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MATURATION OF THE CALICO SCALLOP, *Argopecten gibbus*, DETERMINED BY OVARIAN COLOR CHANGES [1]

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ABSTRACT:: Ovarian color was described for the calico scallop, *Argopecten gibbus*, by sizes and seasons from May 1970 to October 1971 on the Cape Canaveral grounds, Florida. Seven stages of ovarian development were recognized primarily by color and sequence of development and graded from immature to ripe to spent. Scallops as small as 20 mm shell height can be ripe. There were distinct changes in developmental stage by season. Most scallops were ripe from January to May; in August, large scallops were spent or developing and small scallops were immature. Based on seasonal occurrence of ripe and partially spawned scallops, spawning extended primarily from about November to July and was intense from January to May. There was no spawning in August. Variations occurred in the spawning pattern between years.

The calico scallop, *Argopecten gibbus*, a benthic marine mollusk found in the western North Atlantic Ocean, is most abundant at depths from 28 to 65 m (15 to 36 fm). Commercial beds of the calico scallop are fished off North Carolina and off the east and west coasts of Florida (Allen and Costello, 1972).

The biology of the calico scallop was studied by the Bureau of Commercial Fisheries, Tropical Atlantic Biological Laboratory (now National Marine Fisheries Service, Miami Laboratory) from 1969 to 1971. One objective of the study was to describe color changes in ovarian tissue of the calico scallop and to relate those changes to maturity of the ovaries. Ovarian color was then used to recognize and delimit the following aspects of maturation:

(1) rate of development;
(2) developmental stages by season; and
(3) spawning.

Other factors that might influence ovarian color were also determined.

Color changes in scallop ovaries with maturation and spawning have been reported previously. In the sea scallop, *Placopecten magellanicus*, the sexes are separate; the ovaries are brilliant coral red when ripe, pale pink when partially spent, and clear when spent (Posgay and Norman, 1958). Posgay *et al.* (1962) listed the following stages of development by ovarian color for the sea scallop:

Stage I: Immature, sexes indistinguishable, gonads translucent.
Stage II: Immature, developing, light pink.

[1] Contribution Number 80-11M, Southeast Fisheries Center, National Marine Fisheries Service, NOAA, Miami, FL 33149.

Stage III: Immature, orange-pink to orange-red.
Stage IV: Mature, ripe, coral-red.
Stage V: Mature, partially spent, color still bright.
Stage VI: Mature, spent, sexes difficult to distinguish, dull gray-orange.

Color was also used to describe ovarian development in the hermaphroditic bay scallop, *Argopecten irradians*, a species closely related to the calico scallop. Belding (1910) reported that with development the ovaries change "from an indiscernible pink to a deep orange color." According to Gutsell (1931), the ovaries are pink or red when ripe. Costello *et al.* (1957) reported that the ovaries were bright orange-pink when ripe and pale after spawning. Castagna and Duggan (1971) found that ripe ovaries were reddish-orange, although black epithelium sometimes obscured the initial color change of the ovaries. Sastry (1963) distinguished the following stages of development by ovarian color:

Stage I: Immature, sexes indistinguishable, transparent.
Stage II: Immature, sexes indistinguishable, translucent.
Stage III: Immature, pale orange.
Stage IV: Mature, ripe, bright orange.
Stage V: Mature, partially spent, pale orange.
Stage VI: Mature, spent, sexes indistinguishable, light brown.

In the hermaphroditic calico scallop, Roe *et al.* (1971) observed that ovarian color changes occurred with maturation. Undeveloped ovaries were whitish, resting ovaries whitish-yellow, maturing ovaries yellow-orange, and ripe ovaries bright reddish-orange. They noted that:

"Yellow-orange coloration was seen in very few scallops during the August cruise, but by September the rate and incidence of color change was highly noticeable. Coloration and incidence increased into fall and winter and by February ovaries were predominantly reddish-orange or ripe. The majority of ovaries taken in April were bright reddish-orange. June ovaries were largely uncolored."

From the progression of color changes, Roe *et al.* (1971) concluded that the maturation period "begins in August and ends in March or April."

Ripe calico scallops, which had orange-red ovaries, were induced to spawn in the laboratory and produced viable eggs, larvae, and juveniles (Costello *et al.* (1973).

