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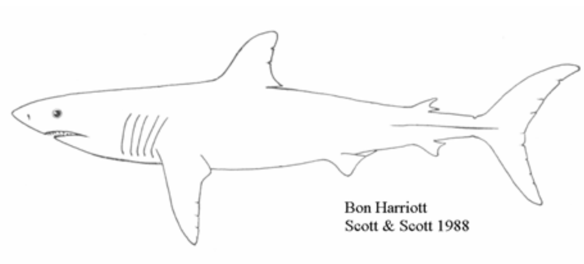
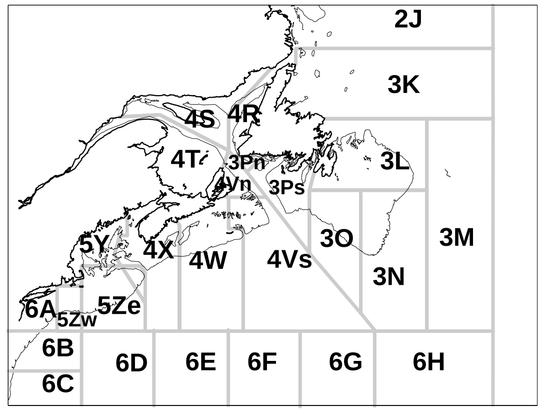
Canadian Science Advisory Secretariat
Science Advisory Report 2005/043

RECOVERY ASSESSMENT REPORT ON NAFO SUBAREAS 3 – 6 PORBEAGLE SHARK





Context

In 2004, porbeagle sharks (<u>Lamna</u> <u>nasus</u>) were designated as Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and are being considered for listing on Schedule 1 of the Species at Risk Act. This designation was based on the status of the population to 2001. At this time, the Northwest Atlantic population of porbeagle shark had been significantly affected by fishing pressure. Abundance of the population was low; it was estimated at about 4,400t which corresponded to 11% of the virgin biomass in 1961. The porbeagle population was considered to be at risk due to its low population growth rate and by exploitation. Given the low productivity of this species, it was expected to take at a minimum several decades to recover from its current low abundance level. Uncertainty was expressed by COSEWIC whether the quota reduction to 250t, implemented as a recovery action in 2002, would be sufficient to allow recovery. At that time, there was no evidence to indicate that the decline in porbeagle abundance had ceased, and the estimated population trends met the COSEWIC criterion for endangered status.

SUMMARY

- Landings in 2002-2004 have ranged from 139-229t, or about 23% the landings from 1998 to 2001, primarily due to quota reductions as part of a management plan to affect recovery.
- Status and recovery potential of porbeagle was assessed using an age- and sex-structured, forward projecting population model that used the landings, catch-per-unit-effort, the proportions-at-length in the catch and tagging data. Three variants of the model were used, each with a different assumed productivity scenario.
- The models place the 2005 female spawner abundance at about 12% to 15% of its 1961 level, and about 86% to 92% its level in 2002. Recent declines in total number from 2002 to 2004 are less, the 2004 abundance being about 99% to 103% that of 2002.
- Two recovery reference points were used in this assessment of recovery potential: the number of female spawners at maximum sustainable yield (SSN_{msy}) and 20% of number of female spawners when the population is at an unfished equilibrium ($SSN_{20\%}$).

- Estimates of the recovery reference points are highest from the model with the lowest assumed productivity, and lowest from the model with the highest assumed productivity. The estimate of the number of female spawners at 20% of the unfished equilibrium range from 14,500 to 17,500 and the number of female spawners at MSY ranges from 31,000 to 41,000.
- All analyses indicate that this population can recover, but recovery potential and times are sensitive to human-induced mortality. Human-induced mortality of about 2 to 4% of the vulnerable biomass is expected to keep recovery times to $SSN_{20\%}$ to one to three decades. Recovery to SSN_{msy} is expected to take much longer.
- The estimate of the vulnerable biomass in 2005 varies depending on the fishery selectivity used, and to a lesser degree on the assumed productivity. Assuming the Shelf-edge selectivity, the estimates of the vulnerable biomass are in the range of 4,500t to 4,800t. A catch of about 185t to 192t in 2005 would correspond with 4% human-induced mortality.
- A fishery-independent large pelagic survey could provide an index of shark abundance and stock status. Since it is unlikely that a periodic survey, by itself, would provide an absolute measure of stock status, it would be most effective if carried out in conjunction with size and catch rate data from some form of fishery.

