant decreases in mean CPUE within the depth interval (101-200 m) of intensive fishing pressure (80-100% of annual landings) at both the broad geographic scale of the entire study area and relatively limited geographic scale of a 10' × 10' survey block. Significant decreases in length and weight of hagfish were also detected over time in a region of intensive fishing pressure in Div. 3O. In Div. 3Ps, the fishing effort is spread out over a greater depth range with 60%, 30%, and 10% of the annual landings coming from the 101-200, 201-300, and 301-400 m depth intervals. Analysis of the effect of year (2005-2007) on mean CPUE in the annual research survey indicates a significant decrease in CPUE in the 15.1 mm trap in the greatest depth interval (301-400 m) at the broad geographic scale of the entire study area and significant decreases and persistently low mean CPUE in the 15.1 mm trap within depth intervals of intensive fishing pressure (101-300 m) at the relatively limited geographic scale of a 10' × 10' survey block. Total landings over the provisional fishery are in the order of 565 mt for Div. 3O (2004-2007) and 517 mt for Div. 3Ps (2005-2007). Over the duration of the provisional fishery, the mean landed CPUE among blocks has ranged from 0.5 to 2.1 kg/trap/hour in Div. 3O and from 1.1 to 2.5 kg/trap/hour in Div. 3Ps in mostly overnight sets (20.1-24.5 hour mean soak time). There is very little bycatch in the provisional commercial fishery. A single sea lamprey (*Petromyzon marinus*) and 2 slatjaw cutthroat eels (*Synaphobranchus kaupi*) have been reported from Div. 3Ps and the snubnose eel (*Simenchelys parasiticus*) has been reported from Div. 3O when traps were deployed at depths of 400 m or more. Level of sea lice (amphipod) predation upon hagfish in baited traps appears to be related to habitat with increased occurrence and prevalence in relatively cold shallow waters in proximity to sand substrate.

Analysis of 2007 research survey catch data indicated that the 15.1 mm trap captured significantly fewer (18-19%, divs. 3O and 3Ps, respectively) undersized (<80 g) hagfish than the

14.3 mm trap (30-39%, 3O and 3Ps, respectively). Preliminary discard experiments, which consisted of evenly distributing 60 recently captured hagfish between three 227 L barrels with 3.2 mm drainage holes and lowering them to the ocean floor for 3-5 days, revealed a mean range in mortality of 1.8-25% among 4 experiments in Div. 3Ps and 100% in a single experiment in Div. 3O. However, in Div. 3Ps, the barrels were lowered through a 40-50 m subzero cold intermediate layer that hagfish are unlikely to penetrate given their low tolerance to changes in temperature.

In 2006 and 2007, detailed biological analyses were conducted on hagfish collected from 3 separate depth intervals in each of divs. 3O and 3Ps. Data collected included: total length, wet body weight, gutted wet body weight, liver weight, sex, presence/absence of brown bodies in the mesovarium, number and size (maximum length and width) of developing eggs, number and size of arrested eggs, presence/absence and size of recently ovulated follicles (a.k.a., corpus lutea) and older ovulatory follicles, and presence/absence of ‘tufted’ eggs, presence/absence of ovulated eggs, presence/absence of eggs entangled in mesentery.

Discussion

Several participants noted differences in gear configuration and fishing practices between Newfoundland and Nova Scotia, and suggested that it would be useful to document these and to attempt to understand the rationale behind them. It was agreed that C. Jones would work with members of Industry and Fisheries and Aquaculture Management in the 2 regions to prepare an overview of regulations and fishing practices for presentation on the second day.

Some discussion focused on the survival of small discards. Grant indicated that if discarded at sea where sea surface temperatures were approximately 7-9 ºC, hagfish seemed to swim downwards after an initial period of disoriented swimming at or near the surface and, provided they were not preyed upon by seabirds, some may have made it back to the bottom. In addition, it seemed that the longer the soak time (12-32 hours), the fewer small hagfish there would be to sort, while still protecting the catch quality from suffering. An Industry participant from Newfoundland noted that while it may be beneficial to sort hagfish at sea and return small individuals to the water, motion of the vessel makes this very difficult to accomplish. Furthermore, sorting onshore results in better separation of the larger (>80 g) hagfish for packing for market. It was indicated that the best escape hole size to use to minimize retention of hagfish <80 g (<41 cm in length) was 19/32”.

There were a number of questions surrounding the rationale behind the initial Total Allowable Catch (TAC). Grant indicated that it was established through consultation with Industry who felt that it was a reasonable amount to store and market. Initial indications suggest that this initial TAC may be too high. An Industry member from Newfoundland indicated that of the amount landed, approximately 10-15% is comprised of slime and water.

