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Changes in the timing and location of cod spawning in Placenta Bay

(NAFO sub-division 3Ps), 1997-1998

By

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Abstract

We examine changes in the timing and location of cod spawning in Placentia Bay between 1997 and 1998, through a combination of acoustic surveys and direct sampling of spawning aggregations. Three spawning grounds were located in spring of 1997, at Bar Haven, Perch Rock, and Oderin Bank. Spawner density at Bar Haven peaked at 0.008 fish/m^2 in April of 1997, but in 1998 peaked at 0.002 fish/m^2 in June, a delay of more than 80 days. The timing of peak spawning is not as easily ascertained from our data at Perch Rock and Oderin Bank. However, a delay in spawning at these sites is suggested. Furthermore, the densities of cod at the spawning grounds shifted dramatically from 1997 to 1998. Densities at Perch Rock decreased, and at Oderin Bank increased, by orders of magnitude. These results, together with related studies of larval abundance and juvenile settlement in Placentia Bay, suggest that later spawning has important consequences to successful cod recruitment within Placentia Bay.

Résumé

Nous faisons l'examen des variations du moment et du lieu du frai de la morue dans la baie Placentia, entre 1997 et 1998, en utilisant à la fois les résultats de relevés acoustiques et ceux de l'échantillonnage direct des concentrations de géniteurs. Trois zones de frai, situées à Bar Haven, à Perch Rock et au banc Oderin, ont été décelées au printemps de 1997. En 1997, la densité maximale des géniteurs à Bar Haven, de 0,008 poisson/m^2, a été atteinte en avril tandis qu'elle n'a été atteinte, à 0,002 poisson/m^2, qu'en juin, un retard de 80 jours, en 1998. Le moment du pic de la concentration de frai n'est pas aussi facilement déterminé à partir des données de Perch Rock et du banc Oderin. Il semble cependant y avoir eu retard du frai à ces endroits. En outre, la densité des morues aux lieux de frai a varié de façon extrêmement importante de 1997 à 1998. Les valeurs de Perch Rock ont diminué et celles du banc Oderin ont augmenté, cela par plusieurs ordres de grandeur. Ces résultats, et ceux d'études connexes portant sur l'abondance larvaire et la migration vers le fond des juvéniles dans la baie Placentia, portent à croire que le retard du frai influe de façon importante sur la réussite du recrutement de la morue dans la baie Placentia.

Introduction

Knowledge of the timing and location of cod spawning is important to the study of cod recruitment and the conservation of spawning stocks. Although spawning in inshore regions of NAFO sub-division 3Ps has been documented (Hutchings et al., 1993), no reports exist of exactly where and when cod spawn in these inshore areas. Furthermore, previous reports were limited to the examination of female gonad condition, with little information on spawner abundance at any given site and time.

We examine changes between 1997 and 1998 in the timing and location of cod spawning in Placentia Bay. We accomplish this through a combination of acoustic surveys and direct sampling of cod aggregations. This combined approach allows spawning grounds to be located, cod density to be measured, and female gonad condition to be determined.

Methods

Location of spawning grounds
In April, May, and June of 1997, whole-bay acoustic surveys of Placentia Bay were performed along a systematic grid of transects running east-west across the bay at intervals of 4 nmiles (Figure 1). Surveys employed two Biosonics single beam digital DT4000 echosounders (38 and 120 kHz, 6° half-power beam widths, pulse durations 0.4 ms, 42 kHz digital sampling rates, pulse rates 2 pings/s). Transducers were mounted on a 'dead weight' body towed at 4 knots (7.4 km h^{-1}) and a depth of 1.5 m alongside either the MV Innovation, MV Mares (Marine Institute of Memorial University of Newfoundland research vessels, < 14 m), or CSS Shamook (Canadian Coast Guard vessel, 23m). Calibrations were performed *in situ* with a 38 mm tungsten carbide standard target according to standard practices (Foote *et al.*, 1987).

Spawning grounds were located via these surveys by defining spawning aggregations as groups of cod whose internal densities reached 0.1-1 individual/m^2 and where at least 10% of females sampled in the aggregation were in spawning condition (defined below). Identified spawning grounds were periodically re-visited throughout the summer, to follow the seasonal spawning cycle and determine peak spawning time.

