

Reproductive Colorations, Paternal Behavior and Egg Masses of Kelp Greenling, *Hexagrammos decagrammus*, and Whitespotted Greenling, *H. stelleri*

Abstract

Males and females of *Hexagrammos decagrammus*, a northeastern Pacific greenling with striking sexual differences in fundamental color patterns, exhibit different sexual dichromatisms during courtship. Males of *H. decagrammus* and its congener, *H. stelleri*, defend benthic adhesive eggs against conspecifics and other fishes. Males often simultaneously tend > 1 mass of spawn; circumstantial evidence suggests that these eggs are the clutches of > 1 female.

Introduction

The kelp greenling, *Hexagrammos decagrammus*, inhabits shallow rock reefs from the Aleutians to southern California (Eschmeyer *et al.* 1983) and contributes significantly to shore, skiff and scuba recreational fisheries, particularly in northern California (Frey 1971) and Puget Sound (Barker 1979). The whitespotted greenling, *H. stelleri*, a smaller and less exploited species, inhabits coastal rocky and vegetated regions (Hart 1973) from Puget Sound to northern Japan (Eschmeyer *et al.* 1983).

Little has been published on the reproductive biology of either species to complement Kendall and Vinter's (1984) recent review of the larvae of these and other hexagrammids. *Hexagrammos decagrammus* spawns masses of blue eggs during the fall in British Columbia (Hart 1973) and Puget Sound (Patten 1980), and during late summer farther north (Gorbunova 1970). Feder *et al.* (1974) inferred winter spawning in southern California, because of springtime observations of planktonic larvae and benthic juvenile recruits. *Hexagrammos stelleri* also spawns clusters of blue eggs (Hart 1973) during late summer-winter, depending on latitude (Gorbunova 1970, Hart 1973, Barker 1979, Patten 1980). In this paper I provide new information on spawned eggs and clutches, spawning substrates, and reproductive colorations and paternal behaviors of these two hexagrammids.

Study Areas and Methods

Most observations of *Hexagrammos decagrammus* were made during October-December 1972 and November 1973 at natural and artificial rock reefs in Puget Sound and adjacent waterways and during December 1973 and December 1974-January 1975 at natural reefs off Cannery Row, Monterey, California. The physical characteristics and biotas of these areas are described by DeMartini and Anderson (1980). Additional observations were made off Mitchell, Eagle and Limestone Points on San Juan Island, Washington (48° 30' N, 123° 05' W) during October-December 1972. Underwater observations were made using SCUBA at depths of 0-15 m (Washington) and 5-10 m below MLLW (Monterey). Incidental observations were made at 9-25 m depths on a submerged seamount off Point Buchon (35° 15' N, 120° 54' W) in central California during December 1976. Some low intertidal spawns in Puget Sound were surveyed while emergent during nighttime minus tides.

Observations of *H. stelleri* were made during October 1972 in the cove immediately offshore of the Friday Harbor Laboratories (FHL) of the University of Washington on San Jan Island, Washington (see Shimek, 1983, for habitat description). Observations of *H. stelleri* were made in and near an eelgrass (*Zostera marina*) bed at depths of 3-16 m.

SCUBA observations were made during 0930-1630 h (PST) when lateral underwater visibilities exceeded 3 m. Notes were recorded on plastic slates and later transcribed to permanent records.

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The Washington and Monterey observations I describe complement detailed field studies of the population ecology and mating system of another hexagrammid, *Oxylebius pictus* (DeMartini and Anderson 1980, DeMartini 1985).

Observations

Reproductive Colorations and Spawn Tending

Kelp greenling. On dives of 5 December 1974 and 1 January 1975 at Monterey, I observed two different male *Hexagrammos decagrammus*, both engaged in interactions with a gravid-appearing female. When first sighted at 1000-1300 h, the males and females were on the bottom, within .5-m distance of each other, on inclined surfaces of reef. One pair was adjacent to two masses of *H. decagrammus* spawn, both in early (unpigmented) developmental stages, that were nestled amongst encrusting epifauna. In both instances, the male mostly lacked the fundamental male color pattern illustrated by Eschmeyer *et al.* (1983: Plate 22); instead, each was uniform, dark slate-grey on its anterior, as well as posterior trunk. The typical pattern of blue, stellate spots (outlined in reddish-brown) was especially pronounced on the head region of the males. (Such "spawning" coloration has been noted previously by Hart, 1973, from aquarium observations.) The eyes of both males had a conspicuous, unusually bright golden sheen. Both females also lacked the fundamental pattern of uniform, small reddish-brown spots (Eschmeyer *et al.* 1983); trunk coloration of the females was dominated instead by numerous, large (several cm-wide) dark-brown blotches.

Male *H. decagrammus* were observed tending from one to six masses of spawn on seven other occasions off Monterey. Twenty-one male *H. decagrammus* were observed tending from one to ten (mean = 4.5) masses of spawn at reefs in Puget Sound and near San Juan Island, Washington. Spawns were found over the range of depths surveyed off Monterey and at depths from +1 to -14 m in Washington waters. Neighboring masses within male broods were adjacent to 1.9 m apart. Water temperatures were 9-12°C.

Hexagrammos decagrammus eggs were usually deposited among encrusting epifauna, often

the empty valves of the large barnacle, *Balanus nubilus*. At Buchon Reef, one mass of spawn was sequestered between the branches of a colony of living hydrocoral, *Allopora californica*, at 15-m depth. A minority of all egg masses were laid directly on rock substrate.