DESCRIPTION OF THE ISSUE

Rationale for Assessment

The Species at Risk Act (SARA) provides legal protection to species listed in Schedule 1 and prohibitions under SARA would apply to porbeagle if added to the list. If listed, activities that would harm the species would be prohibited and a recovery plan would be required. Until such a plan is available, section 73(2) of SARA authorizes competent Ministers to permit otherwise prohibited activities affecting a listed wildlife species, any part of its critical habitat, or the residences of its individuals.

Under section 73(2) of SARA, authorizations may only be issued if:

(a) the activity is scientific research relating to the conservation of the species and conducted by qualified persons;
(b) the activity benefits the species or is required to enhance its chance of survival in the wild; or
(c) affecting the species is incidental to the carrying out of the activity.

Section 73(3) establishes that authorizations may be issued only if the competent minister is of the opinion that:

(a) all reasonable alternatives to the activity that would reduce the impact on the species have been considered and the best solution has been adopted;
(b) all feasible measures will be taken to minimize the impact of the activity on the species or its critical habitat or the residences of its individuals; and
(c) the activity will not jeopardize the survival or recovery of the species.

Decisions made on permitting of incidental harm and in support of recovery planning need to be informed by the impact of human activities on the species, alternatives and mitigation measures to these activities, and the potential for recovery. An evaluation framework, consisting of three phases (species status, scope for human–induced harm and mitigation) has been established by DFO to allow determination of whether or not SARA incidental harm permits can be issued. The analysis provided herein will inform decisions relating to the listing of porbeagle and its recovery planning. In the context of this status report, “harm” refers to all prohibitions as defined in SARA.

Species Biology

The porbeagle shark (*Lamna nasus*) is a **large cold-temperate pelagic shark** species of the family Lamnidae that occurs in the North Atlantic, South Atlantic and South Pacific oceans. The species range extends from Newfoundland to New Jersey and possibly to South Carolina in the west Atlantic, and from Iceland and the western Barents Sea to Morocco and the Mediterranean in the east Atlantic. The porbeagle has a low fecundity, late age at sexual maturation and low natural mortality. Age at maturity is about eight years in males and about thirteen years in females. In the northwest Atlantic, mating occurs from September through November, and live birth occurs eight to nine months later. Reproduction is thought to occur annually. Litter sizes range from two to six young and average about four. The porbeagle life span is estimated to be between 25 and 46 years and generation time is about 18 years.

ASSESSMENT OF ISSUE

Summary of Current Status

Status of porbeagle was assessed using an age- and sex-structured, forward projecting population model that used the landings, catch-per-unit-effort, the proportions-at-length in the catch, and tagging data to estimate population size. Three variants of the model were used, each with a different assumed productivity scenario. Landings in 2002-2004 have been in the range of 139-229t, or about 23% the landings from 1998 to 2001, primarily due to reduced quotas. The catch-per-unit effort data indicate a declining trend for mature porbeagle from 1985 to 2004. CPUE for immature porbeagle declined during the 1990s, but has been high since 2003. Estimates of the population size in 2005 are similar among the models: 188,000 to 195,000 fish. The estimated number of mature females are in the range of 9,000 to 13,000 fish, or about 15% of the population. Based on the model estimates, the population is 12% to 24% its size in 1961, and female spawner abundance has declined to about to 12% to 15% of its 1961 level. Most of the decline was estimated to have occurred in the early 1960s. A management plan was implemented in 2002 that was intended to allow recovery of the population. The population is estimated to be 99% to 103% its size in 2002, indicating that the management plan has been effective for halting the decline.