The Hagfish Fishery in the Maritimes – An Industry Perspective

G. Black

Presentation Highlights

G. Black of Sable Fish Packers (1988) Limited made a presentation on behalf of the Nova Scotia Hagfish Association on developing and managing a sustainable fishery for hagfish. Sable Fish Packers (1988) Limited, located on Cape Sable Island, pioneered the development of the Nova Scotia hagfish fishery in the late 1980s, working closely with DFO, local harvesters, and prospective clients. Research by Sable Fish Packers (1988) Limited during the late 1980s and early 1990s into the harvesting, marketing, and biology of hagfish suggested that a new experimental fishery for this underutilized species could provide a much needed economic boost to the region during a time of decline in groundfish stocks and fisheries. In order to establish this new fishery, in 1989, Sable Fish Packers and a few enterprising fishermen, in conjunction with government, began the long process of building a market, as well as experimenting with gear and the procedures involved in processing the hagfish. During 1989-2007, Sable Fish Packers (1988) Limited reported landings ranging from 15,869 lbs in 1993 to 3,405,105 lbs in 2004, with values of $7,141 and $1,835,833, respectively. During 1989-2000, hagfish were exported from Canada for the tanning industry. where skins were made into an assortment of leather products. Since 2000, hagfish have been exported for a meat market, as well as tanning. In terms of economic impact, approximately 100 families (through 76 employees and 30 fishermen) in southwest Nova Scotia have depended on the hagfish fishery during the past 3 years, and there are numerous other indirect benefits. The following conclusions were presented:

1) Hagfish is an important species to Industry stakeholders in southwest Nova Scotia.
2) A conservation management plan for hagfish is crucial for sustainability of the stock and associated industry.
3) The formation of an advisory and management board is needed.

Discussion

One participant asked whether there was any direction of where vessels would fish and Black indicated that vessels were not directed, but harvesters know that they must fish areas where they can return with catches of 5,000-10,000 lbs/day to make it profitable. Another participant asked how much of the catch was below market size (18”) and it was indicated that approximately 10-15% fell into this category.

Additional information provided by Black included the following:

1) Sable Fish Packers is supplied by approximately 5 licence holders in southwest Nova Scotia.
2) Harvesters fish only March to October.
3) Data collected by Sable Fish Packers (1988) Limited on the length of hagfish landed suggests that, on average, hagfish are about 1” smaller now than they were earlier in the fishery (approximately 10 years ago).
4) Freezing at -30 ºC is required to provide storage life of 2-3 years to the product.
5) It is the opinion of the Nova Scotia Hagfish Association that there be no increased effort in hagfish (i.e., licenses) until such time that scientific data is available to support such an increase.

Science for Sustainable Management of Hagfish Resource on the Northeastern Scotian Shelf
A. Mugridge, M. Jones, and B. Hatcher

Presentation Highlights

Researchers at Cape Breton University have formed a partnership in research with Louisbourg Seafoods Ltd. to explore the potential for ecologically sustainable exploitation of the Atlantic hagfish by the people of Cape Breton. With funding from the Company and the Canadian Centre for Fisheries Innovation, 3 research projects have been completed between 2005 and 2007. In 2006, a total of 16 days of experimental fishing were conducted at 72 independent locations on the Eastern Scotian Shelf. These ecologically defined areas were sampled with modified commercial gear systematically at specific sites in 4' x 4' grid cells (n=72 trap line sets of 15-48 hour duration, with 9 baited traps per line for a total sampling effort of 648 pot hauls in 2006).

Total catch and catch per unit effort (CPUE) was determined for all hauls, providing a spatial mosaic of relative abundance that is compared with attributes of the benthic habitats in the various ecosystems. Size (total length) frequency distributions (n=3000) were determined from sub-sampled catch in pots having 1 of 5 different sizes of escape hole to determine size-selectivity of the gear and mean size at first capture. Further sub-samples of catch across the entire size range (n=500) were weighed to determine size-mass relationships and dissected for determination of gender, sexual maturity, and fecundity. Resulting estimates of mean size at first maturity were compared to size at first capture in order to predict the effect of the gear on reproductive production. The methods and results were compared with those from parallel studies in Newfoundland and causes for discrepancies identified.

This successful research collaboration has helped position the Company for transition to a commercial license, contributed significant new knowledge of the species and its response to fishing mortality, and built capacity for research and science-based decision making in both the University and Corporate partners. Most importantly, the results will inform future management decisions based on the compatibility of economic and ecologically sustainable development of a hagfishery offshore of Cape Breton.

Discussion

Some participants noted a large difference in female size at maturity between Newfoundland and Nova Scotia and questioned whether this might be a result of differences in methodology. It was suggested that attempts be made to standardize sampling procedures across Atlantic Canada and that histological examination of the reproductive organs be included in future research. Increased collaboration among research groups would prevent unnecessary duplication of research and minimize costs.

Fishery Sustainability and Ecosystem Considerations
T. Worcester

Presentation Highlights

A presentation on an Ecosystem Approach to Fisheries Management (EAFM) in the Maritimes Region was presented by T. Worcester (based on a presentation provided by Stratis Gavaris). EAFM attempts to manage human activities in a way that controls our impacts on the ecosystem and enables us to respond to ecosystem influences on these activities. There are several important reasons to approach EAFM in a structured way. Firstly, we must manage impacts of human activities on *all* ecosystem components, not just on the harvested resources. Secondly, we need to be able to integrate cumulative effects across *all* human activities, i.e., we cannot ignore impacts from one sector while trying to manage similar or related impacts from another sector. EAFM is not new or revolutionary – it is the progressive evolution of good fisheries management practice to address emerging conservation concerns. Traditionally, fisheries have been managed to maintain productivity of the harvested resource, focusing largely on controlling exploitation and defining management units that reflected stock structure. Under EAFM, this scope is broadened to include consideration of the role of the harvested species in the food web, the potential for incidental bycatch of other species, and the potential for other impacts to the environment/habitat. Key issues that are currently being addressed through EAFM within the Maritimes Region include the management of discards and incidental mortality, as well as disturbance of benthic habitat.

