ROLE OF DIFFERENT FACTORS ON REPRODUCTION OF FISH

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Abstract: *Reproduction (or procreation) is the biological process by which new offspring individual organism are produced from their parents. Reproduction is the fundamental feature of all known life, each individual organism exists as the result of reproduction. Fish reproductive organs include testis and ovaries. In most species, gonads are paired organs of similar size, which can be a range of secondary organs that increases reproductive fitness. The method of reproduction varies but most fishes lay a large number of small eggs, fertilized and scattered outside the body. Successful reproduction and, in many cases defense of the young are assured rather by courtship and parental behavior along with other factors mentioned in this article.*

Key Words: *Fish, Reproduction, temperature, Incubation period, egg.*

1. INTRODUCTION:

Reproduction refers to the release of unfertilized planktonic eggs by female fish, which is the reproductive pattern for most marine fishes. The eggs are fertilized shortly after release by males. Some fishes also deposit unfertilized eggs in nests where they are fertilized and develop.

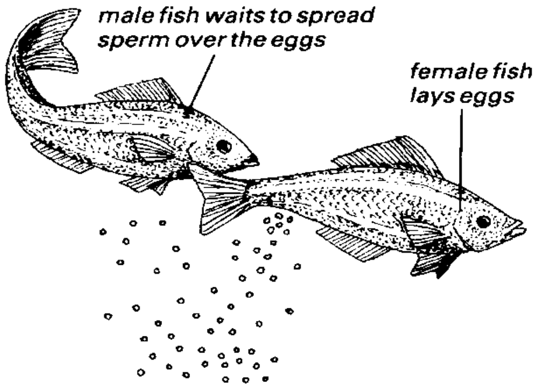


Fig: SPAWNING

Fishes with internal fertilization release free-swimming larvae, or juveniles. The ripening of eggs and spawning are controlled by hormones, nutrition of the female and external (ecological) factors (Hempel 1979). Usually maturation and spawning are controlled by a combination of endogenous and exogenous controls and are not governed by any specific factor.

2. VARIOUS FACTORS INFLUENCING REPRODUCTION:

There are various factors involved in the Spawning behaviour of fishes. They are,

- Endocrine control
- Temperature in related to HPG axis
- Stress
- Ocean acidification
- Physiological factors
- Ecological factors
- Nutrition status of the female
- Environmental factors

3. ENDOCRINE CONTROL:

Changes in environmental variables are transduced into effects on reproductive processes through the hypothalamo–pituitary–gonadal (HPG) axis. This begins with hypothalamic synthesis and synaptic release of peptide gonadotropin-releasing hormones (GnRH) onto the gonadotropic cells of the pituitary gland, where they stimulate the synthesis and release of the protein hormones, follicle-stimulating hormone (FSH) and luteinising hormone (LH).In many species, there is also inhibitory tone imposed by the action of dopamine (DA)-secreting neurones, with the release of FSH and LH being dependent on the balance between GnRH stimulation and DA inhibition. The GnRH–pituitary interaction is further modulated by melatonin produced by the light-sensitive pineal gland by as-yet poorly understood mechanisms, by the kisspeptin system through direct effects on the activity of GnRH-producing neurones and by the feedback effects of gonadal steroids.

FSH is involved in stimulating the early stages of gamete development and LH in the control of maturational events, with both exercising their effects at the gonadal level through binding with G protein-coupled membrane-bound receptors in the ovary and the testis, giving rise to an increase in intracellular cAMP levels. This in turn results in the activation of protein kinases and the susbesequent *de novo* synthesis and releases of gonadal steroids through the sequential cleavage of the base molecule cholesterol. In males, the predominant steroids produced are the androgens, testosterone (T) and its more biologically active metabolite 11-ketotestosterone (11KT); females also produce T but this is further metabolised to the oestrogen 17β-oestradiol (E_2). Both sexes also produce a progesterone-like maturational steroid (typically 17,20β-dihydroxy-4-pregnen-3-one, 17,20βP or 17,20β,21-trihydroxy-4-pregnen-3-one, 20β-S) in response to gonadal stimulation by LH.The actions of gonadal steroids include the stimulation of gametogenesis in both sexes, spermiation in males and vitellogenesis (yolk accumulation) and oocyte maturation in females, as well as regulating secondary sexual characters and a suite of sexual behaviours. A key step in the reproductive development of females is the stimulation by E_2 of hepatic synthesis of the egg yolk precursor vitellogenin (Vtg) which is released into the plasma from where it is taken up by the developing oocytes. E_2 also stimulates the ovarian and hepatic synthesis of zona pellucida proteins (ZP) that will ultimately form the chorion (egg shell) of the ovulated ovum.