All solitary male *H. decagrammus* observed tending spawn on reefs off Monterey and Washington had the usual male color pattern illustrated by Eschmeyer *et al.* (1983). On two occasions in Puget Sound, a male did not retreat when I approached with 1-2 m of the spawn it was tending, and maintained its fundamental sexual dichromatism.

Tending and nontending male *H. decagrammus* were seen chasing conspecific males on Puget Sound reefs. I once saw a nontending male chasing an adult copper rockfish, *Sebastes caurinus*, on a reef near San Juan Island during the breeding season. Males maintained their fundamental sexual dichromatism during intra- and interspecific chases.

Whitespotted greenling. The body and fin colorations of male *Hexagrammos stelleri* observed at the FHL cove differed from the typical color pattern illustrated by Eschmeyer *et al.* (1983: Plate 22). On dives of 14 October 1972 (1230-1400 h) and 22 October 1972 (1520-1630 h), I saw seven male *H. stelleri*. Individuals were recognized by differences in body size and location within the eelgrass bed. One male was noted attacking another male. Four fish circled me aggressively; and two males bit my facemask. One of the latter fish (ca. 30 cm total length, TL) chased a female *H. decagrammus*. This male was guarding seven masses of spawn at a depth of 8 m. Six masses had been laid among the branches of a red alga (*Aghardiella* sp.), and the other was nestled in the holdfast of a laminarian kelp, < 10-cm distant. Another fish (a mature male 25 cm TL, collected by spear and sex confirmed by dissection) was guarding three masses of spawn at 7 m. All eggs had been spawned in branches of the red alga *Prionitis* sp. Both guardian fish had unusually dark bodies, noticeably dusky pelvic and anal fins, and each had a conspicuous black blotch on the anterior dorsal fin. The sexually monomorphic white spotting characteristic of the species (Ruttenberg 1970, Eschmeyer *et al.* 1983) was present on the body and head of both males. Water temperature was 10°C.

Spawn Characteristics

Kelp greenling. Thirty-two discrete golf ball- to tennis ball-sized masses of benthic adhesive eggs were collected from substrates near paternal male *Hexagrammos decagrammus* at reefs in Puget Sound and near San Juan Island, Washington. The number of eggs present in each mass was determined by wet gravimetric method (Bagenal and Braum 1971) to the nearest mg. Egg number varied from 1,580-9,660 (mean = 4,340; SD = 1,760) for these 32 spawns. Eggs (including capsules) ranged from 2.2-2.5 mm (mean = 2.3 mm) in diameter and 6.8-8.7 mg (mean = 7.6 mg) live weight. Each mass of *H. decagrammus* spawn tended by an individual male usually differed in yolk coloration (from rose, green, and blue, to grey) and developmental stage. Fertilized eggs contained numerous, small whitish to yellow-orange oil globules. Older masses of spawn often had a luxuriant diatom epiflora. Embryos required about 30 days to progress from pre-germ ring stages to hatching when held in the laboratory at 10°C.

Whitespotted greenling. The ten masses of *Hexagrammos stelleri* spawn contained from 1,200-5,200 embryos each (mean = 3,460; SD = 1,060). Eggs ranged from 2.0-2.5 mm (mean = 2.2 mm) in diameter and 5.2-7.1 mg (mean = 6.4 mg) live weight. Egg masses differed in yolk coloration (ranging from green, blue, and violet, to grey) and stage of embryonic development. The numerous, small oil globules ranged from pale straw to golden in color. Embryos required about 30 days to hatch at 10°C.

Discussion

Territorial Spawn Tending and Reproductive Colorations

Male *Hexagrammos decagrammus* are both inter- and intraspecifically territorial (Barker 1979, this study). Male defense of spawn and spawning sites has been described for several other eastern Pacific greenlings (lingcod, *Ophiodon elongatus*: Lariviere *et al.* 1981 and references; painted greenling, *Oxylebius pictus*: DeMartini and Anderson 1980, DeMartini 1985) and is suspected for hexagrammids in general (Gorbunova 1970).

The courtship colorations of male and female *H. decagrammus* are sexually distinct variations

of the species' fundamental sexual dichromatism. *Oxylebius pictus* also has both fundamental and socially modified sexual dichromatisms (DeMartini 1985).

Adult male and female *H. decagrammus*, like adult *O. pictus* (DeMartini and Anderson 1980, DeMartini 1985), segregate by habitat and depth in Puget Sound (Moulton 1977, Barker 1979). Perhaps intersexual competition for resources as well as sexual selection has contributed to the evolution of striking sexual dichromatisms in hexagrammids (DeMartini 1985).

Spawning Substrates

Most spawns of *Hexagrammos decagrammus* and all of the relatively few spawns of *H. stelleri* observed were laid on three-dimensional biological substrates. Rugose substrates probably provide more secure attachment sites for eggs and increased protection from oophagous fishes. Data are insufficient to evaluate whether any biological substrates are preferred over bare rock surfaces.

Egg Masses

The discrete nature of masses of *Hexagrammos decagrammus* and *H. stelleri* spawn, plus the usually distinct yolk coloration and developmental stage of each mass, strongly suggest that each mass is contributed by a different female. The sizes and average numbers of eggs present in *H. decagrammus* and *H. stelleri* spawns resemble those of several other similar-sized *Hexagrammos* spp. (Gorbunova 1970), which is consistent with this hypothesis. Each mass of eggs represents a female clutch in *Oxylebius pictus* (DeMartini and Anderson 1980). If this relation exists for *H. decagrammus* and *H. stelleri*, males often fertilize and tend the eggs of many females in multiple-clutch broods, as is typical for *Hexagrammos* spp. (Gorbunova 1970). Studies of female fecundity are needed to substantiate this for *H. decagrammus* and *H. stelleri*.

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