Using Life History to Determine Optimum Placement of Marine Reserves

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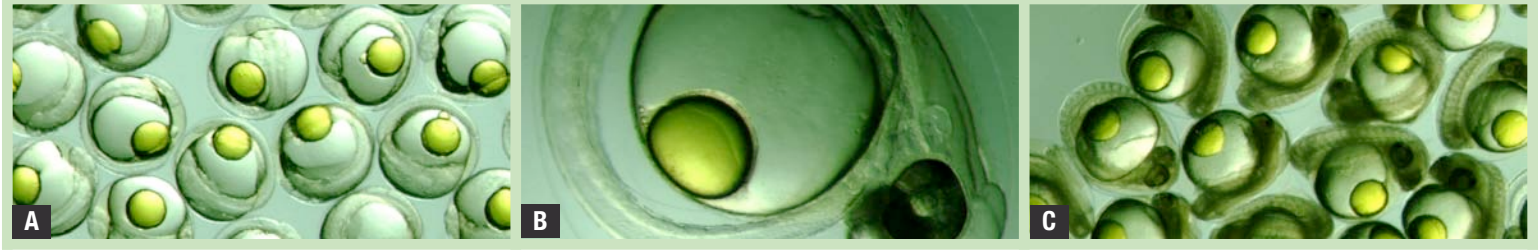

Summary

Relative to a handful of other rockfish species, widow rockfish are a strong candidate for marine reserve protection. To a lesser extent, so are aurora and yellowtail rockfishes. Because of their particular reproductive patterns, darkblotched rockfish and Pacific ocean perch are not. These conclusions are the results of a study funded by the California Department of Fish and Game and are relevant to the state's Marine Life Protection Act.

Widow rockfish were said to be the strongest candidate for marine reserve protection because of their age-related reproductive patterns, in which females gain fecundity as they age. This fecundity is in part the result of when older females spawn (earlier in the season, when plankton production is at a peak.) The older females also tend to have larger oil globules, making larvae less vulnerable to starvation. Such maternal age effects were most strikingly pronounced in widow rockfishes, less so in aurora and yellowtail rockfishes. The pattern was absent in darkblotched rockfish and Pacific ocean perch.

"Female widow rockfish just get better with age," explained the project's leader, UC Santa Cruz professor Steven Berkeley, a pioneer in rockfish studies who died of cancer in June 2007. He was 60. Marine reserves could protect these older, larger animals from being harvested, he believed.

Project

The "big-fat mamma" hypothesis – that older, bigger females produce more viable offspring than younger ones – was originally used to describe the reproduction of a shallow-water species, the black rockfish. This study attempted to expand the hypothesis to shelf and slope rockfishes by asking: Do older females give birth earlier in the season and do their larvae have higher rates of survivorship than those from younger fish?

Method

Scientists collected 1,285 mature female rockfishes in California and Oregon, representing eight different species of the genus *Sebastes*, including aurora, chilipepper, darkblotched, greenstriped, olive, widow and yellowtail rockfishes, as well as Pacific ocean perch.

The ovaries were examined to document their developmental stage. The eggs and larvae were also photographed through a dissecting microscope to measure the yolk and oil globule volumes. (The yolk feeds the developing embryo. The oil globule, in contrast, is the source of food for the developing larva, which initially is unable to forage on its own.)

In addition, each fish was measured, weighed and aged by examining the otoliths (ear bones). The liver was also weighed to determine the fish's energy reserves.

Objectives

Timing – The first objective was to determine whether older fish give birth earlier in the season than younger ones. To do this, scientists developed a model for estimating the date of parturition (birth) based on the stage of the extracted eggs or larvae. They then looked for patterns with age, within species.

Among the eight species studied, widow rockfish displayed the strongest age-modulated timing of parturition. That is, there was a strong correlation between a widow rockfish's age and when she released larvae. As with the shallow-water species, the oldest, largest widow rockfish were predicted to give birth earliest in the season. Conversely, the youngest, smallest females were predicted to be the last to release larvae. Yellowtail and aurora rockfish showed a similar, though less striking pattern.

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Age-modulated parturition was not observed in darkblotched rockfish, Pacific ocean perch or chilipepper rockfish. However, the chilipepper rockfish data were dominated by one year-class, and therefore the pattern cannot be considered conclusive. There were also insufficient data spanning the entire spawning season for greenstriped and olive rockfishes, and so meaningful conclusions cannot be drawn for these species either.

Larval Quality – The scientists made two significant assumptions in their attempt to evaluate larval quality as a function of maternal age. One was that oil globule volume at birth could serve as a proxy for larval quality. The second was that they could estimate what the oil globule volume would have been at birth, based on observed rates of yolk and oil globule depletion over time.

This method, however, did not reveal any correlation between maternal age and larval quality for widow or yellowtail rockfish, though both of these species showed age-related parturition.

There was, however, a correlation between maternal liver weight (a measure of energy reserves) and oil droplet size for these two species. Steve Parker, the co-investigator on the project (now a biologist at the National Institute of Water and Atmospheric Research in Wellington, New Zealand) said the pattern suggests that females are giving some of their energy reserves to their larvae. Larvae may utilize this extra energy prior to parturition; or it is possible that oil globule volume is too simplistic a model for measuring maternal age effects, Parker said.

Conclusions

The results of this study suggest that marine reserves – if properly sited and of sufficient size – could enhance the long-term sustainability of widow, yellowtail and aurora rockfishes because marine reserves allow a natural age structure to develop, protecting the big-fat mamas from fishing. In contrast, because darkblotched rockfish and Pacific ocean perch showed no maternal age effects, they would benefit less from marine reserve protection.

Age-modulated parturition does not appear to be universal to *Sebastes* species and likely depends on the challenges each species faces in successfully reproducing.

Oil globule size may not be the only functional link explaining higher survivorship in larvae from older, larger rockfishes. Future research will need to examine other mechanisms that older mothers may use to increase the survival of their offspring.

* Deceased

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Steve Parker

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(Front) David Stafford, UCSC (Back portrait) Michael Schirripa

Stages of Chilipepper Rockfish Larvae:

Refer to images on front

A 26 days to parturition
B 19 days to parturition
C 18 days to parturition

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