4. TEMPERATURE AND HPG AXIS:

Temperature change has the capacity to affect the HPG axis at multiple sites through its reaction-rate-determining effects on hormone synthesis and action, and its effects on hormone structure. This is reflected in a minimum temperature threshold for most endocrine events, increasing hormone synthesis, activity and metabolism across the physiological tolerance range and decreasing activity at the top end of that range. Inhibitory effects at higher temperature may arise from conformational changes in proteins (e.g. FSH, LH and their receptors, steroid-synthesising enzymes), and also the increasing tendency for steroid hormones to form water-soluble conjugates at high temperatures. Steroid conjugates (usually sulphates or glucuronides) suffer the dual fate of no longer being soluble in (and able to pass through) cell membranes to gain access to their intracellular receptors, and of being more available for kidney filtration and excretion in the urine, significantly reducing their plasma residence times.

Irrespective of the mechanisms involved, it is clear that thermal inhibition of reproduction is present across a wide spread of taxa, habitats and temperature ranges with the main difference between species being the absolute temperature at which the suppressive effects occur. In cold temperate and sub-Arctic species, the inhibitory effects typically appear at temperatures of 11–12°C, among cold-temperate species at around 18°C, temperate species at ~24°C and tropical species at 30°C and above. This supports the view that all species are likely to show similar responses to rising temperatures, but that the thresholds for these effects will vary in relation to specific thermal tolerance ranges. There is also some evidence that the ranges over which normal function can be maintained may be broader in cool-water and temperate species than among tropical species.

Examples-

SPECIES	**HABITAT**	**EFFECTS**
Arctic charr(Salvelinus alpinus)	Cold temperate/sub-Arctic freshwater	Inhibition of LH secretion, ovulation(10-11°C)
Wolf fish(Anarhichus lupus)	Cold temperate/sub-Arctic marine	Reduced steroid (T and E2) production, ovulation, fertility and survival(12°C)
Lake whitefish(Coregonus lavaretus)	Cold temperate lacustrine	Delayed ovulation and spawning
Atlantic salmon(Salmo salar)	Cold temperate anadromous	Reduced Vtg and ZP gene expression(T,E2 and 17,20BP) production,aromatase activity,ovulatory frequency,fertility,egg survival(18°C)
Rainbow trout(Onchorhynchus mykiss)	Temperate freshwater	Reduced steroid (T and E2,17,20BP) production, ovulation, fertility and survival(18-21°C)
Redseabream(pagrus major)	Temperate marine	Aromatase and 11B-hydroxylase inhibition(24°C)
Spiny damselfish(Acanthochromis polyacanthus)	Tropical marine	Reduced reproductive output, aromatase activity,E2 production(30°C)

5. STRESS AND REPRODUCTION:

Stress is known to have marked inhibitory effects on reproduction in fish. Stress stimulates activation of an acute catecholamine-mediated response that has the primary effect of rapidly increasing energy availability and the delivery of O_2 to the tissues, followed by a longer and more sustained activation of the hypothalamic–pituitary–interrenal (HPI) axis, resulting in plasma elevations of the steroid cortisol in teleosts and chondrosteans, and 1α-hydroxycorticosterone in elasmobranchs. Short-term increases in corticosteroids increase the availability of a variety of energy substrates, but longer-term exposure to elevated cortisol results in suppressive effects on a range of functions including reproduction, growth and immune function .Some of the longer-term effects can be explained by the largely catabolic effects of cortisol, but stress is also capable of suppressing plasma levels of T and E_2 in as little as 15–30 min after the imposition of stress, and there is equivocal evidence that this rapid effect is the direct result of cortisol action .