METHODS

A study site for calico scallops on the Cape Canaveral grounds, Florida, designated Buoy 2, was established at latitude 28°49.1'N and longitude 80°29.0'W in a depth of 22m (12 fm) (Figure 1). A scallop bed located immediately west of Buoy 2 was sampled seasonally by two 5-min tows of a 3m (10 ft) otter trawl (trynet) equipped with a double-tickler chain between the trawl doors. Buoy 2 was the primary source of scallops for the ovarian color study, and 11 samples were obtained there from May 1970 to October 1971 (Figure 2). Each sample contained at least 10 scallops selected over the size range of those caught, except that for July 1970, which contained 9 scallops. In May, June, and August 1971, each sample included 10 additional scallops less than 41 mm shell height is a straight line measurement of the greatest distance between the umbo and the ventral margin) to establish minimum size at maturity. The live scallops were opened 1 to 2 hours after capture and the color of the ovaries was observed. In March 1971, an additional 10 scallops were kept alive in running

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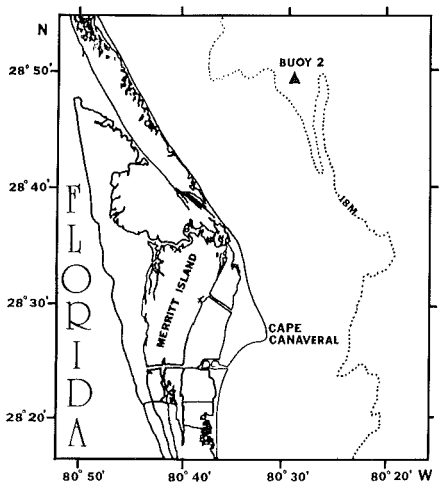

Figure 1. Location of calico scallop sampling site at Buoy 2 off Cape Canaveral, Florida.

seawater for about 16 hours after which the ovaries were compared to those examined soon after capture. Additional, random observations of ovarian color were made on small and large scallops collected at several sites on the Cape Canaveral scallop grounds. To follow development through time of live individual scallops, the ovarian colors were observed through the gaping valves of the live scallops.

We recognized that for comparing ovarian colors, a standard would be required. The standard we used was the Pantone Color® Specifier, [2] which designates color by number, not by name. The color names we apply to the Pantone numbers do not follow a previously established system. When the ovaries were parasitized, or of a drab color, *i.e.*, lacking orange or red pigments, we did not assign a Pantone number.

[2] Designers Edition of the Pantone Matching Systems of Pantone, Inc., New York, N.Y. Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

RESULTS

Relation of Ovarian Color to Developmental Stages:

By reference to work of earlier investigators and from our laboratory and field observations, we were able to relate ovarian color to maturation stages. As points of departure we observed the color and texture of ovaries of:

(1) young, immature scallops raised from the egg in the laboratory;
(2) ripe scallops before they spawned in the laboratory and produced healthy, viable eggs;
(3) those same scallops (2) after they partially spawned in the laboratory;
(4) young, immature scallops in the field;
(5) small, mature scallops which had recently spawned and were in a spent condition;
(6) ripe scallops in the field; and
(7) those same scallops (6) after they partially spawned in holding tanks in the field.

The ovarian colors distinguished in our samples were taken over an 18-month period, May 1970 to October 1971, and are shown by shell height by season in Figure 2. The colors were initially separated into four groups: (1) drab, with ovaries lacking orange or red pigmentation; (2) brownish-orange, Pantone 156-158; (3) reddish-orange, Pantone 163-165; and (4) dark orange-red, Pantone 170-172.

An additional color may indicate infection of scallops by nematodes or trematodes. Dissection of a scallop gonad colored irridescent orange revealed that gonadal tissue was destroyed and that the ovary and testis were occupied by more than 50 reddish, immature nematodes (unidentified). Bisexual differentiation by color was obliterated. The irridescent color was not identifiable to any Pantone color and was easily distinguishable from that of normal ripe

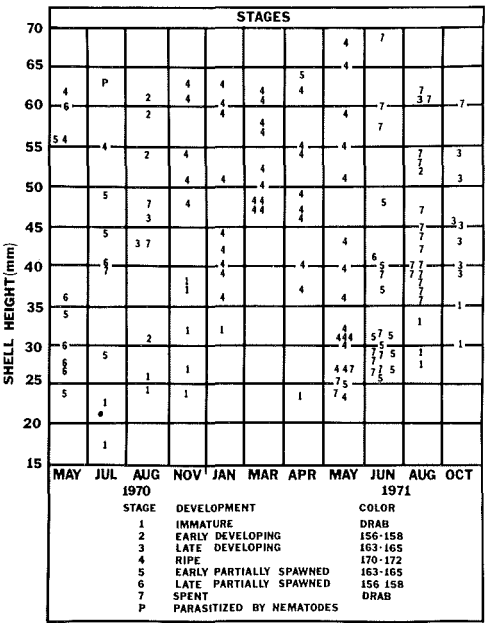

Figure 2. Ovarian colors, developmental stages, and sizes of calico scallops from Buoy 2 off Cape Canaveral, Florida, May 1970 to October 1971.