Discussion

A participant inquired whether the framework was being used beyond the Maritimes Region. Worcester indicated that the conceptual objectives were national in scope.

Science and Management Strategies for Emerging Fisheries
R. Claytor

Presentation Highlights

A presentation on DFO Maritimes regional draft approach to dealing with science and management strategies for new fisheries was presented.

For this presentation, new fisheries were defined as:

1) "Fisheries involving new species and/or stocks that are not utilized or not fully utilized, and not currently covered by a management plan".
2) Fisheries that extend into previously unfished areas or unassessed areas may be considered as new fisheries.

New fisheries are characterized by having sparse information for decisions. A draft protocol for new fisheries science and management has been developed by a joint effort of DFO Oceans and Habitat, Fisheries and Aquaculture Management, and Science branches. It includes a new emphasis on ecosystem effects, indicates where documentation and review are required, and defines the broad strategies associated with each stage.

The draft protocol is outlined below:

1) Stage I: Screening (1-3 months), fishery potential, and red flags (≤2 seasons).
    a) Goal: Determine if economic catch rates are possible and to identify ecological impacts.
    b) How:
        i) On-board monitoring of catch and effort by position, bycatch, and gear description.
        ii) Experimental licenses, no retention.
        iii) Phase should be short.
    c) Basis for decision: Catch rate or levels indicate money can be made, no ecosystem red flags, information documented and reviewed.

2) Stage II: Evaluate move to a commercial fishery (multi-year).
    a) Goal: Determine if a long-term sustainable fishery strategy is possible.
    b) How:
        i) Biology, geographic distribution, and gear impacts.
        ii) Conduct mitigation experiments if necessary.
        iii) Explore management strategies .
        iv) Define well-managed stock.
    c) Basis for decision:
        i) Well managed stock with objectives can be defined.
        ii) Framework assessment undertaken prior to Stage III commencing.

3) Stage III: Full fishery (continuing).
   a) Goal: Implement chosen regulations consistent with long-term sustainable management strategy and objectives.
   b) How:
      i) Usual stock assessment and management protocols.
      ii) Increase information base from previous phases.
      iii) Plan and fine tune to changing stock and fishing effort.
   c) Basis for decision:
      i) Assessments with frequency outlined in framework.

It was emphasized that the protocol is a living process and is undergoing development. The major issues to be addressed are:

1) Improving evaluation of ecosystem effects.
2) Evolution of clarification of the differences between Stage I and II.
3) Building the framework – Stage II.
4) Cost.
5) Use of fish.

The DFO Emerging Fisheries Working Group can form the basis for addressing these issues and implementing the policy.

Discussion

Following the presentation, there was a question regarding what might be the expected duration of Stage II. Claytor indicated that there is no set time, but rather it depends upon how much is known at the onset of the fishery – 5 years might be anticipated on average. The key is to determine the science requirements at the onset of Stage II and devise a plan to achieve them. Industry members noted that some harvesters have been in the fishery for 14 years or more but do not have commercial licences. Industry members expressed the opinion that these exploratory licences should be made commercial. In response, it was highlighted by science participants that there are still questions about sustainability of this fishery. For instance, examination of landings data shows peaks and valleys over time that are not understood. One Industry member indicated that this strictly relates to market conditions, not resource availability. That being said, there has been an apparent shift in fishing locations on the Scotian Shelf over time which may be indicative of local depletion and decreasing catch rates. Industry may have data that would help resolve this issue. Lack of planning at the onset of this fishery is largely to blame for the small amount of progress to date.

Some participants questioned what was wrong with the old model, i.e., why do we require this new approach for addressing new fisheries? Claytor stated that there was lack of consistency in approach in the past, plus added ecosystem issues at present. Some participants also questioned whether the new model is realistic, particularly given the availability of resources within DFO Science. Claytor replied that the model is realistic, but DFO should not be expected to do the work alone – strong partnerships with Industry will be vital, and collaborative opportunities with university-based researchers should be explored. It is expected that Industry will bear much of the cost in new fisheries and some Industry participants questioned whether the new approach might be too demanding, e.g., how can Industry commit to a 5-year research plan without knowing whether they will have access to the resource at the end? Furthermore, this approach would appear to exclude those Industry members without access to large financial resources. It was noted that information requirements will need to match the management strategy and that quota-based fisheries have different research and monitoring demands than those based on effort controls.

Science and Management Strategies – Surf Clam Example
D. Roddick

Presentation Highlights

A presentation was made on the offshore clam surveys as an example of a survey based assessment with no fishing history. During the clam surveys, at each tow, data is collected on the numbers and weight of clams caught, length frequencies of the clams and detailed information on the bycatch. Length stratified samples for morphometrics and ageing are retained from each tow for later analysis. During the survey, additional studies are carried out, small clams are collected to determine the size and age at maturity, and tows are conducted to examine the selectivity and efficiency of the survey dredge. Once the samples from the survey are aged, growth curves are constructed, and an age-length key built to convert the population numbers at size from the survey estimates to numbers at age. From these data, the mortality rate is estimated, and an estimate of variations in recruitment is obtained. Once all the survey data are analysed, we have estimates of biomass, growth, productivity, mortality, and size/age of maturity, as well as estimates of gear selectivity and efficiency. With these data, models such as Yield Per Recruit and Maximum Constant Yield can be used to estimate TAC levels.

The key differences between clams and hagfish are that we have a validated method to age clam species and that clams are sedentary. A method of ageing hagfish would provide a great deal of necessary information about the species, such as growth and mortality rates.