The porbeagle fishery is included in the model as three separate fisheries based on region: the “Basin”, “NF-Gulf”, and “Shelf-edge” regions. These regions were chosen because the vulnerability of porbeagle to fishing was thought to vary among these regions. The selectivity of the “Shelf-edge” region was used in the population viability analysis described later, based on the expectation that much of the bycatch would occur in this region.

The estimate of the mid-year vulnerable biomass in 2005 varies among models and the assumed fishery selectivity. Using either the Shelf-edge or Basin selectivity, the estimates of the vulnerable biomass are in the range of 4,500t to 4,800t. If the NF-Gulf selectivity is used, the vulnerable biomass is estimated to be in the range of 3,400t to 4,100t. The models with the lowest assumed productivity produce the highest estimates of the vulnerable biomass.

Recovery Reference Points

Standard reference points to **characterise recovery** have not been developed. In the absence of accepted reference points for recovery, two reference points sometimes used in fisheries management were used in this assessment of recovery potential: the number of female spawners at maximum sustainable yield (SSN_{msy}) and 20% of the number of female spawners when the population is at an unfished equilibrium ($SSN_{20\%}$). The former is a standard reference point for fisheries management and the later has been proposed as a limit reference point for bony fishes. These points are not recovery targets, but reference values against which population growth can be gauged.

The **model** used to assess status is an integrated model that combines life history theory and fishery assessment. Reference points are calculated within the model based on biological characteristics of porbeagle and characteristics of its fishery, including reproductive rates, natural mortality, growth rates, maturity schedules and fishery selectivity.

Often in these types of models, fishery selectivity and natural mortality cannot be estimated simultaneously, and often the slope at the origin of the spawner-recruit model (a measure of productivity) cannot be reliably estimated. Due to these issues, three variants of the model were used each with a different **assumed reproductive scenario**. In the lower productivity model, the maximum number of offspring per mature female that survive to age-1 was assumed to be 2. Values of 2.5 and 3.2 were used in the middle and higher reproductive scenarios. Instantaneous rate of natural mortality was assumed to be 0.1 for immature porbeagle and 0.2 for mature porbeagle in all scenarios.

Estimates of reference points are highest from the model with the lowest assumed productivity, and lowest from the model with the highest assumed productivity. The estimate of the number of female spawners at 20% of the unfished equilibrium range from 14,500 to 17,500 and the number of female spawners at MSY ranges from 31,000 to 41,000.

A key **source of uncertainty** for establishing reference points for recovery is the productivity of the population. The overall productivity of the population, including both reproductive rates and natural mortality rates, was not successfully estimated using the model. Three productivity scenarios were analysed to address this uncertainty. Additionally, the fishery takes place in a much smaller geographic area than in the past, making interpretation of CPUE difficult. Two lines of evidence exist that indicate that present abundance is being underestimated by the models: the tagging data and recent high CPUE in the Basin and Shelf-edge regions. If estimated abundance trajectories are incorrect, the reference points are also likely to be incorrect. An unresolved issue is the uncertainty in estimates of the reference points. The model presently produces standard errors (a measure of the precision of the estimates) for all model parameter estimates that are unrealistically small.

Recovery Potential

A model for **population viability analysis** (PVA) was developed within the life history-assessment model. The model projects the population forward through time from the estimated 2005 population size and age structure using the life history parameters either assumed or estimated within the assessment model. Projections are made either deterministically (no random variability assumed), or stochastically (with random variability added). Projections were done over a 100 year time horizon. When random variability was added, 200 population simulations were carried out, and the probability of meeting the reference points within a given time frame was calculated as the proportion of the simulated populations that recovered within the time frame. The effect of human-induced mortality was modelled as bycatch mortality assuming a fishery selectivity identical to the directed fishery in the Shelf-edge region.