scallop ovaries (Figure 3). The parasitic infection prevented interpretation of ovarian development by color in some specimens. A nematode, *Sulcascaris sulcata*, has been reported from the gonads of calico scallops by Lichtenfels *et al.* (1978) but these authors did not mention associated color changes in the scallop gonads. However, similar color changes have been observed in Gulf of Mexico mollusks infected by trematode sporocysts (Dr. E.W. Cake, Jr., Gulf Coast Research Laboratory, pers. comm.).

Based on our knowledge of calico scallop life history, and from scallop samples taken sequentially at Buoy 2, we were able to follow the maturation cycle of age groups and distinguish between developmental stages having the same color. We found that, except for dark orange-red, which represented a single developmental stage (ripe), the remaining ovarian colors (drab, brownish-orange, and reddish-orange) each represented two developmental stages which could, however, be separated into single stages.

Drab ovaries of the calico scallop, like the bay scallop (Sastry, 1963), represented two stages, the beginning and end of maturation. Drab ovaries represented the immature stage of juvenile scallops and the spent stage of mature scallops. We were able to distinguish the spent stage from the immature stage in late spring and summer by our knowledge of scallop size and growth.

Brownish-orange ovaries represented two stages well-separated in time. The early developing stage occurred in the fall following the spent stage of summer; the late partially spawned stage occurred just before the spent stage, in late spring and early summer.

Reddish-orange ovaries represented two stages: the late developing stage occurred in late fall or early winter just before the ovaries became ripe; the early partially spawned stage (Figure 4) occurred after partial spawning and near the end of the spawning season in late spring and summer. Since we observed this color following partial spawning in the laboratory and field, and very few scallops were seen with this color from January to April, we concluded that reddish-orange (early partially spawned) rapidly reverts to dark orange-red (ripe).

From the above information, we established seven stages of ovarian development for the calico scallop:

Stage 1: Immature, drab,
Stage 2: Early developing, brownish-orange (Pantone 156-158).
Stage 3: Late developing, reddish-orange (Pan tone 163-165).
Stage 4: Ripe, dark orange-red (Pantone 170-172).
Stage 5: Early partially spawned, reddish-orange (Pantone 163-165).
Stage 6: Late partially spawned, brownish-orange (Pantone 156-158).
Stage 7: Spent, drab.

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Table 1. Ovarian development stages of calico scallops (by percent) from Buoy 2 off Cape Canaveral, Florida, May 1970 to October 1971.

Developmental Stage and Color		1970			1971						
		May	July	Aug.	Nov.	Jan.	Mar.	Apr.	May	June	Aug.	Oct.
Stage 1:	Immature, drab*.	0	25	20	50	10	0	10	0	0	15	20
Stage 2:	Early developing, brownish-orange, Pantone 156-158.	0	0	40	0	0	0	0	0	0	5	0
Stage 3:	Late developing reddish-orange, Pantone 163-165.	0	0	20	0	0	0	0	0	0	5	70
Stage 4:	Ripe, dark orange-red, Pantone 170-172.	20	12	0	50	90	100	80	80	0	0	0
Stage 5:	Early partially spawned, reddish-orange, Pantone 163-165.	30	38	0	0	0	0	10	5	45	0	0
Stage 6:	Late, partially spawned, brownish-orange, Pantone 156-158.	50	12	0	0	0	0	0	0	5	0	0
Stage 7:	Spent, drab.	0	12	20	0	0	0	0	15	50	75	10
Total Percent		100	99	100	100	100	100	100	100	100	100	100

*Lacking orange or red pigmentation, so not assigned a Pantone number.

These developmental stages were used to determine scallop maturation as related to rate of development, season, and spawning.

Rate of Development:

We determined changes in ovarian development with time, based on field and laboratory observations. Scallops changed from early developing to late developing in 8 to 14 days. We speculate that scallops can change from late developing to ripe within a month. From ripe to early partially spawned takes place within 12 hours. Even after spawning for several hours, scallops can remain early partially spawned, rather than changing to late partially spawned. We speculate further that early partially spawned scallops may rapidly revert to a ripe condition, since in some months there was only a small percentage of early partially spawned scallops as compared with a large percentage of ripe scallops (Table 1). The high percentage of ripe ovaries observed through several months suggests that the calico scallop may be an intermittent spawner, spawning many times during the period it is ripe, as has been indicated for the bay scallop by Castagna and Duggan (1971).

