

Dr. Karl Karnacky). The ambient temperature was 23°C on this occasion. Ten cycles of exchange were conducted between distilled water and 2x sea water, once every 10 minutes. Again the fry remained vigorous and healthy. They showed no behavioral change, nor any morbidity or mortality. At the end of the experiment they were returned to normal full strength sea water where they continued their development for several days before being returned to the sea.

I conclude that young *Fundulus heteroclitus* are euryhaline at hatching and infer that this physiological property is developed during embryogenesis. Adjustment to acute reversal of osmotic conditions of the medium is rapid (well within ten minutes), perhaps almost instantaneous and is continuously renewable and reversible over a period of several hours.

These data give rise to further questions with regard to the survival value of euryhalinity in estuarine fish and the selection processes through which this physiological characteristic has developed and is maintained. Further acute experiments are planned as well as an analysis of the bioenergetics of the process.

REPRODUCTIVE ECOLOGY OF SPINY DOGFISH, *Squalus acanthias*

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There are many examples of homeostasis at population levels amongst the higher vertebrates, by which population density is adjusted to meet changes in environmental resources. In deer and rats, for example, under conditions of high density and overcrowding, a proportion of mature females do not bear young and many pregnancies are aborted at an early stage. When population members are heavily reduced, the proportion of pregnant females rises and the incidence of multiple births increases (Severinghaus, J. Wildlife Manag., 15:73, 1951; Davis, Trans. N. Amer. Wildlife Conf., 15:461, 1950).

Elasmobranch fishes, like mammals, produce few large young and often provide them with some form of protection. The spiny dogfish, *Squalus acanthias* is ovoviviparous and retains the eggs within the uterii for about two years (the longest gestation period known in the vertebrates). There are no data on density-dependent fecundity relations in elasmobranchs.

The spiny dogfish in the North Atlantic provides interesting material for such a study because there are considerable differences in the density of the populations in European and American waters, and we can compare their fecundities and the commitment of energy to reproduction. The spiny dogfish, valued as a food in Europe, are heavily fished and population density is low. By contrast, the dogfish populations off the Eastern seaboard of America are little disturbed; they are unfished, their natural predators are few and, correspondingly, population numbers are high.

During the summer of 1976 a total of 370 mature female fish were sampled, ranging from 3.0 kg to 8.0 kg, and lengths from 92 to 108 cm. All the fish in this size range were mature; females of less than 3.0 kg body weight were immature. The length, weight and liver weight of each female was recorded. Intact egg capsules (candles) were carefully removed from females in their first year of gestation, capsule weight determined and the number of contained eggs counted. From females in the second year of gestation large embryos were removed, measured, and weighed, the yolk sac dissected free and weighed. Fish which appeared to have lost intrauterine young were not included in this analysis.

In this report we consider the fecundity relationships in 122 females in the second year of gestation with embryos of 16 cm or larger. Similar conclusions also apply to females carrying capsules. The term "maternal weight" refers to the total weight of the female, excluding the weight of the embryos in utero.

Maternal weight and total weight of the young

The results showed a strong positive correlation between the total weight of the intrauterine products (embryos plus yolk) and maternal weight, expressed as:

$$Y = 131.3 + 66.4 X$$

where Y = total weight of the young (g) and X = maternal weight (kg); the correlation coefficient "r" was 0.41 and p = .001 (Figure 1). The weight of embryos of small females of 3 kg weight was 110 g embryos per 1 kg maternal weight, for larger females the rate of increase in total embryo weight was rather modest, being only about 66 g for every increase of 1 kg maternal weight.

Maternal weight and the number of embryos

There was a significant positive relationship between maternal weight and the number of intra-uterine embryos, which was expressed by the formula:

$$Y = 4.2 + 0.7 X$$

where Y = embryo number and X = maternal weight (kg). The correlation coefficient, "r" was 0.28 and p = .001 (Figure 2).

Maternal weight and mean weight of the embryos

An increase in the number of young of the same weight would alone give a significant positive correlation between total embryo weight and maternal weight. I have, therefore, compared the mean embryo weight in females of different sizes to determine whether there was an increase in the size of individual young as the female grew larger. Analysis of the data showed that there was a significant positive correlation:

$$Y = 46.5 + 2.6 X$$

where Y = embryo mean weight (g) and X = maternal weight (kg); "r" was 0.29 and p = < .001 (Figure 3). The increase in average weights of embryos was small, thus a doubling in maternal weight from 3 kg to 6 kg was accompanied by only a 14% increase in embryo weight.

The results of various trawling surveys off the East coast suggest that the population of dogfish is stable and numbers do not appear to vary greatly from year to year. We have therefore assumed that the fecundity relationships described for this population at Mount Desert Island are probably typical for normal, undisturbed populations. We have compared them with data from a stock of spiny dogfish which has undergone drastic reduction in population size from commercial fishing.

Comparison with European stock

The stock of spiny dogfish in the North-east Atlantic is heavily fished, particularly by Scots and Norwegians. The comparative fecundity data from this European population were collected by us in collaboration with Mr. M. J. Holden of the Fisheries Laboratory, Lowestoft, U.K. The regression analyses are included in the figures.

