Submersible Observations on Lingcod, *Ophiodon elongatus*, Nesting Below 30 m off Sitka, Alaska

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Introduction

Lingcod, *Ophiodon elongatus*, is an important sport and commercial species throughout the northeast Pacific and is the target of a developing troll fishery in southeast Alaska. Male lingcod are nest-guarders and are especially susceptible to harvest during the nest-guarding period. The Alaska Department of Fish and Game has protected some shallow-water spawning grounds, but the extent of spawning below 30 m is unknown.

Lingcod are lithophils (Balon, 1975); nest sites are usually in cracks or crevices in rocky habitat, often in areas of high current (Cass et al., 1990). Nests are reported in shallow water, generally < 36 m (Low and Beamish, 1978; LaRiviere et al., 1981; Bargmann, 1982), and Jewell (1968) noted a greater density of nests in shallow water. Cass et al. (1990) reported that spawning occurs in British Columbia and Washington in nearshore areas with high current. Previously, anecdotal information suggested nests occur in deeper waters. Miller and Geibel (1973) and Cass et al. (1990) proposed that nests occur in deep water because ripe males were caught on hook-and-line gear in waters deeper than 30 m. The occurrence of ripe males does not confirm the presence of nests, however. Males enter spawning condition before females do, and not all mature males successfully defend a territory and spawn.

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ABSTRACT—A research submersible was used to delineate the depth distribution of lingcod, Ophiodon elongatus, *nests (egg masses) below 30 m. Although nests were not seen deeper than 97 m, behavior and dark coloration distinctive of nest-guarding lingcod were seen as deep as 126 m. Males guarding nests were distinctly colored, i.e., dark with little or no mottling, and most were obviously scarred. Two types of guarding behaviors were observed: 1) Males lying directly on or beside the nest and remaining nearly motionless unless touched and 2) males lying on a sentry post and defending the nest when other fish swam close.*

Male lingcod move into shallow water and begin defending territories prior to spawning, whereas females migrate into the area to spawn and then return to deeper waters (Cass et al., 1990). Ova are deposited and fertilized in layers. Once spawned, the eggs are sticky, adhering to each other and the rock substrate. Individual ova are 3.5 mm in diameter; the entire egg mass may be from 3 to 65 l in size (Cass et al., 1990). The male guards the nest from predation by fishes and invertebrates throughout the incubation period which lasts about 7 weeks (Cass et al., 1990). Miller and Geibel (1973) found that the nest-guarding period lasts through March in California, whereas in British Columbia the majority of eggs hatch by mid-April (Low and Beamish, 1978). Later hatching is reported in areas of lower currents (Giorgi[1]).

Male lingcod are territorial throughout the nest-guarding period. This behavior makes them extremely susceptible to harvest, and once males are removed from the nest, the nest is usually lost to predation (Low and Beamish, 1978). This, in turn, can cause overharvest of local stocks because adult movement is limited and their reproductive mode does not promote geographic dispersal of young (Cass et al., 1990).

To protect nest-guarding males from harvest, the Alaska Board of Fisheries recently (1991) enacted a regulation for a winter-spring closure of commercial fishing for lingcod inside a line running along the outer coast of southeast Alaska. This line, termed the "surf line," runs from point to point between major headlands. Most of the water inside the closed area is less than 30 m deep. This closure was based on the understanding that lingcod nests occur primarily in shallow water, as reported in the literature. For area closures to be effective, a knowledge of the depth distribution of nests is important. I used a submersible to document both the distribution of lingcod nests below 30 m and the characteristics and behavior of nest-guarding fish.

Methods

I used the two-person submersible *Delta* to make 21 dives between 30 and 145 m to delineate the depth distribution of lingcod nests. The *Delta* is a 4.7 m submersible operational to 345 m with a cruising speed of 1.5 knots. The M/V *Jolly Roger* provided support facilities for the submersible.