Discussion

Following the presentation, there was some discussion about the utility of undertaking a depletion study to estimate gear efficiency or catchability of hagfish. In addition, it was suggested that experiments be undertaken to examine selectivity of commercial traps with respect to both size and sex.

There was also a question as to whether the expense of the survey and associated research was commensurate with the value of the fishery. Roddick noted that the approximate cost of the survey was $750,000, plus the salary for technicians. Survey costs are covered by Industry at present. The commercial fishery has been ongoing since 1986, and there are 2 license holders.

Science and Management Strategies – Monkfish Example
D. Beanlands

Presentation Highlights

Monkfish were historically taken as bycatch of groundfishing and scallop ventures. There were no markets specific to monkfish, so they were typically divided up as crew share and sold for tails. In the early 1990s, the development of Asian markets for whole fish and livers were changing the pattern of fishing from a bycatch to a directed fishery. Catches by the mobile gear fleet <65’ went from 100 t in 1989 to well over 600 t by 1994. In order to control the development of this fishery, licence conditions in 1995 limited this fleet to a 20% bycatch until other management options were explored.

Developing a rational plan for the exploitation of monkfish required understanding monkfish population biology (including age, growth, maturity, reproduction, distribution, and mortality). The decision was made to allow the mobile gear fleet <65' to submit conservation harvesting proposals for a 5-year cooperative Science/Industry study that would run from 1995 to 1999. Five vessels were chosen based on criteria established by DFO, and 200 t of quota were allocated to these vessels. As part of the study, participants were required to conduct a survey in each year. In 2000, DFO conducted a stock assessment that incorporated the data collected and provided information to managers on the viability of a directed monkfish fishery.

The survey indicated high abundance levels but low biomass, and there were concerns over the loss of large fish over 60 cm. Effort levels declined in the directed fishery, and the 200 t quota was only taken in the last year when low market values rebounded slightly. These results, coupled with concerns regarding over exploitation in the few areas being targeted, led managers to not support a continuing directed fishery. In 2000, monkfish reverted to a bycatch fishery.

Discussion

It was noted that monkfish is a good example of how a plan might be developed and implemented to assess the feasibility of a new fishery. In this particular example, it was decided that a directed fishery could not be supported and at the end of the research program, Industry supported the decision to return to a bycatch fishery.

SCIENCE AND MANAGEMENT STRATEGIES

The afternoon started with a presentation by C. Jones of the comparison made of regulations and fishing practices between DFO's Maritimes and Newfoundland and Labrador regions.

Comparison of Regulations

	Maritimes Region	**Newfoundland and Labrador Region**
Type of licence	Experimental, Exploratory, and Commercial	Exploratory
Dockside monitoring	20% for Exploratory and Commercial, 100% for Experimental licence	100%
Hail in/out	100%	100%
Observer coverage	None although biologist on board for all trips made by Experimental licence holder	100% + biologist during surveys
VMS	Only required for Experimental licence	Required
Fishing seasons	No (1 Apr – 31 Mar) except for Experimental licence	Yes
Quotas	No	Yes

Fishing zones	Areas of operation within designated NAFO units are not specified for Exploratory and Commercial, areas of operation within designated NAFO units are specified for Experimental licences	Areas of operation within designated NAFO units are specified
Limited access	7 licences, <45' wet fish vessels	2 licences, 65' freezer vessels
Trap limit	500 (200 for Experimental licence)	200
Number of entrance cones	4	4
Number of escape holes	≥24 (~100 used by Experimental licence)	115
Escape hole diameter	≥9/16" (Experimental licence has experimented with 17/32-5/8")	40% 9/16", 60% 19/32"
Minimum fish size	No	<60 g, limited to 5% of total catch

Comparison of Fishing Practices

	Maritimes Region	**Newfoundland and Labrador Region**
Soak time	12 hours during night	12 hours during night
Traps/string	8-10 for 42' vessel, 20-25 for 45' vessel	30
Distance between traps	50 fathoms	30 m
Traps/vessel	Up to 180	Up to 150
Bait	3-8 lbs herring or mackerel/trap	5-7 lbs mackerel/trap for 9/16" holed traps, 7-10 lbs for 19/32" holed traps
Average catch rate	30-40 kg/trap	19/32" holed traps: 30 kg/trap of large fish; 9/16" holed traps: 40-80 kg/trap of small fish
Average set depth	100 fathoms	70-150 fathoms
Use of thermometers	No	Yes – low catch rates <6 ºC, catch rates improve dramatically at 8.5 ºC
Distance from port	4-12 hours	30 hours
Type of vessel	42-45', 17-24' wide open decked vessels	65' enclosed deck freezer vessel, 8-10 crew members
Sorting at sea	Preliminary sorting at sea	Sorted on board, small fish returned

Storage at sea	Stored on board via barrelled ice at 3-5 ºC or held in grey boxes of slush ice at 1 ºC	Frozen live via plate and blast freezer
Land-based processing	Final sort by size in plant, plate frozen, exported via freezer container	Exported direct via freezer container (frozen at sea)
Market	Predominantly leather market and meat	Predominantly food market and leather
Trap type	Multi-coloured 55 gallon barrels with galvanized clamps and screw on caps	Multi-coloured 55 gallon barrels with threaded lids
Mechanism to secure cones in barrel	Biodegradable rubber shock cords	Biodegradable line
Escape hole configuration	24 9/16" holes/barrel	110 escape holes/barrel (required on upper side)
Discards	10-15% in plant (used for fish meal)	3-10% at sea (returned), large percentages may occur due to plugged holes
Fishing patterns	Shift location based on catch rates, market demand, and size ratios	Shift location based on catch rates which appear influenced by water temperature (e.g., Trip 1: 6 ºC, 25 mile range over 10 days, 33,000 kg; Trip 2: 7.4 ºC, 11 mile range over 12 days, 48,000 kg)
Gear storage during inclement weather	Gear left in water unbaited	Gear stored on board