High exploitation is the only **cause for the decline** in population size that has been identified for porbeagle. Population growth rates for different levels of bycatch mortality are estimated based on the three productivity scenarios.

Estimates of the time to reach the recovery reference points from the deterministic projections varied among models due to the different assumed productivities (Figure 1) as well as the estimated sizes of the population at present. The age structure of the population creates a cyclical pattern in the early years of recovery as the population age structure stabilizes. All models indicate that, in the absence of human-induced mortality, recovery to $SSN_{20\%}$ should occur by about 2015. An incidental harm rate of 2% of the vulnerable biomass delays recovery to $SSN_{20\%}$ to the period between 2015 and 2020. At an incidental harm rate of 4% of the vulnerable biomass, estimated recovery to $SSN_{20\%}$ from all models occurs before 2020, although in the low productivity scenario, the population then drops slightly, increases again, and then remains stable at about $SSN_{20\%}$ for the remainder of the century. At an incidental harm rate of 7% of the vulnerable biomass, recovery to $SSN_{20\%}$ occurs only in the model with the highest assumed productivity.

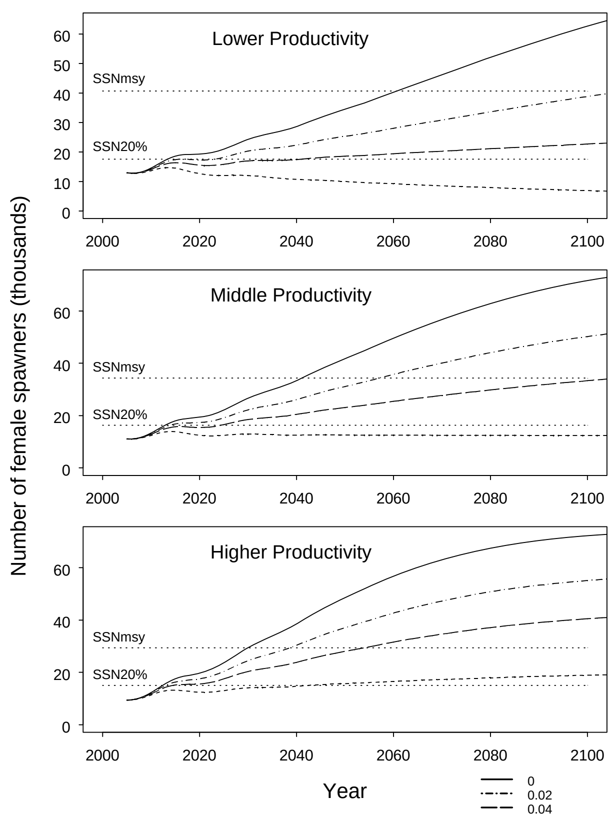


Figure 1. Comparison of the recovery reference points and recovery trajectories obtained from three models, each with a different productivity scenario. Four different exploitation rates are shown in each panel. Population trajectories begin in 2005 from the abundance by age and sex predicted by each model, and are projected deterministically (no random variability added) using the life history parameters obtained from the model and the assumed exploitation rate. The selectivity for the fishery on the Shelf-edge was used in each case.

In the absence of human-induced mortality, the three models place recovery to SSN_{msy} sometime between 2030 and 2060. An incidental harm rate of 4% of the vulnerable biomass is predicted to delay recovery to SSN_{msy} into the 22nd century (or later) by all models except the one with the highest productivity (a delay of 28 years relative to the scenario without human-induced mortality). At an incidental harm rate of 7% of the vulnerable biomass, the population will not recover to SSN_{msy}.

