

Introduction to the symposium on rockfishes

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The genus *Sebastes* is derived from a predominantly tropical family, yet represents an important component of shelf and slope fish faunas of temperate and subarctic regions. Although ecologically important in many habitats, most *Sebastes* spp. have reproductive and early life history features that are rather poorly understood. Understanding the dynamics of the reproductive process and the ecology of early life history stages is essential to knowledge of fisheries exploitation, stock dynamics and aquaculture. Recent research on the genus has modified our thinking about reproduction, particularly related to energetics and mechanisms involved in the live-bearing mode of reproduction. Equally significant advances have been made in our understanding of the early life history of many species.

This publication is the result of a seminar entitled 'Rockfishes of the genus *Sebastes*: their reproduction and early life history' convened to bring together scientists interested in these topics and to share the different scientific approaches taken in North America and Japan. In this introduction, we make some brief comments on the genus and describe the development of the different research approaches.

The ecological importance of *Sebastes* is evident from its speciose nature. With a center of distribution in the North Pacific, this genus has the greatest diversity on the west coast of North America (about 69 species), followed by the waters of Japan and south to Taiwan (about 32 species), the North Atlantic (some 4 species), and in the Southern Hemisphere (at least 1 species). Species range from small, short-lived shallow-water fishes, such as *S.*

emphaeus (Moulton 1975), to large, long-lived, very abundant, shoaling fishes such as *S. marinus*, *S. alutus* and *S. entomelas*. These latter species are commercially exploited, but fisheries for *Sebastes* have not typically been success stories: worldwide catch declined from 768,481 metric tons (t) in 1976 to 483,733 t in 1986 (FAO 1977, 1988). During this time interval, the U.S. catch decreased from 17,144 to 10,325 t and the Japanese catch decreased from 54,310 to 2006 t. A dramatic case in stock decline is that of the Pacific ocean perch, *S. alutus*, for which biomass estimates of the west coast stock decreased from 144,000 to 13,500 t from 1958 to 1975 (Ito et al. 1987). The decline of catch in the northeast Pacific is now well documented (Bracken 1987), as are declines in biomass of northwest Atlantic species. The alarming reduction in the Japanese catch, combined with increased interest in coastal fisheries after the establishment of 200 mi exclusive economic zones in the mid-1970s, prompted aquaculture research on *Sebastes* with the goal of releasing hatchery-raised juveniles to enhance depleted stocks in coastal waters (Sakai et al. 1985). In the United States and Canada, by contrast, management measures, often including closure of fisheries, have been instituted (Gunderson 1984). There are clearly concerns by U.S. and Japanese scientists, among others, about the status of *Sebastes* stocks.

Diversity in reproductive biology characterizes the family Scorpaenidae, which has some 60 genera and 330 species in 8 subfamilies. Many of the subfamilies are distributed in tropical and subtropical regions from deep to shallow waters. Seven of the subfamilies are characterized by a strictly ovipa-

rous reproductive mode, with external fertilization and development of eggs. In the Sebastinae, however, internal fertilization seems to be the rule. This subfamily has been reviewed by Barsukov (1981), and his system of phylogeny, although disputed by many taxonomists, clearly demonstrates the complexity of the subfamily. Four genera are typically recognized, with 2 species of the most primitive (and poorly known) *Hozukius*, 13 of *Helicolenus*, 3 of *Sebastiscus*, and approximately 103 of *Sebastes*. *Sebastiscus* has been called a subgenus of *Sebastes* by Barsukov & Chen (1978), but most continue to recognize it as a genus. *Sebastes* seems to be the most highly derived genus in the subfamily, if not in the family, from both evolutionary and reproductive standpoints.