In May 1998, the transect grid was again surveyed to locate spawning aggregations. A survey of the outer bay was performed in June 1998 from the CSS Teleost, using an EK500 split-beam echosounder (a June 1996 survey was also conducted from the Teleost). Distinct spawning aggregations were less evident than in 1997, but no new grounds were detected. Grounds chosen for re-visiting through the summer were therefore the same as chosen in 1997.

Quantifying spawning on each ground
The protocol at each identified spawning ground first involved sampling acoustically-located cod using jiggers with feather-hooks. Samples were taken with a bottom trawl in June of 1996 and 1998 at Oderin Bank. Cod were sampled for sex, length, weight, age,

and gonad condition. Only female gonad condition was used for analysis of spawning time, as it is believed that male gonad condition (where spawning is defined by presence of milt in the vasa deferentia) is strongly affected by the stress of capture. Females were categorized, after Templeman et al. (1978), as either immature or mature, with mature gonads further recorded as preparing (visible opaque eggs maturing to spawn in the present year), spawning (hydrated eggs present, possibly some eggs already extruded), or spent (spawning complete, no or very few hydrated eggs present).

A fixed acoustic transect covering each ground was run once during each spawning ground survey. As transects on different grounds covered different areas and aggregations sizes, it is not known whether they are strictly comparable between sites. Acoustic data were echo-integrated from surface to bottom using FASIT software (Fisheries Assessment and Species Identification Toolkit; LeFeuvre et al., in press), in bins of 100m horizontal distance along the transect. All data were first edited to ensure full separation of fish from bottom echoes. Only data from the 38 kHz echosounder were analysed in 1997, and only from the 120 kHz in 1998, since the 38 kHz echosounder was not operational in 1998.

Details on the removal of autocorrelation in areal backscatter measures from the 100m bins, and on the scaling of density from backscatter using length and thereby target strength distributions, are given in Rose and Lawson (1999). Direct sampling of cod with jiggers allowed ground-truthing and the measurement of length distributions for target strength calculations. Target strength scaling employed the relationships TS=20logL-67.5 and TS=20logL-66.5 for 38 and 120 kHz data, respectively (Rose and Porter, 1996). Both mean total cod density and spawner density were calculated. The latter was derived by multiplying total density by the proportion of fish sampled that were mature, and then by the proportion of females sampled which were in spawning condition. This assumes that female spawning condition is representative of both sexes.

Results

In 1997, spawning aggregations were found at Perch Rock, Oderin Bank, and Bar Haven (see Figure 1 for location of grounds, Figure 2 for cod density distribution). Concentrations of fish were located at other sites, but these were at much lower densities, or were not comprised of spawning fish.

Cod density in 1997 at Bar Haven was highest in April (0.04 fish/m^2), and decreased over the course of spring and summer 1997 (Figure 3a). The proportion of females in spawning condition, by contrast, increased from 26% in April to a peak of 55% in May, and decreased in June to remain at background levels (<15%) through until late fall. In 1998, cod density at Bar Haven peaked in late June at 0.003 fish/m^2, while the proportion of spawning females was highest in late July (Figure 3b).

Combining cod density with proportion of females in spawning condition indicates that peak spawner density decreased from 0.008 fish/m^2 in 1997 to 0.002 fish/m^2 in 1998

(Figure 4). Furthermore, peak spawning was more than 80 days later in 1998 than in 1997. It should be noted that the estimated peak in spawning of 1997 occurred at the first sample period of that year, and that we are not aware of what took place prior to this time.

Length of mature females during peak spawning at Bar Haven was greater in 1998 than 1997 (Table 1). Length of mature females showed an increasing followed by decreasing trend over the course of the spawning cycles, within each year.

Due to logistic constraints, spawning grounds at Oderin Bank and Perch Rock were surveyed less often than Bar Haven. The timing of peak spawning at these sites is therefore not easily ascertained. At Perch Rock, spawning was observed only in May in both years (Figure 5a). In May 1998, a lower proportion of fish were in spawning condition and a higher proportion in preparing state than in May 1997, which is consistent with later spawning in 1998.

At Oderin Bank, the proportion of females in spawning condition in 1997 decreased from June to August (Figure 5b). Cod density was at a peak in August of 1997. In June of 1997, the ratio of spawning to spent females was much lower than in June of 1998, again indicating that spawning was later in 1998.