By 2015, this porbeagle population will have been fished for three generations. Using these models, in the absence of human-induced mortality, the **population size in 2015** is predicted to be in the range of 228,000 to 260,000 individuals, including 47,000 to 50,000 mature animals. At a human-induced mortality rate of 4% of the vulnerable biomass (Shelf-edge selectivity assumed), the population size is predicted to be in the range of 197,000 to 226,000 individuals. Both of these scenarios represent increases in total abundance from 2005 (lower productivity model: 195,000 fish; middle productivity model: 191,000 fish; higher productivity model: 188,000 fish). At a human-induced mortality rate of 7% of the vulnerable biomass, the predicted population size in 2015 is less than the population size in 2005 from all but the most productive model.

Predicted Total Number of Porbeagle in 2015

Percentage of the vulnerable biomass removed as catch	Productivity Scenario		
	lower	middle	higher
0%	228,000	242,000	260,000
2%	212,000	225,000	242,000
4%	197,000	210,000	226,000
7%	178,000	189,000	204,000

Predicted Number of Mature Porbeagle in 2015*

Percentage of the vulnerable biomass removed as catch	Productivity Scenario		
	lower	middle	higher
0%	50,000	48,000	47,000
2%	47,000	45,000	44,000
4%	44,000	42,000	41,000
7%	40,000	38,000	37,000

*ratio of 1.7 mature males per mature female assumed

Based on the middle productivity model, when random variability is added to recruitment and natural mortality, median recovery times to $SSN_{20\%}$ are slightly longer (Figure 2), and recovery times are less certain. In the absence of human-induced mortality, the simulated populations show little variability in recovery to $SSN_{20\%}$. As human-induced mortality increases, the variability in time to recovery to $SSN_{20\%}$ also increases. At a human-induced mortality rate of 4% of the vulnerable biomass, 80% of the simulated populations recovered to $SSN_{20\%}$ between 2016 and 2037. At a human-induced mortality rate of 7% of the vulnerable biomass, 42% of the simulated populations recovered to $SSN_{20\%}$. although none recovered to SSN_{msy}.