There is also the consideration as to whether environmental conditions are routinely stressful for fish in the natural environment, and the conclusion is that there is not strong evidence for initiation of stress responses under quite wide ranges of environmental conditions. The caveat here is that events that do stimulate stress responses in free-ranging vertebrates from other classes are typically associated with extreme weather events. For fish populations, this is likely to coincide with storms and floods, when sampling from wild populations is generally precluded. However, environmental changes predicted for riverine environments such as increasing temperatures, decreased flow rates and O_2 saturation may well generate conditions that do stimulate activation of the HPI axis. A reasonable prediction is that this will contribute to reproductive suppression in these environments, separately or additively to direct thermal effects on reproductive endocrine processes.

6. OCEAN ACIDIFICATION:

Uptake of additional CO_2 at the ocean surface, owing to increasing concentrations of CO_2 in the atmosphere, is causing ocean pH to decline and reducing the carbonate ion concentration of the shallow ocean. This process, known as ocean acidification, is considered to be a serious threat to marine species, especially for calcifying species that require carbonate ions to form their shells and skeletons. Elevated pCO_2 can also have a direct physiological effect on aquatic species through disruption of acid–base balance and limiting oxygen supply. The effects of increasing pCO_2 in water is probably of greater concern than reducing pH, because of the high permeability to biological tissue of gaseous CO_2 relative to hydrogen ions. Experiments with red seabream (*Pagrus major*) demonstrate that larval fish are more sensitive to the effects of acidification with CO_2 than to the same pH achieved with mineral acids. Increased pCO_2 in tissue causes acidosis (lowering of pH and accumulation of bicarbonate), which can be detrimental to many cellular processes, including protein synthesis, enzymatic function and oxygen transport. Fish compensate for acidosis by acid–base equivalent ion transport from the body to the environment, mostly across the branchial epithelium, and to a lesser extent, via the kidneys and intestine.

The few preliminary studies available suggest the impacts might not be substantial. Sperm motility of the flounder, *Limanda yokohamae*, is arrested by mild increases in pCO_2, but similar effects were not observed in 10 other species from a range of families or in the Baltic cod, *Gadus morhua* .Eggs of pelagic spawners might be more sensitive to CO_2 stress than the eggs of benthic spawners such as clownfishes, because pelagic eggs probably experience less fluctuation in environmental pCO_2 than benthic eggs, but this hypothesis has not been adequately tested.

One potential concern is that higher pCO_2 may limit the scope for aerobic performance in adults, which could affect reproductive output. Aerobic scope of two tropical cardinalfishes, *Ostorhinchus doederleini* and *O. cyanosoma*, declined by 33% and 47%, respectively, a loss in aerobic capacity has an effect on reproduction, but it is reasonable to suspect that it will. For example, collapse of aerobic scope in association with anomalously high water temperature has been linked to failed migration (and thus spawning) in sockeye salmon, *Oncorhynchus nerka*. The possible effects of elevated CO_2 on endocrine pathways that mediate reproduction in fishes.

7. PHYSIOLOGICAL FACTORS:

Physiological factors includes nothing but the hormones. Hormones govern,

- Migration
- Timing of reproduction
- Morphological changes
- Mobilization of energy reserves
- Elicit intricate courtship behavior

The pituitary is the major endocrine gland that produces gonadotropin, which controls gametogenesis, the production of gametes, namely sperm (spermatogenesis) and eggs (oogenesis), by the gonads. The pituitary also controls the production of steroids (steroidogenesis) by the gonads; once the gonads are stimulated by the pituitary they begin producing steroids, which in turn control yolk formation (vitellogenesis) and spawning. The control of spawning by the pituitary is often used in fish farming such as in the production of caviar from sturgeon (Acipenser spp.) where spawning is induced by injecting pituitary extract at a late stage of gonadal development, usually in combination with changes in temperature and light periodicity.

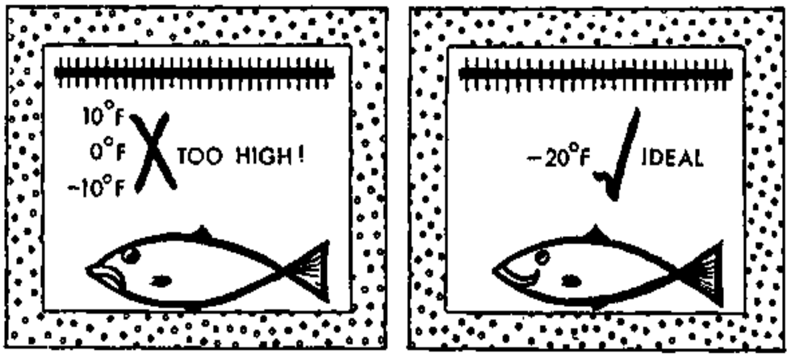
8. ECOLOGICAL FACTORS:

Ecological factors are associated with timing so that food availability is optimal for the larvae. Some ecological factors important to spawning are

- Temperature
- Photoperiod
- Periodicity
- Tides
- Latitude
- Water depth
- Substrate type
- Salinity
- Exposure

Temperature:

An important factor in determining geographical distributions of fishes. Temperature controls maturation and spawning in fishes, for many marine and freshwater fishes the temperature range in which spawning occurs is rather narrow, so that in higher latitudes the minimum and maximum temperature requirement for spawning is often the limiting factor for geographical distribution and for the successful introduction of a species into a new habitat.



For example, Pacific halibut (Hippoglossus stenolepis) are found spawning primarily in areas with a 3–8°C temperature. In fact, even in highly migratory tuna, spawning is restricted to water of specific temperature ranges.

Photo period:

The daylength (photoperiod), in some cases at least, is thought to influence the thyroid gland and through this the fishes migratory activity, which is related to gondal development (maturation).In the northern anchovy, by combining the effects of temperature and daylength, continued production of eggs under laboratory conditions was brought about by keeping the fish under constant temperature conditions of 15°C and a light periodicity of less than 5 hours of light per day. In high latitudes, spawning is usually associated with a definite photoperiod (and temperature), which dictates seasonal pulses of primary production in temperate regions to assure survival of larvae. In low latitudes, where there is little variation in daylength, temperature, and food production, other factors may be important such as timing with the monsoons, competition for spawning sites, living space, or food selection.

Periodicity:

Reproductive periodicity among fishes varies from having a short annual reproductive period to being almost continuous. There is a tendency for the length of the reproductive period to shorten with increasing latitude. Thus tropical fishes spawn nearly continuously, whereas subarctic fishes spawn predictably during the same few weeks each year. Presumably times of Spawning have evolved so larval development will coincide with an abundant Food supply. Within spawning seasons, fish may spawn on a daily or Monthly tidal cycle or on a diel cycle, or in association with some other environmental cue, such as a change in day length, temperature, or runoff. A notable instance of spawning periodicity associated with the tidal cycle is The California grunion (Leuresthes tenuis), which spawns intertidal at the Peak of the spring high tides. Within species, spawning times May vary with latitude: Generally, in species that spawn as day length Increases, spawning occurs earlier in the year in lower latitudes than at higher latitudes. In species that spawn as day length decreases, spawning takes place earlier in the year at higher latitudes than at lower latitudes.

Tides:

The dependence of spawning on tides in California grunion spawning on California beaches is an extreme example of external factors controlling reproduction in fishes. Grunion are adapted to spawning on the beach every two weeks in the spring during a new or full moon. Spawning is just after the highest high tide, therefore eggs deposited in the sand are not disturbed by the surf for 10 days to a month later. Eggs will hatch when placed in agitated water (which simulates surf conditions). In surf smelt (Hypomesus pretiosus) spawn year-round, except in March. Surf smelt deposit eggs at high tide in sand and gravel (but not necessarily at the highest tide).Tides are also refered as Moon cycles.

Latitude:

Timing, duration and frequency of spawning variation with both Temperate and Tropical latitudes.

FACTORS	TEMPERATE LATITUDES	TROPICAL LATITUDES
Timing	Early winter, Spring	Late(spring, summer, or continuous)
Duration	Short (3-4 months)	Long(5-6 months or more)
Frequency(per year)	Once (refers to entire group of eggs to be spawned, not how spawned)	Several times

In general, older fish usually spawn first and younger fish later, which means that a prolonged spawning period for a population may not be true for individual fish. Once a set of eggs is mature and hydrated, the female may release them all at once or in several batches.

Water depth:

Reproduction not occurs in the same depth for all the fish species. It occurs in different ranges of depth. Some of the species spawning in inshore areas, some of them in deeper waters.

DEPTH	EXAMPLE
Off shore area(300-400m)	Petrale sole(*Eopsetta jordani*)
Near shore area(up to 200m)	Atlantic Herring
Deepest area	Tuna

Substrate Type:

Spawning substrates vary according to species and its spawning behaviour.