Given that the spawning cycle appears to have been delayed between 1997 and 1998 and that the times of peak spawning at Perch Rock and Oderin Bank are not known, direct comparisons of changes in spawner density at these grounds between years may be misleading. At similar sample periods in May of 1997 and 1998, however, mean spawner density at Perch Rock decreased by three orders of magnitude (1.6×10^{-2} fish/m^2 in 1997 vs. 2.4×10^{-5} fish/m^2 in 1998). Spawner density at Oderin Bank in June 1998 (9.7×10^{-3} fish/m^2) was much greater than in June of either 1996 (6.2×10^{-4} fish/m^2) or 1997 (6.7×10^{-5} fish/m^2).

Conclusions

Three spawning grounds were located in Placentia Bay in 1997, the positions of which correspond well with concurrent surveys of cod egg distribution (Bradbury et al., 1999). Between 1997 and 1998, spawner density decreased slightly at Bar Haven, and drastically at Perch Rock. Spawner density at Oderin Bank was higher in 1998 than has been recorded since 1996 (see also Rose and Lawson, 1999 for Oderin biomass estimates).

Spawning at Bar Haven peaked in April of 1997 and in June of 1998, a difference of more than 80 days. Related studies found larval abundance (Bradbury et al., 1999) and juvenile settlement (Robichaud and Rose, 1999) in Placentia Bay greatly increased in 1998 from 1997. This change in larval abundance and settlement likely resulted from the delay in spawning, together with the warmer summer water temperatures and concomitant shorter development times experienced by these later 1998 eggs. Later spawning appears to have important consequences for successful cod recruitment within

Placentia Bay. This finding may be of considerable importance to the potential use of seasonal fishery closures as a management strategy for protecting spawning cod.

To determine the timing and location of cod spawning, both density and proportion of females in spawning condition should be considered. Spawner density is more relevant than either of the two component measures alone, as a high proportion of fish in spawning condition of a low density aggregation may not represent meaningful egg contribution at the population level. The lack of correspondence between peak cod density and peak proportion of females in spawning condition further supports this contention.

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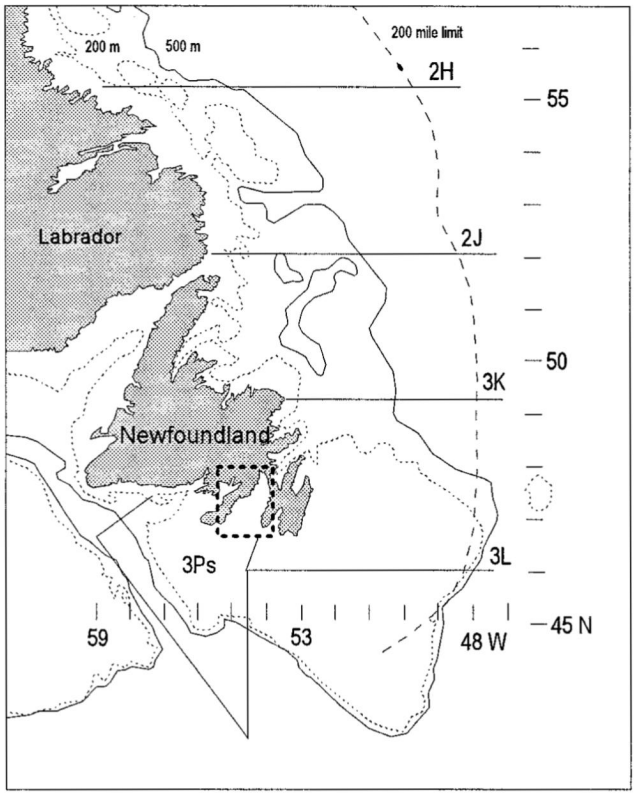
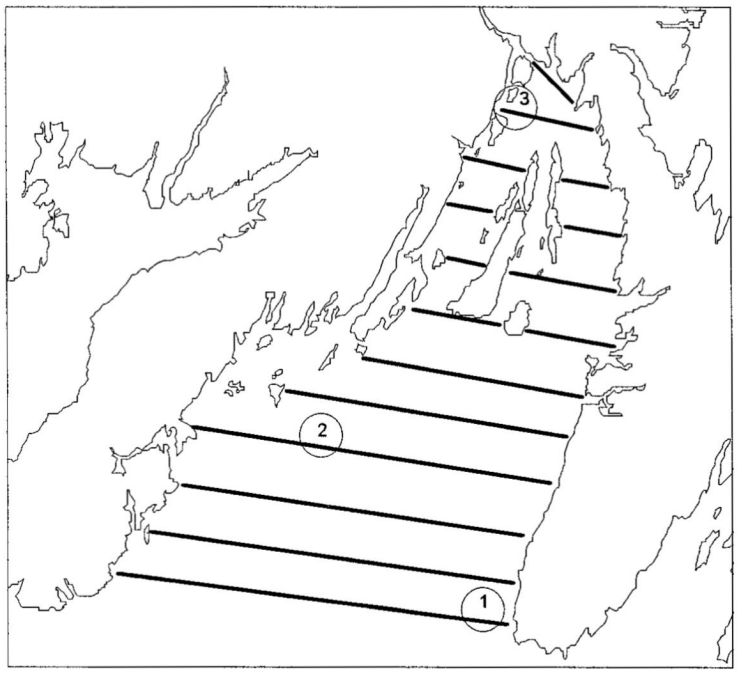
Table 1 – Mean length (cm) of mature females sampled at Bar Haven spawning ground for each survey period of 1997 and 1998. SE given in parentheses.