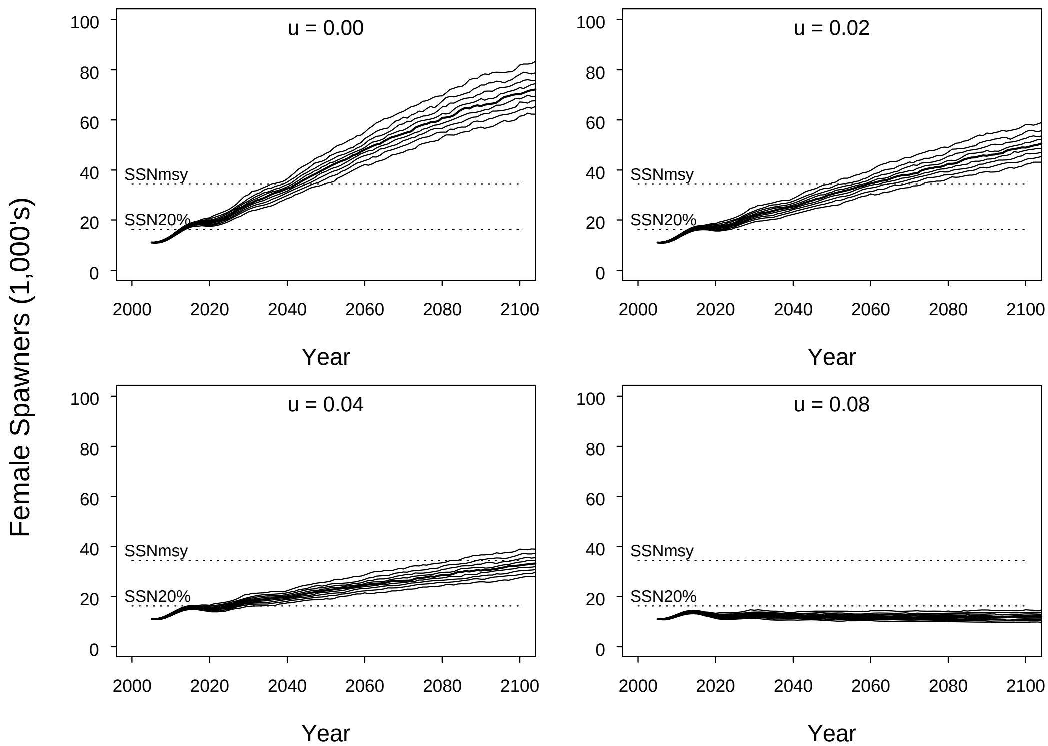


Figure 2. Recovery trajectories for porbeagle obtained from the population viability analysis (based on the middle productivity model) under four exploitation scenarios. Each plot summarizes the results of 200 population simulations with random variability added to reproduction and survival. The lines connect the quantiles of the population size in each year from low (bottom line = 0.1) to high (top line = 0.9). The Shelf-edge selectivity was used to model exploitation.

At a human-induced mortality rate of 2%, time to recovery to SSN_{msy} varied by about 3 decades and 90% of simulated populations recovered to SSN_{msy} by about 2075. At a human induced mortality rate of 4%, about 30% of the populations did not recover to SSN_{msy} within 100 years. None of the simulated populations recovered to SSN_{msy} at a human-induced mortality rate of 7% of the vulnerable biomass.

Prior to the proclamation of SARA, a five-year recovery plan was established for this population covering the time period 2002 to 2007. The effects of continuing the plan for its duration (a 250t quota until the end of 2007) on recovery times was evaluated using deterministic projections. Continuing with the current management plan until 2007 would delay the predicted recovery times by about 5 years.

All analyses indicate that this population can recover, but recovery potential and times are sensitive to all levels of human-induced mortality. Exploitation rates less than about 4% of the vulnerable biomass are expected to allow recovery to both $SSN_{20\%}$ and SSN_{msy} (Shelf-edge selectivity assumed).

Under the most conservative scenario, recovery to $SSN_{20\%}$ occurs if human induced mortality is less than 4% of the vulnerable biomass. Catches of 180t in 2005 would correspond with this rate, a level at which population recovery is expected. Under the most productive scenario, a catch of 7% of the vulnerable biomass, corresponding to 315t, would allow slow population growth.

Sources of Uncertainty

There is uncertainty around present population size and population trajectories. Two lines of evidence exist that indicate that present abundance is being underestimated by the models: the tagging data and recent high CPUE in the Basin and Shelf-edge regions.

If variability exists in the recruitment and natural mortality processes, but is not included in the projection model, the estimates of recovery time are known to be biased. The effect of this bias is to underestimate recovery time.

The population dynamics are modeled as a compensatory process (increasing juvenile survival as population size decreases). Allee effects (decreased juvenile survival at low population size) are not considered but could substantially slow recovery times.

Autocorrelation (natural “cycles” in survival and reproduction) were not included in the projection model. If autocorrelation exists, recovery times could be greater or less, depending whether survival and reproduction are presently low or high. Given the low fecundity and late age at maturity of porbeagle, recovery times are unlikely to be much faster than predicted.

The selectivity of the bycatch fishery is unknown and would affect recovery trajectories.

Projections of population trajectories are made using the 2005 population size and age structure as a starting point. When estimating recovery times, the effect of uncertainty in the starting population size and recovery targets was not evaluated.

ALLOWABLE HARM/PROVISIONS OF RECOVERY PLAN

The only **sources of human-induced mortality** identified for incidental harm permitting are fisheries that capture porbeagle as bycatch within Canadian waters (Table 1). Catches by foreign (i.e. Japanese) vessels fishing outside of Canadian waters are not well known. During 2000 – 2002, estimates ranged from 15t to 280t annually. Most Canadian bycatch is taken by Scotia-Fundy vessels in swordfish and fixed gear groundfish fisheries. The bycatches by both foreign and domestic vessels from 2002 to 2004 were 68t, 58t, and 59t respectively (Table 1), levels that are not expected to prevent recovery. The effect of fishing on food sources is not considered significant because of the diverse diet of porbeagle.

