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Near Extinction of a Large, Widely Distributed Fish

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Are extinctions of marine vertebrates as rare and unlikely as current data indicate? Long-term research surveys on the continental shelf between the Grand Banks of Newfoundland and southern New England reveal that one of the largest skates in the northwest Atlantic, the barndoor skate (*Raja laevis*), is close to extinction. Forty-five years ago, research surveys on St. Pierre Bank (off southern Newfoundland) recorded barndoor skates in 10% of their tows; in the last 20 years, none has been caught, and this pattern of decline is similar throughout the range of the species.

Elasmobranchs, such as sharks and rays, tend to be very susceptible to the effects of fishing because they generally grow slowly, mature late in life, and produce few offspring (*1*). Species of the family Rajidae, although the most fecund of the elasmobranchs (*2*), are known to experience varying degrees of resilience to exploitation (*3*) because of the large range in life history characteristics within this family. Although shark fisheries usually cause a sharp decline in species abundance (*4*), dogfish and skates on Georges Bank have increased in biomass after the depletion of groundfish stocks (*5*). It has been suggested that the energy released into the ecosystem by these depleted stocks has provided resources for elasmobranch populations to increase. The recent introduction of a directed fishery for dogfish and skate on Georges Bank, however, has resulted in a marked decline of these species (*6*).

The barndoor skate, *Raja laevis*, is one of the largest skates in the northwest Atlantic (*7*), and it ranges from Cape Hatteras to the Grand Banks of Newfoundland (Fig. 1). Once common (*8*), this distinctive species, with a maximum body width of just over 1 m, now appears to be near extinction. Although the extinction of marine species is thought to be rare (*9*), the closely related "common" skate in the northeast Atlantic, *Raja batis*, was shown to be locally extinct in the Irish Sea (*10*). If current population trends continue, however, the barndoor skate could become the first well-documented example of extinction in a marine fish species.

Biomass (in kilograms per square kilometer) of the barndoor skate (Fig. 2) was determined from research vessel surveys (*11*) that have been conducted in the spring on the southern Grand Bank and St. Pierre Bank since 1951, in the summer on the Scotian Shelf since 1970, and in the autumn from Georges Bank to southern New England since 1963. The population trend is similar for all regions, with biomass decreasing into the early 1970s, after which barndoor skates were caught only on Browns Bank and nearby Georges Bank (*12*).

The longest time series available are for the southern Grand Bank, at the species' northern limit on the continental shelf, and St. Pierre Bank, where barndoor skates were once commonly found. Compared with other skate species on St. Pierre Bank, the barndoor skate had been one of the most numerous skates, second in abundance only to the thorny skate (*Raja radiata*) (*13*). If we consider the mean biomass of the barndoor skate in each decade and the corresponding mean weight of individuals on St. Pierre Bank, the average number of barndoor skates in the 1950s would have been on the order of 0.6 million. That number would decrease to about 0.2 million individuals in the 1960s and to less than an estimated 500 individuals in the 1970s. The other smaller skate species, namely thorny skate and smooth skate (*Raja senta*), were actually increasing in biomass over this time period.

The mean weight of individual skates on St. Pierre Bank is a good indicator of their vulnerability to commercial trawls. Species large enough to be caught in trawls have been decreasing in size over the time period, whereas the size of the smallest species, the smooth skate, has remained fairly constant. The regulated mesh size on commercial fishing gear has ranged from 7 to 14 cm over the survey period, although a smaller mesh size has been used illegally (*14*). The barndoor skate is vulnerable to commercial trawls from hatching at a length of about 20 cm (*7*).

Direct biological information on skates in the northwest Atlantic is scarce. Sufficient comparative information, however, is available to estimate the mortality required to drive this species to extinction. The closest relative of the barndoor skate in the North Atlantic, the common skate (*7*), matures at about 11 years (*10*). We should expect a similar age at maturity on Georges Bank, which has a similar temperature regime (*15*). Maximum egg production, which can be estimated from the inverse relation with the weight of the young at hatching (*16*), is about 47 eggs per year.