Survey month	1997	1998
April	61.000	60.771
	(1.478)	(1.264)
May	66.809	67.750
	(1.411)	(2.246)
June	60.000	70.174
	(3.599)	(2.205)
July	61.171	62.294
	(1.280)	(2.138)
September	55.158	62.385
	(1.234)	(3.151)

Figure 1 -- (A) Map of Newfoundland, with Placentia Bay indicated by rectangle. (B) Systematic transect grid covering Placentia Bay. Circles indicate 1. Perch Rock 2. Oderin Bank 3. Bar Haven



A



B

Figure 2 -- Broad-scale acoustic surveys to locate cod spawning grounds in April-May 1997, and May 1998. Expanding circles represent increasing cod density (fish/m2)

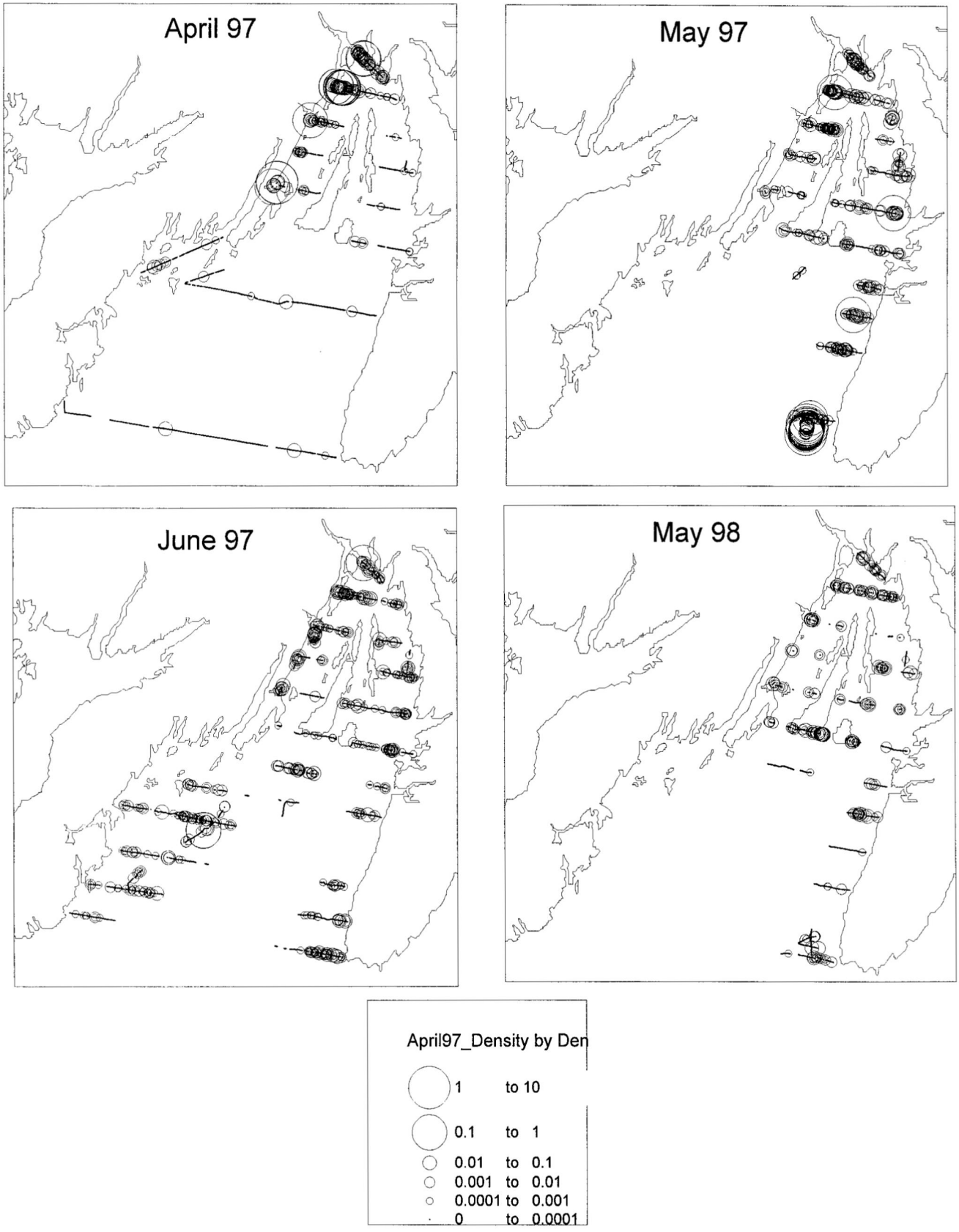
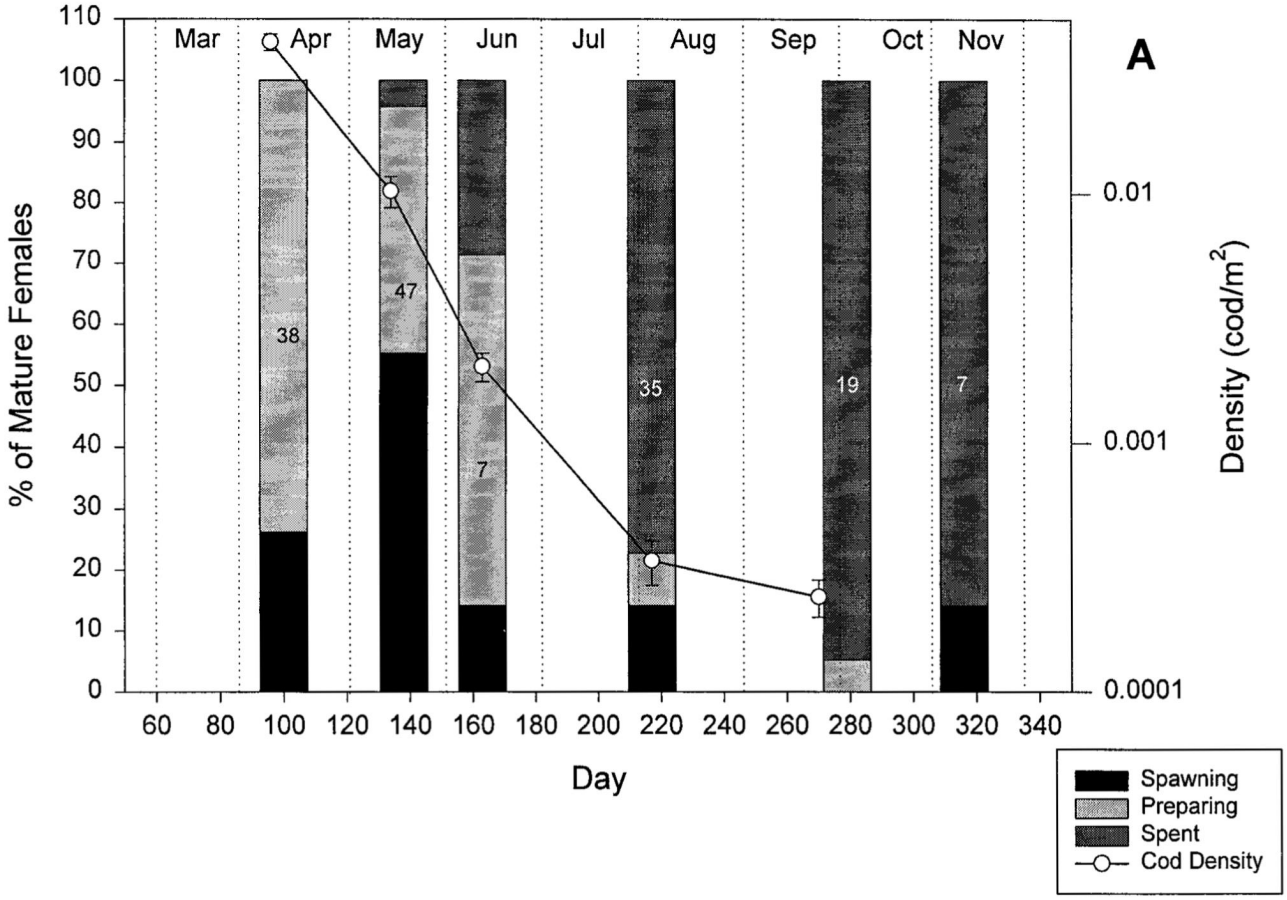