Numerous differences in regulations and fishing practices were reported between DFO's Maritimes and Newfoundland and Labrador regions. During the discussion, it was noted that using mackerel as bait tends to reduce CPUE, and leaves a flavour on the meat. It was also indicated that within the Maritimes Region, all hagfish licences but one are attached to groundfish licences.

The next presentation was of the conceptual biological model of hagfish developed by F. Martini, S. Grant, and B. Hatcher during the previous day.

Conceptual Models for Hagfish Science and Management

Acknowledging the limitations of models in fisheries, we attempt to summarize the collective knowledge and assumptions of workshop participants in the contexts of life history, population, and ecosystem models. Ignorance dominates the early life history model, but sound assumptions are available. Egg development time exceeds 1 year; demersal eggs are deposited in the sediment; an undescribed juvenile appears to live a cryptic, non-dispersive stage for <5 years. Sub-adults (≥100 mm) behave as adults and grow slowly (<2 cm/year) to sexual maturity at approximately 40 cm in total length (depending on nutrition and environment). Longevity may approximate 20 years post hatching. Hagfish are susceptible to predation by many large species. Natural mortality was probably much higher prior to industrial fishing than at present. Nutrition is by opportunistic feeding, the majority of which is predation on epibenthic macrofauna and macroscopic infauna and the minority on carrion. Food appears to be limiting to a variable proportion of individuals, depending on food availability within their ambit. Stenohaline and stenothermal physiology defines the primary habitat constraints within which opportunistic use of a wide range of benthic habitats occurs. Sediments that provide infauna hunting grounds, shelter from predators, and structures for spawning appear to be secondary habitat determinants. In their preferred habitat (mud with prey), given no significant disturbance, hagfish are essentially sessile infauna at the spatial scales of fishing gear and the temporal scales of fishing excursions. Given strong stimulus, they are capable of moderately well directed swimming in the far field (≥2 km) and less well in a saturated near field. Fecundity is extremely low and largely independent of body size. Maturation of the clutch takes >1 year and may be punctuated by 'resting' periods (depending on nutritional status). Fertilization success and survival of fertilized eggs is unmeasured but apparently adequate to maintain populations over time. Females outnumber males in all populations. The closest analog for this species in terms of assumptions for management is an infaunal elasmobranch (i.e., a definned shark).

These life history attributes inform population parameters. Unexploited populations appear to be equilibrial. Resource competition may occur; interference competition does not. Low rates of natural mortality, indeterminate growth plus longevity mean that estimates of Z cannot be derived from size-frequency analysis. The life span is long relative to the typical duration of commercial fisheries. Because this generalist is highly plastic in many aspects of its life history strategies, standard population model assumptions will be violated. Existing knowledge and methodologies preclude application of a 'standard' population model to fisheries management. Spatially explicit habitat, community, and trophodynamic models may have a greater probability of defined indicators, reference points, and targets for ecologically sustainable management of a fishery (e.g., maintenance of site-specific CPUE).

The food web supporting hagfish is entirely dependent on allochthonous inputs of organic material. In the absence of reasonable expectation of suitable population models, adaptive, ecosystem-based management models should be trialed. An important target of management using such models should be the maintenance of hagfish-mediated benthic-pelagic coupling. Research and management efforts must recognize that trawl surveys provide incontrovertible evidence of hagfish presence but not abundance, knowledge of fine scale movement and site fidelity is essential for area-based management, and measurement of un-fished reference sites is essential for defensible science and ecologically sustainable exploitation. Recommended methodologies include tagging and tracking studies to determine effective trap area, deLury stock depletion experiments to estimate virgin stock abundance, inter-site comparisons across a range of spatial scales to resolve environmental correlates with distribution, mapping of habitat to estimate ecosystem-scale biomass, and first-order calculation of roles played by hagfish in the structure and function of ecosystems.

Following presentation of the conceptual biological model of hagfish, there was considerable discussion regarding management and assessment measures to address concerns regarding fishery sustainability and ecosystem impacts, as well as research and monitoring that would be required to support these management and assessment strategies. Recommended hagfish science and monitoring pertaining to ecosystem objectives and strategies is summarized in Appendix 4.

RESEARCH PROGRAM NEEDS AND NEXT STEPS

In reviewing science and monitoring requirements pertaining to ecosystem objectives and strategies, three issues were deemed to be of particular importance:

1) Keep fishing mortality moderate.

   There are no mortality estimates at present and no definition of moderate fishing mortality. The hagfish fishery is primarily a developing fishery, with limits on factors such as number of licences, size and number of traps, and area fished. Existing catch and effort data should be assessed to the degree possible, depletion and/or tagging experiments undertaken, and growth rates and maturity ogives defined. Logbooks, dockside monitoring program (DMP) of landings, and at-sea observers were identified as key monitoring tools. Monitoring could be improved by modifying logbooks to record location by string, bait, soak time, gear configuration, and bottom temperature. In addition, interviews should be conducted with past and present licence holders to document changes in fishing practices over time and how these changes are perceived to have influenced catchability.