Considering the age at maturity and the annual fecundity of the barndoor skate, the

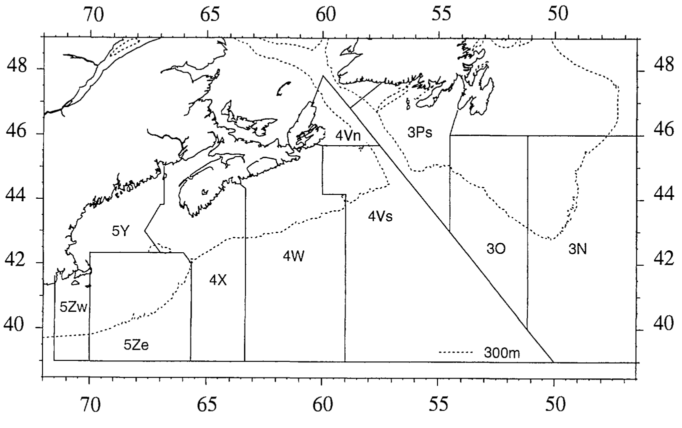

Fig. 1. Map of the Northwest Atlantic Fisheries Organization. Subdivisions in which populations were assessed in this analysis are shown. The 300-m isobath (dotted line) is given for reference. 3N and 3O, southern Grand Bank; 3Ps, St. Pierre Bank; 4Vn, Sydney Bight; 4Vs, Banquereau Bank; 4W, Sable Island Bank; 4X, Browns Bank; 5Y, Gulf of Maine; 5Ze, Georges Bank; 5Zw, southern New England. The numbers on the axes are degrees of latitude and longitude.

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instantaneous mortality rate required to drive this species to extinction is about 0.4 per year, assuming that mature and immature mortalities are equal (*17*). At the northern limit of the barndoor skate's range, where the bottom temperature averages 2.5°C [about 6°C colder than on Georges Bank (*15*)], the age at maturity should be about double (*18*), and the instantaneous mortality required to drive the species to extinction would be expected to be closer to 0.2.

The fishing mortalities for cod (*Gadus morhua*) have been above 0.4 and often much greater in these regions for more than 30 years (*19*). It is therefore not surprising that the barndoor skate population would be reduced to such extreme levels when taken as by-catch in major fisheries, for example, cod and redfish (*Sebastes* sp.). For a species that matures at such a late age (at least 11 years), there is a greater probability that individuals will be caught before they are able to reproduce. This situation is amplified for populations at the northern limit of the range.

The only recent research survey catches of barndoor skate in the Newfoundland area have been very deep (greater than 1000 m) and in an area north of the reported range of this species, where surveys were conducted in support of a new fishery for Greenland halibut (*Reinhardtius hippoglossoides*). Whether or not barndoor skates were commonly found at this depth over the entire range is not known, as research surveys were rarely conducted at such depths. These great depths, however, may have represented one of the last refuges for this species.

Barndoor skates have survived on Browns Bank and Georges Bank probably because of a faster growth rate combined with the seasonal closure of parts of these banks to trawling (*20*). Perhaps the only hope for the long-term survival of this species is to designate an area protected from trawling on all the banks that is sufficiently large to allow for a self-sustaining population. A protected area would also provide a simple and effective means to conserve other species.

Failure to examine historical data has resulted in the largest skate in the northwest Atlantic being driven to near extinction without anyone noticing. If such a large, easily identified species has been allowed to disappear in an area that is well surveyed, the fate of little known species is likely to be worse. This study shows the importance of assembling data on as long a time scale as possible and as wide a spatial scale as possible; otherwise, the near extinction of a very apparent species may be missed.

A directed fishery for skate was initiated off the coasts of Newfoundland and Nova Scotia in 1994 as an attempt to use nontraditional groundfish species. Elasmobranchs experience low natural mortality when compared with teleost fish species and, at low population levels, are not able to compensate, for example, with increased fecundity or reduced natural mortality (*4*). Consequently, the end result of increased mortality due to fishing pressure could be extinction.