Marked differences in the size distribution of the adult females of the European population are immediately apparent - the largest females which we obtained in Europe were between 3.5 and 4.0 kg body weight, whilst in Maine females of about twice that size, from 7.5 to 8.0 kg were not uncommon. In the European stock there were many mature females in both years of pregnancy weighing 2 kg

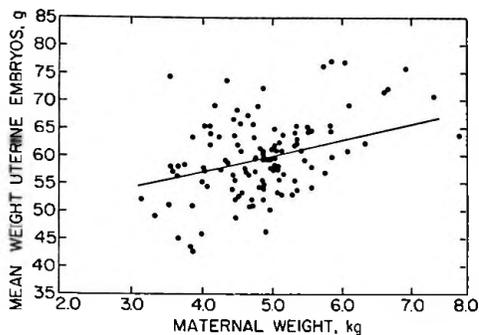


Figure 1. The relation between maternal weight and total weight of embryos in the spiny dogfish. The dashed line is the regression line for the European population.

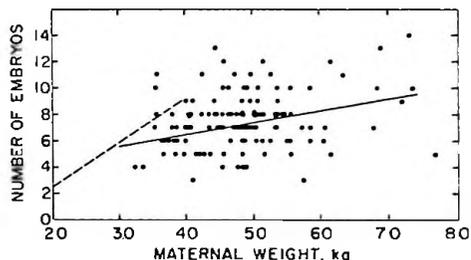


Figure 2. The relation between maternal weight and the number of embryos. The dashed line is the regression line for the European population.

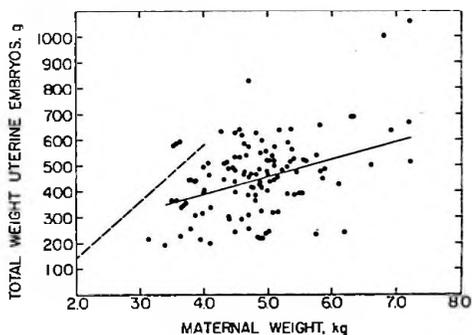


Figure 3. The relation between maternal weight and mean weight of the embryos. There was no significant relationship in the European population.

(confirmed by extensive samples from research vessels and fish markets), whilst in the Maine population the smallest mature females that we obtained were about 3 kg - females smaller than this were immature juveniles. A second outstanding difference is the greater reproductive commitment of the European fish - the rate of increase in the total weight of embryos is about 140 g for each increase of 1 kg of maternal weight, a rate of more than twice that for the Maine

fish. This increase was also reflected in the greater numbers of embryos carried for given size in the European stock.

In the spiny dogfish the reproductive commitment of energy reserves in terms of total embryo and ovary weight to maternal weight is about 10%, which is similar to that of such marine teleosts as cod, herring or flatfish in which the mature ovary weight is about from 8% to 20% of maternal weight. Such teleosts are reproductive opportunists, spawning many thousands or millions of very small eggs so that some larvae may disperse successfully to nursery grounds; in strong contrast, during the course of their very long evolution, the elasmobranchs have tended to produce a few eggs (often with a period of retention in the uterii) allowing large embryos to develop having good chances for individual survival. The Maine dogfish well illustrates this selection for survivorship. The European dogfish appears to have departed in part from the elasmobranch strategy, females mature at a much smaller size, the total weight of embryos carried is greater for fish of comparable size and this reflects an increased number of embryos.

These differences in reproductive capacity are the ones which might be expected in a population which must restabilize rapidly or risk devastation in the face of heavy predation (in this case commercial fishing). The differences in fecundity of dogfish under conditions of reduced population numbers appear to fit a suggestion by Cody (Evolution, 20:174, 1966), that as the environment becomes less stable, and populations are held at low levels, then individuals would be less often faced with competition for resources. Under these circumstances, selection would favour the ability to multiply quickly, i.e., would favour increased fecundity rather than survivorship.

It would be curious if the intervention of man in recent decades were to begin a compensatory reversal of a reproductive strategy developed by elasmobranchs during the course of a long evolution.

During the summer of 1976, spiny dogfish became Maine's newest European export, and some 200,000 pounds of flesh were shipped overseas; it is planned to expand the fishery (Press Herald, Maine, 9/27/76). Records of the few commercial fisheries for elasmobranchs to date present a gloomy picture - initial exploitation was followed by rapid fall in catches to the point of collapse of the fishery. This could easily be repeated again. Further work is needed to clearly establish population parameters before the Maine fishery becomes established.

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TWINNING IN THE SPINY DOGFISH, *Squalus acanthias*

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Uniovular (monozygotic) twins are a regular, though infrequent, feature of reproduction in most vertebrate classes and there is an extensive literature on spontaneous twinning in mammals, birds and amphibia. Twins are fairly common in teleost fishes, although monsters often are produced, in which there is duplication of only a part of the body; these monsters occasionally survive. Twinning appears to be a very rare event in elasmobranch fishes. Amongst the 270 mature females collected during the summer of 1976, however, we found one female bearing twins.