Table 1.

A) Porbeagle catch (kg) by Scotia-Fundy vessels.

Year	**2000**	**2001**	**2002**	**2003**	**2004**
GROUNDFISH					
Groundfish fixed gear 45 - 65	997	789	958	2,400	2,031
Groundfish fixed gear <45	4,743	6,925	13,141	13,041	14,044
Groundfish inshore					56
Groundfish midshore	461	518	697	1384	101
Groundfish offshore	191	285		220	409
Groundfish unspecified	456	1,059	1,184	1,105	1,010
Total Groundfish	6,848	9,576	15,980	18,150	17,651
LARGE PELAGICS					
Directed porbeagle exploratory	870,741	476,703	172,001	86,059	172,520
Swordfish	5,482	9,582	18,939	29,160	22,155
Tuna	1,266	577	18,435	5,559	6,156
SMALL PELAGICS					
Herring		256			23
Total Porbeagle	884,337	496,694	225,355	138,928	218,505
Total Porbeagle bycatch	13,596	19,991	53,354	52,869	45,985
Percent total from bycatch	2%	4%	24%	38%	21%

B) Porbeagle catch (kg) outside of Scotia-Fundy.

Year	**2000**	**2001**	**2002**	**2003**	**2004**
Newfoundland fixed gear	141	946	1,851	1,071	142
Newfoundland mobile gear			40		
Gulf (all gears)[1]	18,976	1,192	11,566	2,565	12,876
USA (all gears)[2]	3,595	785	1,813	1,185	

[1] represents a minimum value; an unspecified shark category ranging between 2,900-8,800 kg annually may also have included porbeagle
[2] landings only

Currently, the **ability to monitor population status** is highly dependent upon individual length measurements from the catch and set by set catch rates, both of which are fishery-dependent activities. A **fishery-independent large pelagic survey** could provide an index of shark abundance and stock status, but would need to be carried out at regular intervals to provide useful results. Since no such survey has been completed to date, the first survey would need to be implemented soon, while population abundance is known. Since it is unlikely that a periodic survey would provide a precise measure of stock status by itself, it would be most effective if carried out in conjunction with size and catch rate data from some form of fishery.

CONCLUSIONS AND ADVICE

All indications are that porbeagle in the Northwest Atlantic can recover if human-induced mortality is sufficiently low. The models estimate of the number of female spawners in 2005 range from 9,000 to 13,000 fish, representing about 15% of the population. Two potential recovery targets from these models are the number of female spawners at 20% of the unfished equilibrium (14,500 to 17,500 fish) and the number of female spawners at maximum sustainable yield (31,000 to 41,000 fish). At incidental harm rates of 1% to 4% of the vulnerable biomass based on the Shelf-edge selectivity, estimates of recovery times to $SSN_{20\%}$ are on the order of decades. At 4%, recovery to SSN_{msy} is expected to be much longer. Estimates of the vulnerable biomass in 2005 are about 4,500t to 4,800t, implying a catch of 180t to 192t in 2005 would prevent further decline. Bycatch in 2002 to 2004 averaged about one third of this value.

MANAGEMENT CONSIDERATIONS

Presently, a 5 year management plan, intended to affect recovery, is in place for this population. In comparison with closure of the directed fisheries, continuation of this plan for its duration is expected to have only minor effects on recovery trajectories (delay of about 5 years), and would allow further data collection and provide an opportunity for uncertainties in the present status to be resolved.

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ISSN 1480-4913 (Printed)

La version française est disponible à l'adresse ci-dessus.

CORRECT CITATION FOR THIS PUBLICATION

DFO, 2005. Recovery Assessment Report on NAFO Subareas 3 – 6 Porbeagle Shark. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2005/043.