The timing of the survey depended on the availability of the submersible. Commercial fishery data suggest that peak spawning occurs in late February

[1] Giorgi, A. E. 1981. The environmental biology of the embryos, egg masses and nesting sites of the lingcod, *Ophiodon elongatus*. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Northwest Alaska Fish. Cent., Seattle, WA, Proc. Rep. 81-06, 107 p.

and early March in southeast Alaska (D. Gordon[2]), and I have observed lingcod nests, while scuba diving, in Sitka Sound through the last week in May. The submersible was only available during the later part of the nesting season; consequently, our field work was conducted from 21 through 30 April, 1992.

The study was conducted off the coasts of Kruzof and southern Chichagof Islands in southeast Alaska (lat. 135°25' – 136°05' W, long. 56°50'-57°31'N) (Fig. 1). Commercial fishing locations were used to pick dive sites. The marine geology in most of the outer coast sites is predominately rocky: Lava pavement is interspersed with bedrock, boulder fields, and rocky outcrops. Poor weather forced us to spend 2 days diving in Slocum Arm and interior Sitka Sound. Bottom habitat in these areas is generally silt and mud bottom, occasionally interspersed with rock outcrops.

Initially line transect methods (see O'Connell and Carlile, In press, for details) were used. However, due both to the scarcity of nests and their cryptic placement, I abandoned line transect methods in order to increase the probability of finding nests. The submersible was run at a slow speed (0.5 knots) close to the bottom. The observer looked for nests and lingcod through the starboard porthole. When a lingcod was sighted, the submersible pilot would alter course to slowly cruise a 100 m^2 area surrounding the lingcod to look for the presence or absence of a nest. The external lighting on the submersible was changed as necessary to illuminate holes and crevices. When a nest was found, information on volume, size, and condition was recorded, as were description of the lingcod's behavior, coloration, size, and the surrounding habitat. Sizes were visually estimated with the aid of two fixed laser beams. I assumed that all lingcod in close association with nests were male. Observations were recorded on both audio and 8 mm video tape; photographs were taken with an externally mounted Photosea[3] camera and a hand-held 35 mm camera with synchronized flash.