At Buoy 2, calico scallops that set in winter or early spring (1970-71) were ripe, partially spawned, or spent in May 1971 (less than 42 mm shell height); partially spawned or spent in June (less than 48 mm); and generally spent in August (35 to 52 mm) (Figure 2). The above sizes by season were determined from length frequencies of scallops on the bed at Buoy 2 (Miller and Hudson, manuscript in preparation).

The smallest ripe scallop observed was 23.0 mm shell height. However scallops

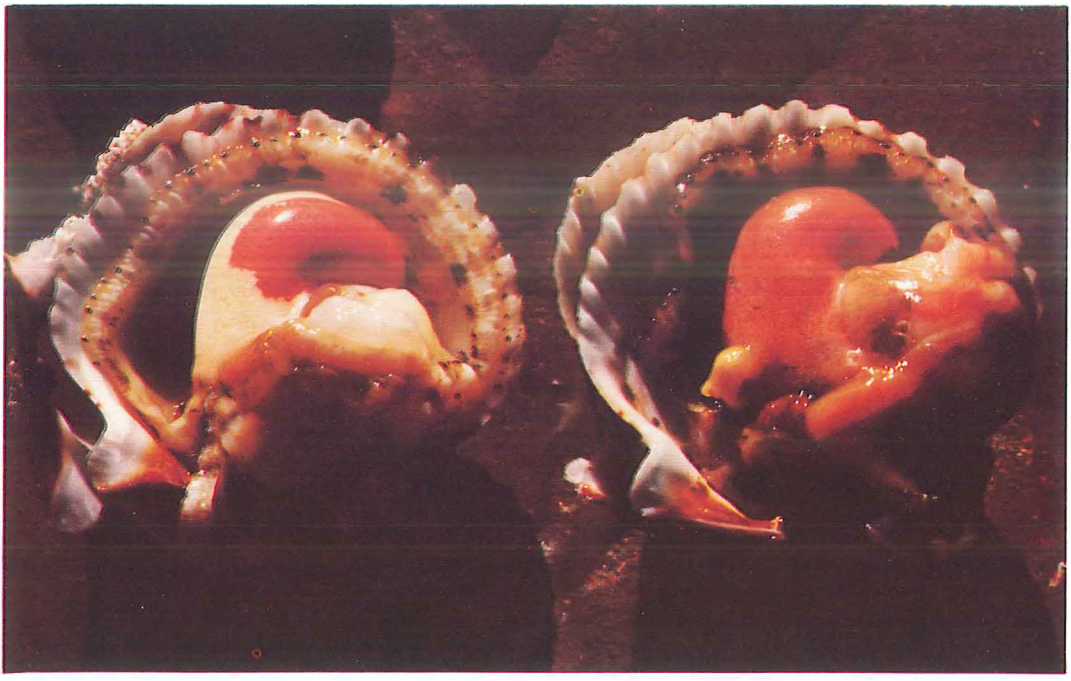

Figure 3. Comparison of normal calico scallop gonad (left) and gonad infected with nematodes (right).