2) Distribute population component mortality as a percentage of component biomass.

   Population structure is unknown. Distribution and relative abundance of hagfish should be assessed using existing data sources such as ecosystem surveys, observer coverage, and directed fishery activities. Associations between hagfish abundance and various habitat characteristics (e.g., depth, temperature, and bottom type) should be explored. Population structure may also be elucidated through basic biological sampling across areas, genetics, and tagging. The feasibility of conducting a survey for hagfish in the vicinity of the Scotian Shelf should be examined.

3) Manage percentage of size/age/sex of capture.

   Size measurement and maturity staging protocols need to be developed, so that size/age at maturity and growth rates can be defined, as well as catch composition and appropriate escape hole size (or other trap modification) for desired selection be determined. Monitoring should include documentation of catch composition by size and sex through use of at-sea observers and port sampling technicians. Minimum capture sizes need to be established.

Time did not permit detailed discussion of timelines and costs associated with these research and monitoring priorities, nor how they might be accomplished. Further discussion of these issues will be required in the future.

CONCLUDING REMARKS

The Chair confirmed that the draft proceedings would be circulated for review and comment before being finalized. All participants were then thanked for a stimulating discussion and the meeting was adjourned.

Appendix 1. Terms of Reference

Workshop on Canadian Science and Management Strategies for Atlantic Hagfish

22 – 23 October 2007

George Needler Boardroom
Bedford Institute of Oceanography
Dartmouth, Nova Scotia, Canada

Terms of Reference

Context

Atlantic hagfish (*Myxine glutinosa*) is widely distributed along both coasts of the North Atlantic. There has been a directed fishery for hagfish off Nova Scotia since the late 1980s. At present, there are seven fishers authorized to harvest hagfish in the Scotia-Fundy portion of Nova Scotia. Of these fishers, two were granted permanent commercial access in 1997, four remain at the exploratory stage, and the remaining one received experimental access in 2005. Exploratory fishing activities have also been ongoing in the Newfoundland region since the 1990s.

While the hagfish fishery is primarily an emerging fishery in Atlantic Canada, Fisheries and Oceans Canada has recognized that a requirement exists to develop a comprehensive fisheries management plan governing activities of current and future license holders. Although there is little biological information available from the Maritimes, other regions (e.g., Newfoundland) and countries (e.g., USA, Japan) have undertaken scientific studies on this and related species (e.g., Pacific hagfish (*Eptatretus stoutii*)). In this regard, there is a need to develop an understanding of the information that exists to assist management, the approaches that could be used for management, and future information needs.

Objectives

- To develop a conceptual model, including uncertainties, on the biology of the Atlantic hagfish resource.
- To discuss fishery sustainability and ecosystem considerations.
- To discuss management approaches to the hagfish fishery and related decision support tools.
- To discuss information requirements for future management of the resource.
- To outline a research program in support of the management decision making.

Outputs

CSAS Proceedings
CSAS Research Document (if appropriate)

Participation

DFO Science representatives
Industry members knowledgeable about the fishery
Fisheries managers

Members of the university community and other non-governmental organizations

Topics for Discussion

Potential topics for discussion are outlined below by elements of the decision process. This is not an inclusive list but rather is to indicate the breadth of the expected discussion.

Population Model

The population model summarizes our understanding of the processes governing the hagfish population from the biology through to the fishery.

Regarding the population, what is known about movement and population structure? Other key issues concern production and mortality processes. What is to be learned from its growth processes? Through analogies with related species and stocks, what can be said about recruitment production? What do we know and need to know about the role of hagfish in the ecosystem?

Regarding the fishery, there is a need to understand its impacts on the ecosystem. What do we know and what research is required?

In summary, what is our understanding of the biological processes governing hagfish and what research is required?

Assessment Model

The assessment model includes both observational activities, such as the industry logbooks, and procedures used to supply indicators for management decisions.

There are a number of possible assessment models to pursue, all of which have their strengths and weaknesses – from Surplus Production, through Delay-Difference to Age/Size Models. Information requirements and thus costs vary dramatically by model. It is likely that size-based methods will be needed. What are the program requirements of the most appropriate and cost-effective assessment approach?

What other information would be beneficial for management?

Decision Support

Management decisions are linked to particular levels or directions of the indicators termed ‘reference points’ and ‘reference directions’ respectively. These decision points depend upon the objectives that one hopes to achieve. Can we state these, at least in a preliminary way? What research do we need to undertake to define appropriate reference points?

Management Measures

Management needs to regulate the fishery. How can this best be achieved - quotas, effort controls, size limits, area restrictions, etc.? What are the related monitoring requirements?