The reproductive mode in *Sebastes* has in the past been characterized as unspecialized lecithotrophic viviparity (ovoviviparity). After mating and copulation, fertilization occurs within the ovary; embryos are brooded for approximately 1 month, and birth (also referred to herein as either spawning or parturition) occurs with the release of relatively undeveloped embryos or larvae, 3–9 mm long. The contrast with matrotrophic viviparity, wherein the embryos receive additional nutrition during gestation, has been questioned by recent research (Shimizu & Yamada 1980, Boehlert & Yoklavich 1984, Boehlert et al. 1986). Nutritional relationships of embryos are of great evolutionary significance and have an important bearing upon our understanding of reproduction in fishes. There are further implications, moreover, for questions of fishery management (Garrod & Horwood 1984), because reproductive energy costs in this genus may be higher than previously thought.

Variability in reproduction may lead to implications for survival at the early life history stages as well. *Sebastes flavidus* appears to deposit less lipid energy reserves in El Niño years (Lenarz & Echeverria 1986); this could conceivably lead to either reduced fecundity or less fit larvae. After parturition, early life history stages of *Sebastes* are planktonic, in some cases in excess of 1 year. The effects of environmental variation on reproduction and the role of the maternal system in post-parturition survival is thus an important concern.

An intimate knowledge of the reproductive process is required for aquaculture of any species, both for brood stock management and rearing of larvae. Similarly, knowledge of early life history and ecology is important, especially when juveniles are released to the wild, as in stock enhancement. Lack of such knowledge may have impeded early attempts at enhancement of cod stocks in the United States and Europe (Shelbourne 1964). High densities, for example, can lead to increased aggression in territorial species of *Sebastes* (Hoelzer 1987). Combined knowledge of reproduction and early life history can increase capabilities in the areas of both fisheries and aquaculture.

Studies on reproductive biology and early life history of *Sebastes* have been conducted for many years in both the United States and Japan, but the motivations for the studies differed somewhat and thus led to different approaches. For both countries, the importance of *Sebastes* in marine fisheries served a major role in stimulating research. The secondary motivations, however, relate to aquaculture potential in Japan and basic ecology pertinent to fisheries management in the United States. The two countries also have different approaches to coastal marine fisheries resources; Japan has developed an energetic aquaculture industry to replenish coastal resources while the United States has concentrated on natural production and management of stocks. An examination of pertinent publications demonstrates the differences between research approaches in Japan and North America (the United States and Canada). Research papers on *Sebastes* in North America have been dominated by the topics of biology, systematics, fisheries and ecology and, to a lesser extent reproduction, physiology and food science (Fig. 1a). Japanese publications, on the other hand, have been dominated by reproduction, physiology, biology, systematics and, to a lesser extent, aquaculture, ecology and fisheries. In North America, early research was principally on systematics and basic biology, whereas studies in fisheries and ecology have increased over recent decades (Fig. 1b). A major goal of the seminar on reproduction and ecology of early life history in *Sebastes* was to join

the separate strengths of U.S. and Japanese investigators.

The role of fisheries in research on *Sebastes* in North America began on the east coast, where depleted stocks of redbfish, *S. marinus*, led to convening one of the first international symposia on the genus (Trout 1961). As west coast fisheries on rockfish took on increasing importance, directed fisheries research on *Sebastes* developed (Phillips 1964). The abundance of larvae was recognized as important from early studies of the California Cooperative Oceanic Fisheries Investigations (Ahlstrom 1961). Ecological studies arose from the many species of *Sebastes* and their importance in coastal ecosystems, particularly on the west coast, resulting in studies on all phases of the life history: ecology of pelagic larvae and juveniles (Ahlstrom 1961, Moser & Ahlstrom 1978), reproduction (Moser 1967, Boehlert & Yoklavich 1984), behavior and ecology of adults (Larson 1980) and ecology and energetics of benthic juveniles (Boehlert & Yoklavich 1983). The importance of many species to fisheries and the effects of declining stocks also prompted research (Gunderson & Sample 1980) and attempts to understand recruitment dynamics (Mearns et al. 1980, Norton 1987). Interest in the genus thus continues.