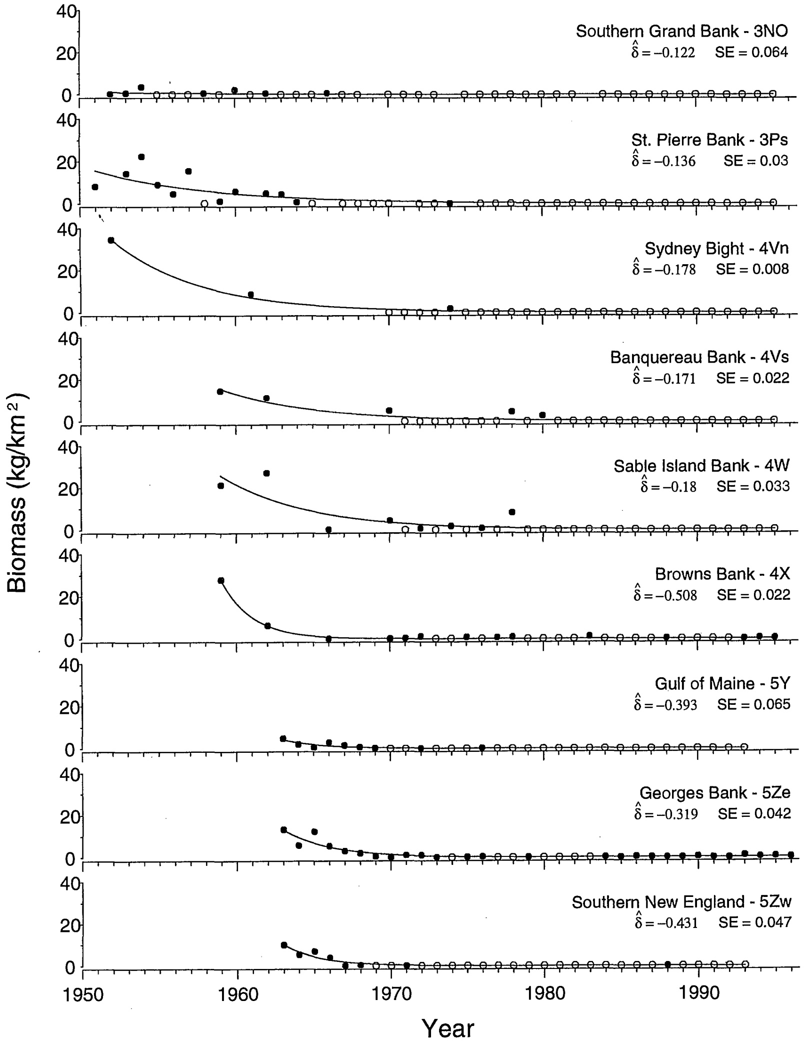

Fig. 2. Estimates of absolute biomass for barndoor skate (*R. laevis*) from the southern Grand Bank (the northern limit of the range) to southern New England (close to the southern limit of the range). Open circles are zero catches. An exponential decay curve ($Ne^{-\delta t}$) was fit to the data with nonlinear least squares, where N is the population size in the first year of the surveys and t is the time since the first year. The estimated rate of population decline ($\hat{\delta}$) was lowest in the northern regions and highest in the southern regions. If only data since 1960 are considered, the population decline on St. Pierre Bank, Sydney Bight, and Banquereau Bank is similar to that in the southernmost regions (that is, Gulf of Maine, Georges Bank, and southern New England). The standard error (SE) of $\hat{\delta}$ is provided.

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the United States, annual research surveys have been conducted with a stratified random survey design [W. G. Doubleday and D. Rivard, Eds., *Bottom Trawl Surveys* (Department of Fisheries and Oceans, Ottawa, Canada, 1981)]. These surveys cover a range of depths from 50 to 400 m and are designed to provide unbiased estimates of abundance. Before 1971, a fixed location survey along line transects was used off the coasts of Newfoundland and Nova Scotia. These surveys were converted to the stratification scheme with the latitude, longitude, and depth of the tow. The earlier surveys were conducted primarily during the day, and, because skates are caught in substantially higher proportions at night, day catches would underestimate the true abundance (J. M. Casey and R. A. Myers, *Can. J. Fish. Aquat. Sci.*, in press). To account for this difference in diel catchability, we converted half of the catches before 1970 to night catches using a factor of 2.08. These surveys would then be comparable with those after 1970 in which day and night tows were conducted in roughly equal proportion. Biomass estimates were based on the stratified random design [W. J. Cochran, *Sampling Techniques* (Wiley, New York, 1977)]. Estimates of absolute abundance were obtained by dividing the biomass estimates by a factor of 0.15, if 10% of the skates in the path of the trawl are caught during the day [R. L. Edwards, in *The Future of the Fishing Industry of the United States*, D. Gilbert, Ed. (University of Washington, Seattle, WA, 1968), pp. 52–60] and 20% of the population would be caught at night. Neither of these conversions affects the observed biomass trends.