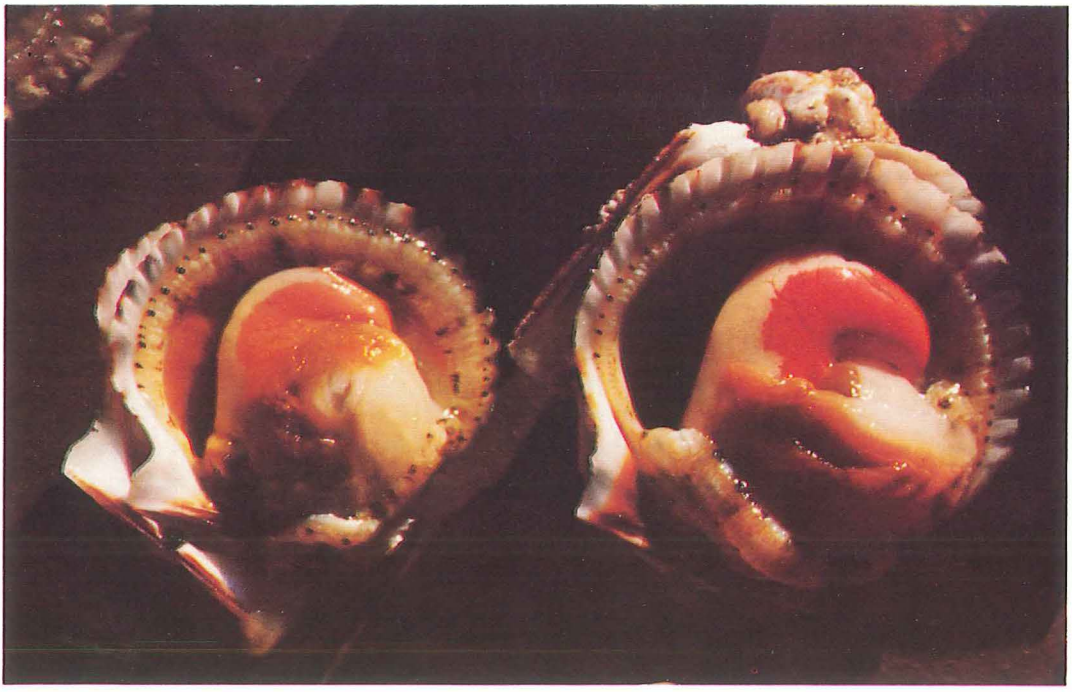

Figure 4. Comparison of ripe, dark orange-red (right) and early partially spawned, reddish-orange (left) calico scallop ovaries.

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19.0 to 21.0 mm were in the late developing stage. Therefore, considering the rate of ovarian development from late developing to ripe, scallops at least as small as 20.0 mm, 71 days old (Allen, 1979), could be ripe.

Developmental Stages by Season:

Calico scallops undergo distinct changes in developmental stages by season. Differences in stages by season between years were perhaps related to environmental variations. Seasonal development from May 1970 to October 1971 is shown in Figure 2 and Table 1; the following observations refer to months of both years. Scallops were ripe, partially spawned, or spent in May. In August, large scallops (35 mm shell height or more) were spent or developing, and small scallops (less than 35 mm) were primarily immature. In October, large scallops (40 mm or more) were generally in the late developing stage and small scallops (less than 40 mm) remained immature. In November, large scallops (45 mm or more) were ripe, and small scallops (less than 45 mm) were immature. In January, nearly all scallops of the older age group were ripe and remained in this condition, except for probable partial spawnings, until May.

Spawning:

While samples were not taken in all months from May 1970 to October 1971, spawning intensity through an annual cycle can be estimated. Calico scallops with ripe and partially spawned ovaries indicated proximity to spawning time (Table 1). Based on percentages of ripe and partially spawned ovaries by month, spawning intensity was apparently highest from January to May, decreased in June and July, and was non-existent in August and perhaps in September. In October, a high proportion of scallops was close to spawning condition. By November, spawning had apparently begun (50% were ripe) and probably increased in December (inferred because 90% were ripe in January).

Scallops that set in winter and early spring will spawn one or more times in spring and early summer at ages 4 to 7 months and will spawn again in winter, spring, and early summer at ages 11 to 18 months. Scallops that set in late spring or early summer will spawn the following winter, spring and early summer at ages 6 to 13 months. A few very old scallops of this late setting may spawn at 18 months of age in early winter.

DISCUSSION AND CONCLUSIONS

There were variations between years in the spawning patterns of calico scallops on the Cape Canaveral grounds. In 1970, only 20% of the scallops were ripe in May, while in 1971, 80% of the scallops were ripe in May. In August 1970, 60% of the scallops were in developing stages, whereas in August 1971, only 10% of the scallops were developing. The difference in rate of ovarian development and time of spawning between 1970 and 1971 may have been due to variations in the annual temperature cycle. For both years, a high proportion of scallops had ripe or partially spawned ovaries from about January to May, indicating major spawning during that time period.

There is evidence that the general seasonal spawning pattern, as determined from our study at Buoy 2, is widespread on the Cape Canaveral grounds. From investigations of calico scallops on the Cape Canaveral grounds in 1967 and 1968, Roe *et al.* (1971) stated "Spawning begins in February or early March and continues to June." Furthermore, in March and April 1970 and 1971, a high incidence of "bright orange-red" ovaries, indicating ripe or early partially spawned scallops, was reported among commer-

cial sized scallops in the Cape Canaveral area by scallop fishermen. In June 1971, scallops sampled over a wide area on the cape Canaveral grounds were observed to be 40 to 60% spent. (Leonard L. May, National Marine Fisheries Service, pers. comm.).

Based on collections of scallop spat (Allen, 1979) and scallop length-frequencies (Miller and Hudson, manuscript in preparation) on the Cape Canaveral grounds, the major recruitment of scallops occurs from about January to June. The recruitment period therefore relates well with the spawning period determined from the annual ovarian developmental pattern.

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