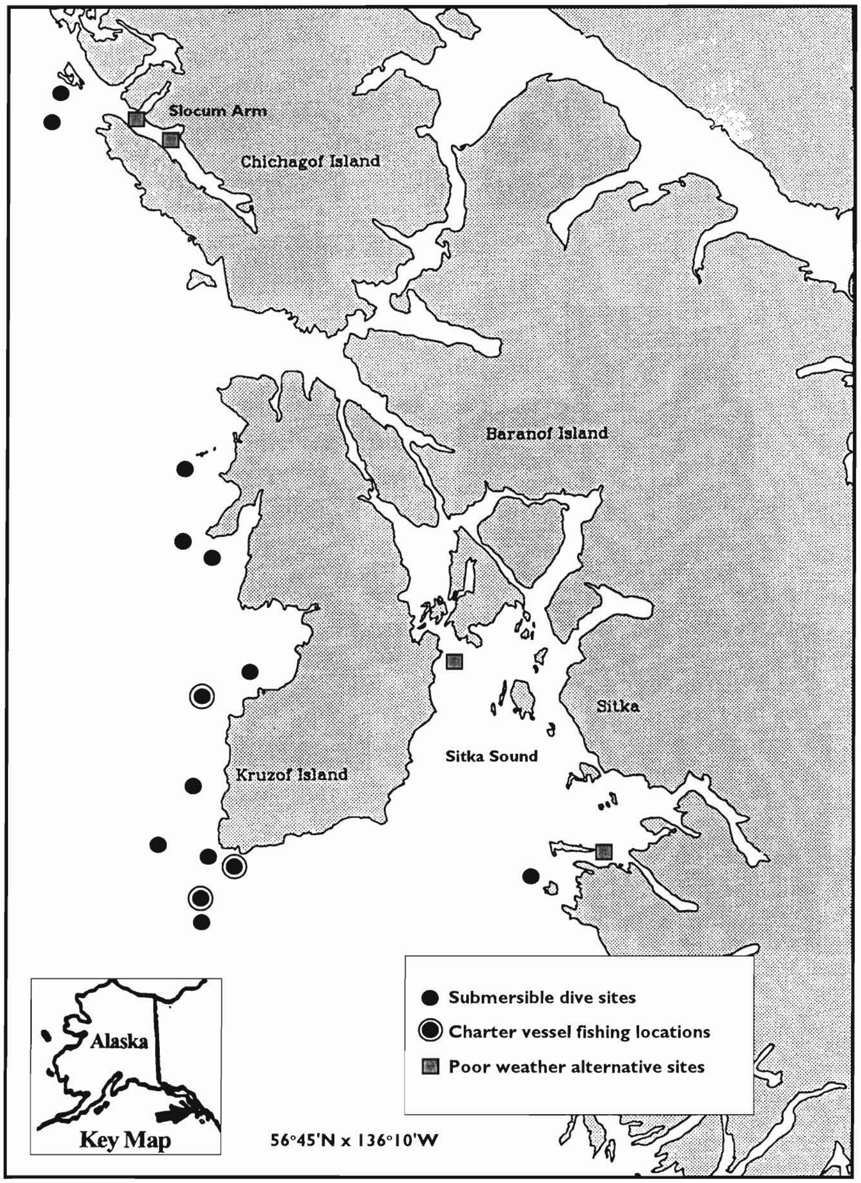

Figure 1.—Lingcod nesting study area, submersible dive locations, and charter vessel sample locations, April 1992, southeast Alaska.

A commercial troll vessel, the F/V *I Gotta*, was chartered to collect lingcod sex ratio and stage of maturity data for three areas surveyed by the submersible (Fig. 1). The vessel fished an area immediately following the completion of submersible transects in that area. The skipper was trained to determine lingcod sex and classify maturity stages as ripe, spent, or immature. Fish that were not readily identified as ripe, spent, or immature were recorded as "other."

Results

Fourteen dives were completed in rocky areas assumed to be typical of lingcod nesting habitat; poor weather forced us to make seven dives in areas

[2] Gordon, D. Alaska Dept. Fish and Game, 304 Lake Street, Room 103, Sitka, AK 99835.

[3] Reference to trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA, or the ADF&G.

predominated by silty bottom, generally uninhabited by lingcod. Thirteen nests were found during the 21 survey dives. Additionally, I saw three other lingcod that exhibited both behavior and coloration characteristic of the nesting males seen (Table 1). Horizontal visibility was excellent in the outside water sites (>15 m) and poor in Slocum Arm and interior Sitka Sound (<4 m). The average water temperature was 7.5° C.

Description of Nests and Nest Locations

Nests were found at depths between 33 and 97 m. The occurrence of nests was low, and 31% of the nest observed showed obvious signs of hatching. Most of the nests were small, between 0.5 and 2 l, and some were remnants of hatched nests. The largest nest (approximately 6 l) was also in the deepest water (97 m), although a trend of increasing nest size with depth was not apparent. Nests were deposited either in narrow, vertical cracks between angular boulders, under overhangs of boulders, or in V-shaped cuts within lava flows. Two nests, however, were deposited in small depressions on the rim of a large lava bowl; in both cases the guarding males were small, approximately 60 cm, and were lying directly on top of the eggs.

Table 1—Description of nests and nest-guarding lingcod observed during April 1992, southeast Alaska.

Approx. Nest Volume (l)	Depth (m)	Est. Size (cm)	Comments
3.0	30	None observed	Some hatching
0.5	30	75	Fish on nest, lava flow
1.0	33	95	Fish aggressive
0.3	40	75	Nest hatched
0.5	41	95	Fish on nest, boulders
1.0	42	60	Nest on rim of bowl, some hatching
1.0	45	60	Nest on rim of bowl, some hatching
2.0	54	95	Sentry post, vertical crack
2.0	57	95	Nest in vertical crack
Not observed	57	95	On ledge, sentry behavior
2.0	65	60	Under flat boulder
2.0	65	Same fish as above	Fish was 5 m away, guarding two nests
0.5	80	60	Under flat boulder
Not observed	84	95	In cave, territorial
6.0	97	115	Under round boulder
Not observed	126	80	In cave, aggressive and territorial

Description of Males and Fish Behavior

All but one of the nests observed were guarded by a lingcod. I saw one site where a single male was guarding two nests: The nests were 5 m apart, and the male was settled between the two and would swim slowly around both nests every few minutes. Nest-guarding males displayed two general behavior patterns. In the first, males were either directly above or next to the nest and remained virtually motionless as we approached; they would only move off the nest site if we physically touched them with the submersible or manipulator arm. Once the fish moved off the nest, it would generally circle back around even if we did not move away.