12. Because barndoor skates have only been caught in research surveys of Browns Bank and Georges Bank in the past 20 years, we examined the statistical power of detecting barndoor skate given a specific low abundance level. On St. Pierre Bank, 504 of 1075 research survey tows were conducted over the past 25 years at depths where, historically, barndoor skates were commonly found (200 to 400 m). We assume that the number n of barndoor skates caught in one tow has a negative binomial distribution, with a probability of $[\Gamma(k + n)/\Gamma(k)n!][\mu^n k^k/(\mu + k)^{k+n}]$, where μ is the mean catch per tow and the constant k is the inverse of aggregation. Then, with a theoretical low mean abundance of 500 individuals in a 7368-km^2 area (the tow sample area is 0.05 km^2, and the probability of catching a barndoor skate if encountered is 0.15) and $k = 0.5$, the probability of not detecting a barndoor skate in 504 tows is 0.77. Greater aggregation (that is, lower k) results in only small changes in this number. If 1000 individuals remained, the probability of not detecting a barndoor skate decreases to 0.6.
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Regulation of a Transcription Factor Network Required for Differentiation and Metabolism

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Hepatocyte nuclear factors (HNFs) are a heterogeneous class of evolutionarily conserved transcription factors that are required for cellular differentiation and metabolism. Mutations in *HNF-1α* and *HNF-4α* genes impair insulin secretion and cause type 2 diabetes. Regulation of HNF-4/HNF-1 expression by *HNF-3α* and *HNF-3β* was studied in embryoid bodies in which one or both *HNF-3α* or *HNF-3β* alleles were inactivated. HNF-3β positively regulated the expression of *HNF-4α/HNF-1α* and their downstream targets, implicating a role in diabetes. HNF-3β was also necessary for expression of *HNF-3α*. In contrast, HNF-3α acts as a negative regulator of *HNF-4α/HNF-1α* demonstrating that HNF-3α and HNF-3β have antagonistic transcriptional regulatory functions in vivo. HNF-3α does not appear to act as a classic biochemical repressor but rather exerts its negative effect by competing for HNF-3 binding sites with the more efficient activator HNF-3β. In addition, the HNF-3α/HNF-3β ratio is modulated by the presence of insulin, providing evidence that the HNF network may have important roles in mediating the action of insulin.

Hepatocyte-specific gene expression is controlled primarily at a transcriptional level and relies on the activity of multiple transcription factors including HNF-1, CCAAT/enhancer binding protein (C/EBP), HNF-3, HNF-4, and HNF-6 (*1*). Our current understanding of transcriptional regulation by these HNFs has been derived primarily from analysis of promoter/enhancer elements of genes selectively expressed in cultured cells with transient transfections (*1*). Although these approaches have provided useful information about tissue-specific regulation of gene expression, it is important to note that such procedures do not measure transcriptional regulation within a native chromosomal context. This is significant, given that HNF-3 proteins have been shown to modify the nucleosomal organization of the albumin enhancer, a finding consistent with the structure of the HNF-3 DNA binding domain, which is highly similar to that of histone H5 (*2*). Analyses of specific promoter elements indicate that HNFs act in various combinations to direct cell-specific transcription during cellular differentiation (*3*). Targeted disruption of transcription factors in mice often results in only moderate reductions in target gene expression, which supports the hypothesis that transcription factors act cooperatively. In contrast to this, we have recently shown that disruption of *HNF-4α* drastically reduces the expression of numerous target genes, implying that it acts as a central regulator of tissue-specific gene expression (*4*). In addition, earlier studies had shown that HNF-4α also positively regulated expression of *HNF-1α*, defining a transcriptional hierarchy involved in maintaining the hepatic phenotype (*5*). We predicted that factors that control the expression of *HNF-4α* could have critical functions in directing cell differentiation. Moreover, the recent finding that mutations in the genes encoding HNF-4α and HNF-1α are responsible for two phenotypically indistinguishable forms of early-onset type 2 diabetes, MODY1 and MODY3, respectively, suggested that such upstream regulators of *HNF-4α* expression could also be necessary for normal pancreatic β cell function and metabolism (*6*).

Evolutionarily conserved HNF-3 binding

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