TYPE OF SUBSTRATUM	EXAMPLE
Vegetative substartun	Pacific herring
Solid substratum	Atlantic herring
Solid substrate(rocks, pilings and cracks)	Plainfin midshipman(Porichthys sp)

Salinity:

Salinity is one of the factor affecting spawning. There are varying salinities in many areas of estuaries. Some species will shift spawning sites because of salinity changes. Various degrees of mixing, precipitation, and freshwater runoff may alter spawning habits.

Exposure:

A clear example of shifting spawning sites in response to temperature and exposure is the black prickleback (*Xiphister atropurpureus*), where spawning is shifted from winter in protected areas to spring in exposed areas. The complex effects of lower or higher wave action and lower or higher temperatures on courtship, gonadal development, and spawning behavior that result in the spawning site shift.

9. NUTRITION STATUS OF THE FEMALE:

Lot of nutrients involved in the influence of spawning in fishes. They are,

- Protein
- Lipid
- Carbohydrate

- Vitamin
- Mineral

Protein:

Dietary protein level influences puberty, oocyte development, spawning performance, and egg quality of fish species. Optimum dietary protein requirement for the different fish species at different stages of breeding is essential. Example:

- In brood stock of Atlantic salmon reported that the relative fecundity and egg size was higher when they were fed 31% dietary protein level of semi moist feed.
- In Nile Tilapia which fed a low protein diet as 17%didn't show oocyte maturation, while females fed 25% protein showed slower oocyte growth and females fed 32% protein levels had early oocyte growth and maturation.
- Supplementation of 0.1% Tryptophan in the diet of Ayu resulted in a significant increase in the serum testosterone level advancing the time of spermiation in males and induced maturation of females.

Lipid:

Lipid plays an important role in spawning and also its one of the energy source in fish. In addition lipids in particular fatty acids have been shown to affect teleost's pituitary gland, which regulate gonadal hormone, and steroids sex levels. In addition, PUFA also regulate eicosanoid production, particularly prostaglandins, which are involved in several reproduction processes, including the production of steroid hormone and gonadal development such as ovulation.

Example:

- Elevation of Dietary lipid level from 12% to 18% in the broodstock diet of rabbitfish (Siganus guttatus) resulted in an increase in fecundity and hatching rate.
- Fecundity in Seabream(Sparus aurata) was found to increase significantly with an increase in dietary n-3 HUFA level up to 1.6%.

Carbohydrate:

Carbohydrates are another important energy sources for the terrestrial animals reproduction, but it is not a primary energy source for Aquatic animals since fish cannot digest it effectively but the level is also less significant when compared to other elements. There is no publication in the role of carbohydrate on the reproduction development of the fish due to its less significance.

Vitamins:

Vitamins are essential for the maintenance of health and growth of fish and act as a cofactors or substrate in some metabolic reaction, and they are required in relative small amounts. Vitamins A, C, and E are known to affect spawning of fish. The vitamin contents becomes more important as the females get older.

Example:

- Vitamin E or a-tocopherol is an essential substance for growth and reproduction of fish. A deficiency of tocopherol leads to an inferior state of development of carp ovaries, resulting in increased moisture content, and reduced fat and protein content of the ovaries.
- In Ayu a reduced alpha-tocopherol level in the broodstock diet caused low survival rates of egg to eyed stage and hatching.
- Vitamins also caused reduced sexual coloration and reproductive activity in Nile tilapia.

Minerals:

Minerals are also take place in the spawning of fishes but not in the high level when compared to other nutrients. The reproductive performance of fish not studied thoroughly. Only limited studies are done in this area.

Example:

- Chromium of 400ug/kg of diet
- Zinc of 30mg/kg of diet

These two elements increase egg production and egg weight of the species.

10. ENVIRONMENTAL FACTORS:

Environmental factors like,

- Temperature,
- Light,
- Water currents and Rain,
- Hormonal Influence

Are controlling factors for the spawning of fish.

Temperature:

- There is an optimal temperature range for spawning of culturable fishes.
- Critical temperature limits exist, above and below which fish will not reproduce.
- Warm temperature plays a primary role in stimulating the maturation of gonads in many fishes. Temperature has a direct effect on gonads, regulating their ability to respond to pituitary stimulation and effects on primary synthesis and release of gonadotropins.
- Major carps breed within a range of temperature varying from 24-31°C.