Appendix 2. List of Participants

Workshop on Canadian Science and Management Strategies for Atlantic Hagfish

22 – 23 October 2007

George Needler Boardroom
Bedford Institute of Oceanography
Dartmouth, Nova Scotia, Canada

Participant	Affiliation
Robert O'Boyle	DFO Maritimes – CSA
Valerie Bradshaw	DFO Maritimes – FAM
Ross Claytor	DFO Maritimes – PED
Jackie Kean	DFO Newfoundland – C&P
Robin Quinlan	Quinlan Brothers
Adam Mugridge	Cape Breton University
Frederic Martini	Shoals Marine Lab / UH-Manoa
Bruce Hatcher	Cape Breton University
Sean Anderson	Dalhousie University
Sherrylynn Rowe	DFO Maritimes – PED
Tonya Wimmer	WWF – Canada
Tom Hurlbut	DFO Gulf – MFD
J. Gary Black	NS Hagfish Assoc.– Sable Fish Packers
Gary Burchell	Fisher
Peter Rodger	DFO Maritimes – O&H
Peter Hurley	DFO Maritimes – PED
Cyril Boudreau	NS Fisheries & Aquaculture
Scott Coffen-Smout	DFO Maritimes – O&H
Brian Boone	NB Dept of Fisheries
Andy Chapman	CCFI
Dannie Hanson	Louisbourg Seafoods
William Hatt	Fisher
Chris Jones	DFO Maritimes – FAM
Bill Dennis	NL Dept of Fisheries & Aquaculture
Shannon McCormick	DFO Maritimes – P&E – CDD
Jason Cannon	Environment Canada
Stephen Robson	Irish Sea Fisheries Board
Peter Comeau	DFO Maritimes – PED
Ian Jonsen	DFO Maritimes – PED
Charles Theault	Les nouvelles pêcheries
Daniel Briand	IFREMER
Brian Johnson	NL Dept of Fisheries & Aquaculture
Rudolph W. Link	Fisher
Mark Showell	DFO Maritimes – PED
Dale Roddick	DFO Maritimes – PED
Diane Beanlands	DFO Maritimes – SARA
Scott Grant	Memorial University
Tana Worcester	DFO Maritimes – CSA

Appendix 3. Agenda

Workshop on Canadian Science and
Management Strategies for Atlantic Hagfish

22 – 23 October 2007

George Needler Boardroom
Bedford Institute of Oceanography
Dartmouth, Nova Scotia, Canada

Agenda

<u>22 October 2007 – Monday</u>

09:00 – 09:30	Introduction (O'Boyle)
09:30 – 10:15	Overview of Hagfish Ecology (Martini)
10:15 – 10:30	Break
10:30 – 12:00	Hagfish Ecology Discussion – *conceptual model of hagfish population*
12:00 – 13:00	Lunch
13:00 – 14:00	Global Overview of Hagfish Fisheries and Resource Assessment (Martini)
14:00 – 14:30	Fisheries and Resource Assessment for Atlantic Hagfish in the Maritimes (Rowe/Comeau/Jones/Hurley/Coffen-Smout)
14:30 – 15:00	Fisheries and Resource Assessment for Atlantic Hagfish off Newfoundland (Grant)
15:00 – 15:15	Break
15:15 – 15:30	The Hagfish Fishery in the Maritimes – An Industry Perspective (Black)
15:30 – 15:45	The Hagfish Fishery in the Maritimes – An Industry Perspective (Hatcher/Mugridge)
15:45 – 17:00	Hagfish Fisheries and Management Discussion – *current management measures and data inputs from fishery*

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09:00 – 09:30	Fishery Sustainability and Ecosystem Considerations (Worcester)
09:30 – 10:30	Fishery Sustainability and Ecosystem Considerations Discussion – *given our current understanding of the biological processes governing hagfish and of hagfish fisheries, what are our concerns surrounding hagfish sustainability and broader ecosystem impacts of the fishery?*
10:30 – 10:45	Break
10:45 – 11:10	Science and Management Strategies for Emerging Fisheries (Claytor)
11:10 – 11:35	Science and Management Strategies – Surf Clam Example (Roddick)
11:35 – 12:00	Science and Management Strategies – Monkfish Example (Beanlands)
12:00 – 13:00	Lunch
13:00 – 15:00	Science and Management Strategies for Hagfish Discussion – *what are the best management and assessment measures to address concerns regarding fishery sustainability and ecosystem impacts?* – *what research and monitoring would be required to support these management and assessment strategies?*
15:00 – 15:15	Break
15:15 – 17:00	Research Program Needs and Next Steps Discussion – *what are the priorities for research and monitoring?* – *what timelines and costs would be associated with these research and monitoring priorities?* – *how might research and monitoring be accomplished?*
17:00	Adjournment

Appendix 4. Science and Monitoring Pertaining to Ecosystem Objectives and Strategies.

Objective – Sub-objective	Operational or emerging strategy with performance indicator	Guide rule incorporating management measure, performance indicator or proxy, reference point	Operational science analysis supporting measure/decision or strategic science analysis for emerging issues or improving advice	Associated or proposed monitoring	Rationale
Productivity – Primary productivity	Limit alteration (excluding catch removals) of essential nutrient concentrations affecting primary production.	No guide rule at present.	Biological/oceanographic modeling to explore role of hagfish in benthic-pelagic coupling.		Hagfish may play role in benthic-pelagic coupling.
Productivity – Community productivity (trophic structure)	Limit trophic level removals with respect to trophic demands of higher levels.	Ensure removals do not exceed reference point (to be developed).	Examine existing diet information (e.g., DFO Maritimes Stomach Data Base) and inclusion of hagfish in Ecopath models.		Hagfish potentially consumed by monkfish, seals, harbour porpoise. Unclear whether these species are hagfish predators or prey. Inclusion of hagfish in Ecopath models may help elucidate role in ecosystem.
Productivity – Community productivity (trophic structure)	Limit total removals within system production capacity.	Ensure removals do not exceed reference point (to be developed).			
Productivity – Population productivity	Keep fishing mortality moderate.	Developing fishery. Limit number of licences, size and number of traps, area fished.	Assess CPUE trends, undertake depletion or tagging experiment, define growth rates and size/age at maturity.	Logbooks, DMP of landings, at-sea observers. Record location by string, bait, soak time, gear configuration, bottom temperature.	No mortality estimates at present, no definition of moderate fishing mortality.