Figure 3 -- Cod spawning at Bar Haven in **(A)** 1997 and **(B)** 1998. Bar plot shows percent of mature females in preparing, spawning, and spent condition (left axis). Number of mature females sampled indicated on each set of bars. Line graph shows cod density by Julian survey day (right axis). Error bars show 95% confidence interval.



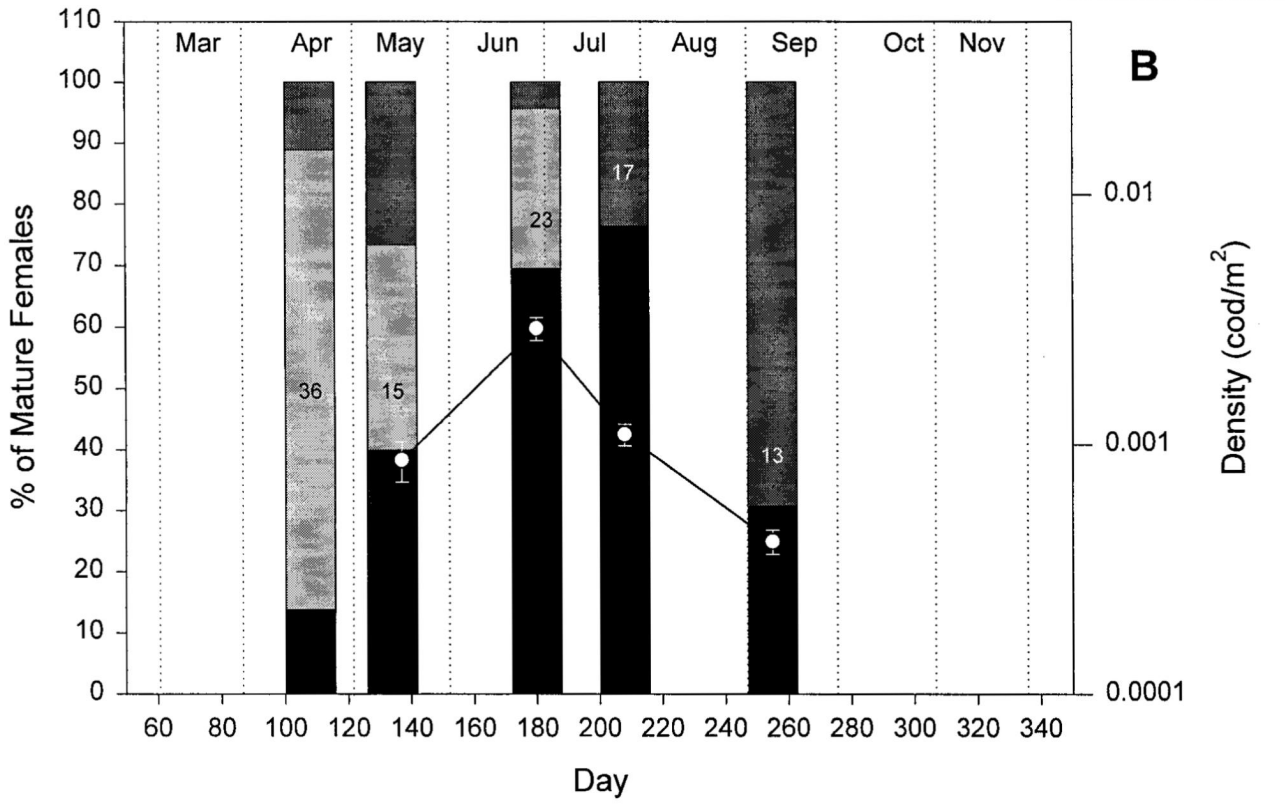


Figure 4 -- Acoustic estimates of spawning cod density at Bar Haven in 1997 (closed circles) and 1998 (open circles), by julian survey day. See text for calculation of spawner density from total cod density. Error bars show 95% C.I.