Light:

- Light is another important factor controlling the reproduction in fishes.
- Enhanced photoperiodic regimes result in early maturation and spawning of fishes like *Fundulus, Oryzias*, etc.
- *Cirrhinus reba* attains early maturation when subjected to artificial day lengths longer than natural day even at low temperature.

Water currents and Rain:

- Rheotactic response to water current is well established in fishes.
- Fresh rain water and flooded condition are the primary factors in triggering the spawning of carps.
- The sudden drop in the level of the electrolytes in the environment caused by the heavy monsoon rains induces hydration in the fish and stimulates the gonads resulting in its natural spawning.
- Successful spawning of fishes has been induced on cloudy and rainy days, especially after heavy showers.

Hormonal Influence:

- Gonadotropins have been found to increase during spawning and decrease afterwards.
- Due to the presence of females, there is an increase in gonadotropin level in males.
- FSH and LH have been reported to influence gonadal maturity in carps.

11. EFFECTS CAUSES DUE TO THE VARIOUS FACTORS:

The various factors causes effects mainly in the

- Incubation of egg.
- Larvae of egg.

Incubation of egg:

- Eggs are one of the most thermally sensitive life stages in fishes and tolerance limits appear to be within ± 6°C of the spawning temperature for many species.
- Small increases in temperature can dramatically increase egg mortality, especially in tropical species.
- Gametogenesis is highly temperature-sensitive in many fish species and breeding may cease before critical thermal limits for egg survival are reached.
- Increased temperature during ovulation can reduce gamete viability and because increased temperature during embryogenesis increases mortality
- Temperature also has a highly significant effect on the rate of embryonic development. For many species, the rate of embryonic development more than triples for each 10°C increase in temperature (i.e. $Q_{10} > 3$).An increased developmental rate means that the incubation period declines as average water temperature increases.
- Incubation period is also dependent on egg size, with larger eggs taking longer to develop than small eggs
- Consequently, increased temperature may advance hatching by minutes to hours in small eggs, and by hours to days in large eggs, with the effects being most marked in cold-water species with long incubation periods.

Larvae of eggs:

- Temperature affects metabolism, growth, developmental rate and stage duration of larval fishes.
- Metabolic rate, measured as mass-specific oxygen consumption, increases sharply with increasing temperature in larval fishes, although responses vary considerably among species.
- Higher metabolic rates mean that fish have higher basal energy demands at higher temperatures.
- Larval growth rates also increase with temperature for both temperate and tropical species, with temperature explaining up to 89% of variation in growth rates among cohorts of some species.
- The larval growth rates will tend to be maintained as water temperatures increase as a result of global warming, even if temperatures exceed optimum conditions for some other life processes.
- In warmer water, developmental rates increase and therefore stage durations are shorter in some of the species.
- The time until yolk absorption, metamorphosis and pelagic larval duration (PLD) are all negatively correlated with temperature, both within species and among species.
- In one of the clearest examples of this effect, PLD of reef fishes is closely correlated with temperature in a range of species.
- There are also strong correlations between PLD and growth rates, with fast-growing larvae often exhibiting shorter larval durations.
- The relationship between growth rate and PLD will influence size at settlement, which is often variable between cohorts because these rates are not perfectly reciprocal and because growth also depends on a range of other factors such as food supply.
- Across a broad range of species, the slope of the relationship between PLD and temperature is steepest in cool-water species, and small increases in water temperature might be expected to have the greatest effect on high-latitude species.
- However, even among tropical fishes, PLD can decline by 4–8% per °C, which could have a significant effect on survivorship.
- Within the temperature range currently experienced by reef fishes, warmer years generally appear to favour good recruitment events for a variety of species, which is consistent with the hypothesis that reduced PLD tends to increase larval survivorship.
- Furthermore, larvae require more food at higher temperatures to sustain higher metabolic rates.

12. CONCLUSION:

There are many factors have been identified as factor influencing spawning, egg quality and reproductive performance of fish. All of the factors are play a vital role in the spawning, egg composition, gonadal development, egg quality and reproductive performance of fish directly and indirectly. All the factors mentioned above should be in a limit range for successful reproduction.

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