In the second type, males were observed on sentry posts, generally a ledge or high rock outcrop in the general vicinity of the nest. Usually these positions were within a line of sight of a nest. Some posts were 5-10 m away from the nests. The male would lie on the sentry post, and if any fish swam into the immediate area, it would aggressively chase them out of the area, circle back, visually check the nest, and finally return to the sentry post.

I observed one male for about 20 minutes. The fish was on a sentry rock about 3 m above the nest. The nest was deposited in a vertical crack between two huge boulders. While I observed the fish, a yelloweye rockfish, *Sebastes ruberrimus*, and another lingcod moved into the nest area. The nesting male chased these fishes out of the area aggressively and even bit at the yelloweye rockfish. It then returned to the nest, first lying vertically along the side of the nest with just its head protruding beyond the nest. The fish then laid directly above the nest, where it observed the submersible for about 5 minutes. Afterwards it moved back to the sentry post. It repeated this sequence of events three times while we watched.

I observed a variation in size and coloration of lingcod during the survey. Fish ranged from approximately 30 cm to 115 cm. Coloration ranged from dark gray with little mottling to tan with much mottling (Fig. 2). All of the individuals guarding nests were dark, with little or no mottling, and almost all had obvious scarring on the head and dorsal areas (Fig. 3). Coloration was not site specific; for example, at one offshore pinnacle I observed approximately even numbers of mottled vs. dark lingcod. The sex ratio of lingcod taken by the chartered troller in this areas was 56% males and 44% females, of which 27% were spent females and 25% were ripe males.

I observed one lingcod at 126 m that exhibited dark coloration, scarring, and territorial behavior typical of the nest-guarding males observed in this study. This fish was lying at the entrance to a cave and did not move off until the submersible bumped it. It then swam slowly off behind the submersible. At this point a yelloweye rockfish swam into the cave and up toward the ceiling. A moment later the lingcod returned, hesitated at the cave entrance, then rapidly swam toward the cave ceiling. The lingcod chased the rockfish out a back opening to the cave and then returned to it's original position at the cave entrance.

Interactions with Other Species

One of two offshore pinnacles surveyed rose steeply up from 126 m to 34 m, the other from 126 m to 61 m. In both, huge boulders were piled around the base and lower portions of these pinnacles. These areas were heavily populated by lingcod (both males and females), yelloweye rockfish, and prowfish, *Zaprora sileneus*. The prowfish inhabited caves and overhangs in close proximity to nesting lingcod and in some cases actually resided in the same space as lingcod, but no aggression or predation between the species was observed. Nest-guarding