Objective – Sub-objective	Operational or emerging strategy with performance indicator	Guide rule incorporating management measure, performance indicator or proxy, reference point	Operational science analysis supporting measure/decision or strategic science analysis for emerging issues or improving advice	Associated or proposed monitoring	Rationale
Productivity – Population productivity	Permit sufficient spawning biomass to evade exploitation.	Selectivity > size at maturity (to be determined).	Develop population model.	Record size and sex composition, reproductive state of population and catch.	Fishery selects gravid females. Spawning biomass could be low even when total biomass is high.
Productivity – Population productivity	Promote positive biomass change when biomass is low.	No guide rule at present. Apply additional TAC restriction so risk of not achieving positive biomass change is low.	Determine how to convert CPUE from logbooks in baited trap fishery to biomass indices.	Logbooks.	No biomass estimates at present.
Productivity – Population productivity	Manage % size/age/sex of capture.	Needs to be developed. Set minimum capture size.	Develop size measurement and maturity staging protocols, define size/age at maturity and growth rates, determine catch composition and appropriate escape hole size for desired selection.	At-sea observers, port sampling. Record catch composition.	
Productivity – Population productivity	Prevent disturbing activity in spawning areas/seasons.	No guide rule at present. Set closed areas/seasons to protect spawning.	Assess life history including location and timing of spawning.	Conduct basic biological sampling.	Location and timing of spawning unknown.

Objective – Sub-objective	Operational or emerging strategy with performance indicator	Guide rule incorporating management measure, performance indicator or proxy, reference point	Operational science analysis supporting measure/decision or strategic science analysis for emerging issues or improving advice	Associated or proposed monitoring	Rationale
Productivity – Population productivity	Manage discarded catch for all commercial species.	Needs to be developed. Minimize bycatch including hagfish discards.	Quantify bycatch of commercial species, review mitigation strategies as necessary, assess survival of discards, determine best practices for release.	Logbooks, at-sea observers. Record bycatch including hagfish discards.	Low bycatch of other species. Unknown level of hagfish discarding at sea, 10-15% by weight (small animals) discarded at plant. Survival of discards at sea unknown but potentially low.
Biodiversity – Biotope/ seascape (community diversity)	Limit % area disturbed of biotope/seascape types.	No guide rule at present. Prohibit fishing in closed areas, develop rule if closed areas inadequate to protect diversity and if traps have measurable impact.	Quantify impact of traps on different bottom habitats.	Logbooks. Record location by string, gear configuration.	
Biodiversity – Biotope/ seascape (community diversity)	Limit trophic level removals to keep trophic levels in proportion in order to conserve trophic structure.	Ensure removals do not exceed reference point (to be developed).	Determine catchability of hagfish to survey gear to estimate absolute biomass and abundance, assess trophic structure of ecosystem and changes over time, quantify impacts of fishing on trophic structure, use modeling to assess sensitivity of ecosystem to changes in trophic structure.	RV surveys, industry surveys, CPR, AZMP.	

Objective – Sub-objective	**Operational or emerging strategy with performance indicator**	**Guide rule incorporating management measure, performance indicator or proxy, reference point**	**Operational science analysis supporting measure/decision or strategic science analysis for emerging issues or improving advice**	**Associated or proposed monitoring**	**Rationale**
Biodiversity – Species diversity	Limit incidental bycatch or mortality for all non-commercial species.	Needs to be developed. Minimize bycatch.	Quantify bycatch, entanglements, temporal-spatial overlap between fishery and marine mammals and turtles. Review mitigation strategies as necessary.	Logbooks, at-sea observers. Record bycatch, entanglements, marine mammal and turtle sitings, incidence of lost gear.	Low bycatch. Potential for marine mammal and turtle entanglement but no reported incidents.
Biodiversity – Species diversity	Minimize change in distribution of invasive species.	No guide rule at present.	Quantify bycatch of invasive species. Review mitigation strategies as necessary.	Logbooks, at-sea observers. Record bycatch of invasive species.	Gear transfer among areas potentially a concern.
Biodiversity – Population diversity	Distribute population component mortality as % of component biomass.	No guide rule at present.	Document distribution and abundance, examine associations with habitat, determine population structure.	Basic biological sampling, genetics, tagging.	Population structure unknown.
Habitat – Bottom	Limit % area disturbed of habitat types.	No guide rule at present.	Quantify impact of traps, anchors, and groundlines on different bottom types.	Logbooks. Record location by string, gear configuration. In-situ observation (i.e., ROV).	Gear may get displaced in rough weather or dragged along bottom during retrieval.
Habitat – Water column	Limit amounts of contaminants, toxins, and waste introduced in habitat.	No guide rule at present.			Not applicable.
Habitat	Minimize amount of lost gear.	No guide rule at present. Minimize ghost fishing.	Determine deterioration rate of gear.	Logbooks. Record incidence of lost gear.	Low incidence of gear loss. Biodegradable trap components minimize ghost fishing.
Habitat	Control noise or light level/frequency.	No guide rule at present.			Not applicable.