In Japan, the commercial importance and peculiar reproductive features of *Sebastes* and *Sebastes* attracted the interest of many investigators. Earlier studies were conducted with some commercially important species on development of embryos and larvae (Fujita 1957, Shiokawa & Tsukahara 1961), age, growth and maturation (Mizue 1957, Harada 1962), reproductive cycles including gametogenesis (Igarashi 1968) and larvae and juveniles (Sasaki 1976, Hoshiai 1977). After the depletion of coastal stocks of rockfishes became apparent, efforts were first directed to construction of artificial shelters for restocking coastal species, based on their ecological and behavioral characteristics in relation to their habitats (Hatanaka & Iizuka 1962, Yamagishi et al. 1984). Establishment of 200 mi economic zones in the late 1970s pushed the Japanese fisheries administration to take more active measures; that is, aquaculture production of young fish to be released into the open sea was

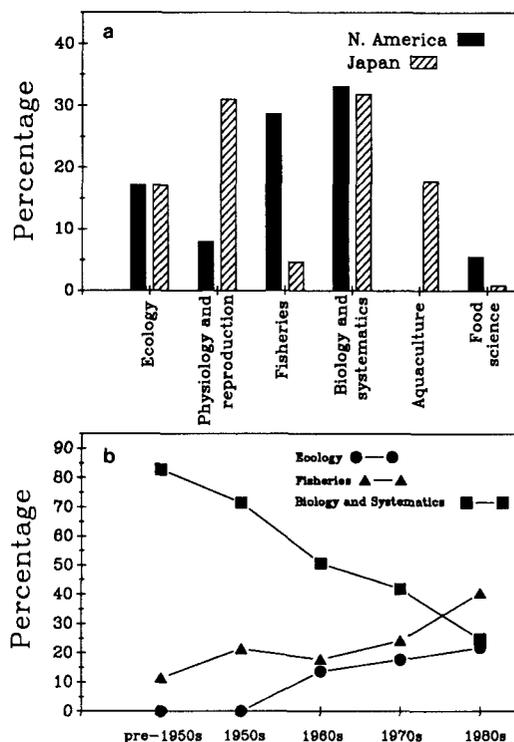


Fig. 1. (a) Differences in research effort on *Sebastes* in North America and Japan as shown by publications, and (b) changes in the disciplinary research effort of North American researchers over time. Data for North America are based upon 456 references from Leet & Reilly (1988); those from Japan are based upon 129 references from Ikehara & Kobayashi (1989). Papers were selected on the basis of having *Sebastes*, *Sebastes* or rockfish in the title. Papers were assigned to the disciplines by content of the title.

encouraged. The main target species were *Sebastes schlegeli* and *Sebastes marmoratus*, with *Sebastes thompsoni* and *S. inermis* in some local areas. Much of the early research on *S. schlegeli* was done at the Hokkaido Institute of Mariculture (Kusakari et al. 1977), and further research activities extended to other laboratories (Ikehara et al. 1980). The aquaculture of *Sebastes marmoratus* was developed in southern prefectures (Ohgami et al. 1979). Based largely on materials available from aquaculture facilities were studies on the reproductive mode (Ouchi et al. 1978, Takemura et al. 1989), ultrastructure of embryos (Shimizu & Ya-

mada 1980), lipid metabolism (Shimma & Tsujigado 1983), temperature tolerance (Ouchi 1977) and ontogeny of immune systems (Nakanishi 1986). Fieldwork on larvae (Kuwahara & Suzuki 1983) and juveniles (Sakai et al. 1985), the latter directed at understanding movements of tagged fish, also has been pursued to better understand ecological requirements of these Japanese species.

The research papers presented in this volume bring together a wide variety of complementary research in the field of reproduction and early life history in *Sebastes*, allowing us to broaden the scope and implications of our studies while identifying future opportunities for collaborative work. Research approaches and, often, goals may differ between the two countries, as noted above. The strengths of each, however, are mutually beneficial. With the cooperative approach fostered by this publication, we hope to bring together these two bases of knowledge and provide significant interchange and continued communication.

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Sebastes inermis from Japan: a male (right) and female during courtship; the male's mouth gaped, all of his fins expanded, and posterior half of his body quivered in front of the female; the female's swollen abdomen is noticeable. Photograph by O. Ezaki.