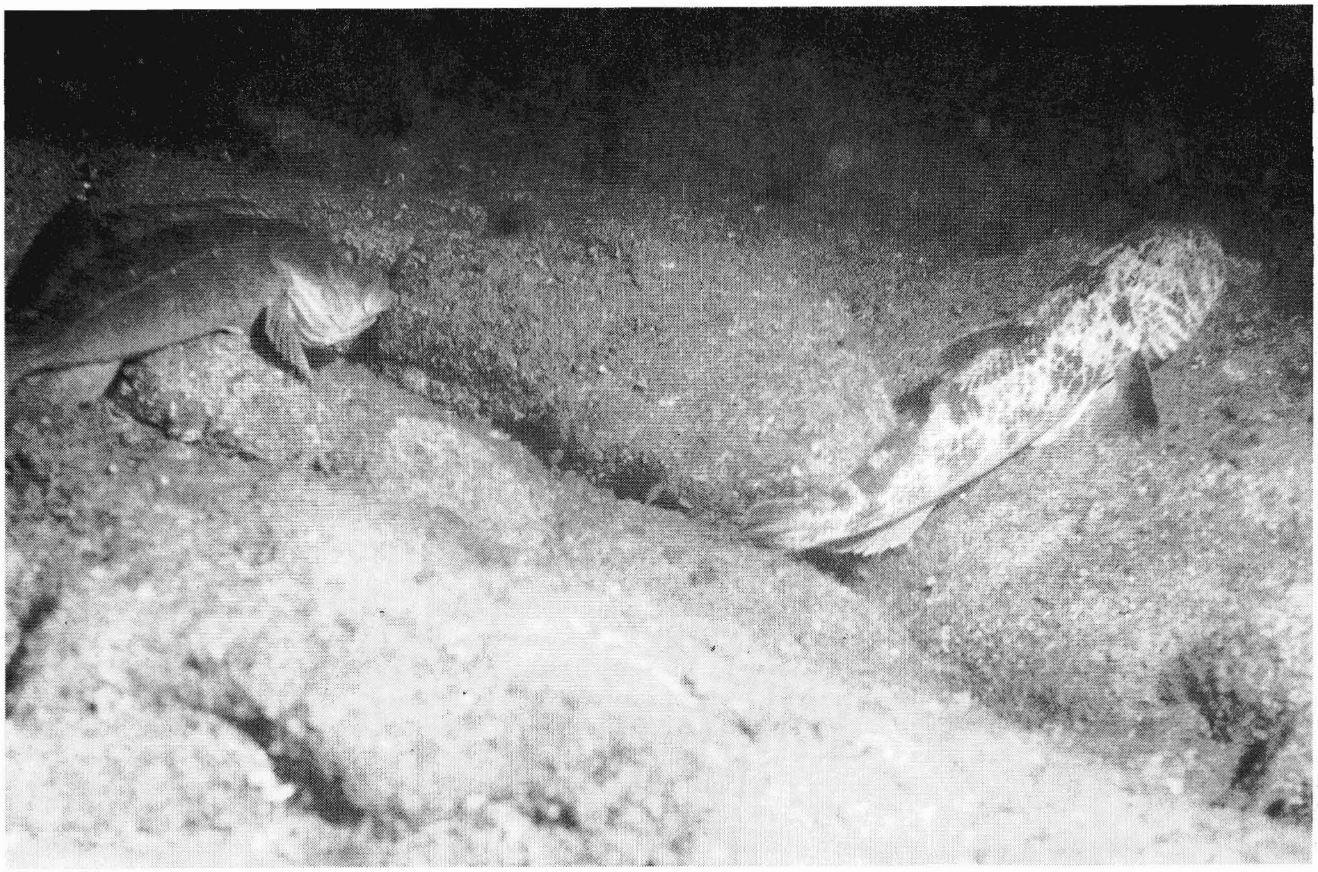

Figure 2.—Lingcod exhibiting both types of coloration observed during lingcod nesting study, April 1992, southeast Alaska.

lingcod did chase other lingcod, yelloweye rockfish, and greenlings, *Hexagrammos* spp., swimming near nests. Local fishermen have reported both female lingcod and yelloweye rockfish full of ingested lingcod eggs. Conversely, schooling fishes, such as black rockfish, *S. melanops*, were observed near lingcod nests but the nesting lingcod seemed undisturbed by their presence.

Invertebrate predators, primarily the carnivorous gastropods *Amphissa columbiana*, *Fusitriton oregonensis*, and *Searlesia dira* were observed on several lingcod nests. I do not know if the snails were eating lingcod eggs or organic matter that may have settled onto the nest. Octopus, *Octopus dofleini*, occurred in most of the rocky habitats surveyed, and in several cases they occupied caves in close proximity (<5 m) to lingcod nests.

Discussion

Some behavior observed in this study differs from previous in-situ studies of nesting lingcod. Low and Beamish (1978) reported that nest-guarding males are usually found within 1 m of their nest. Although some of the fish I observed in this study were directly over or beside their nest, several of the fish were seen lying on sentry posts up to 10 m from the actual nest site.