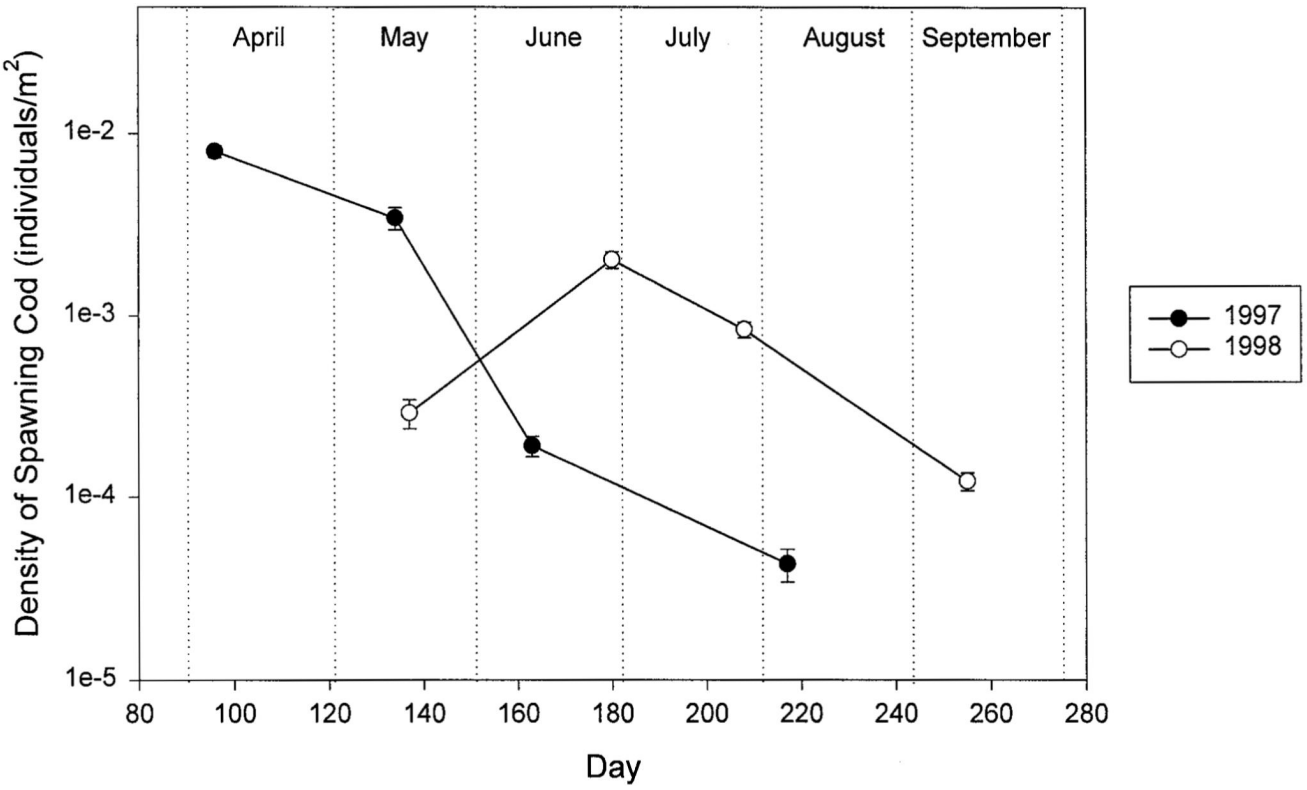


Figure 5 -- Proportion of mature females at **(A)** Perch Rock and **(B)** Oderin Bank in maturing, spawning, and spent condition during sample periods in 1997 and 1998. Sample periods indicated with an asterisk were surveyed from the Teleost, and ran different transects than at other times. Sample sizes (number of mature females) indicated on bars. Acoustic cod density estimates indicated by line graph, with 95% C.I