The coloration of nest-guarding males needs further investigation. Color may vary by season; however it is not clear whether this dimorphism is sexual or related to stage of maturity. Of the fish sampled by the charter vessel for sex ratio, the skipper noted that the females were usually mottled with lighter coloration, and the ripe males exhibited dark coloration and skin scarring. The immature males sampled did not differ as noticeably from females. The scarring I observed probably results from aggression against other fish, although head scarring may also result from rock scratches obtained while picking predatory gastropods off nests. Local fishermen have reported male lingcod with large quantities of snail shells in their stomach during the nesting season.

The literature suggests that sexes segregate seasonally by depth. Females reportedly move into shallow water to spawn and then move back to deeper water, whereas males remain in shallow water (Cass et al., 1990). After spawning, the dispersal of female lingcod back to deep water may be related to prey availability. I found both nest-guarding males and female lingcod residing in close proximity, and in one deep-water area, the sex ratio (of mature fish) was almost equal. It is pos-

Figure 3.—Nest-guarding lingcod exhibiting dark coloration and head scarring, April 1992, southeast Alaska.

sible that the determining factor for distribution of nests is the presence of suitable habitat in areas of high current (Low and Beamish, 1978; Giorgi[1]). In highly productive areas, such as offshore pinnacles, the availability of suitable nesting sites near excellent feeding grounds may make it unnecessary for females to migrate elsewhere.

Many of the nests observed were partially hatched, and it is possible that the majority of nests had hatched prior to the survey. The low numbers of nests were not solely a factor of depth, as shallow transects also had few nests. Our commercial catch data (based on the percent of ripe males in the landings) indicates that late April to early May is the end of the nesting period on the outer Kruzof coast, and our scuba observations indicate that it is the middle of the nesting period in inside waters. The low numbers of nest observed in this survey may reflect the effects of the higher than average water temperature during the winter and spring of 1992; the 5-year average temperature for mid-April is 5.7°C, 2°C lower than the average in 1992 (National Weather Service, Juneau, Alaska, data).

Although a versatile tool, the submersible's size, the cryptic placement of some lingcod nests, and the ruggedness of the observed nesting sites, made it impossible to sight all nests along a transect. Thus, while I was unable to calculate the density of nests by depth, I have extended the known depth range of lingcod nests. Previous studies report lingcod nests in shallow water (Wilby, 1937; Jewell, 1968; Miller and Geibel, 1973; Low and Beamish, 1978; LaRiviere et al., 1981; Cass et al., 1990; and Giorgi[1]). I found lingcod nests as deep as 97 m and found indirect evidence of nests as deep as 126 m. Although a nest was not actually observed at 126 m, the coloration of the lingcod seen was typical of nesting males I observed elsewhere, as was its behavior. The nest-guarding behavior of the lingcod I observed was similar to that described by Low and Beamish (1978). They also reported that males discontinued territorial behavior and left the nesting areas a few days after hatching of the eggs; this information tends to support the conjecture that the lingcod seen at 126 m was nest-guarding.

In conclusion, depth may not be the limiting factor in distribution of lingcod nests. Given the extension of the depth range for lingcod nesting sites, fisheries managers will need to reevaluate the effectiveness of depth-specific closures for protecting nest-guarding lingcod. Additional research is needed to determine the difference in spawn timing, nest density, and hatching success at various depths. The value of protecting the deep-water component of the nest-guarding population could then be weighed against the economic importance of the winter-spring fishery. In the interim, it seems prudent to impose a total seasonal closure of the fishery because the reproductive behavior and early life history of lingcod make local stocks vulnerable to overfishing.

Acknowledgments

The National Undersea Research Program's West Coast National Undersea Research Center provided use of the submersible *Delta* and the support ship *Jolly Roger*. I would like to thank Rich Slater and the crews of the *Delta* and the *Jolly Roger*; Deidra Holum, Bev Richardson, Gary Gunstrom, and Preston O'Connell for their field assistance; Gordon Kruse and David Carlile for their comments on the survey design; and Eric Jordan, skipper of the F/V *I Gotta*. David Gordon deserves special thanks for his assistance in scuba diving and providing lingcod spawn timing information from his commercial fishery observer reports. Two anonymous reviewers provided helpful suggestions.

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