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DEVELOPMENT AND DISTRIBUTION OF *VINCIGUERRIA LUCETIA* AND RELATED SPECIES IN THE EASTERN PACIFIC

By ELBERT H. AHLSTROM AND ROBERT C. COUNTS

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ABSTRACT

Vinciguerria lucetia, family Gonostomatidae, is one of the most abundant pelagic fishes in the eastern North Pacific between the Equator and about 35° N. latitude. It is an important forage fish.

Development is described from the embryonic to the adult stage. The spherical pelagic eggs are moderately small (0.59–0.74 mm.), lack an oil globule, have a segmented yolk and a double shell membrane. The larvae resemble those of the Pacific sardine. The marked metamorphosis has been divided into three stages: prometamorphic, midmetamorphic, and postmetamorphic. Ossification of the vertebral column occurs immediately before metamorphosis. The caudal, dorsal, and anal fins form during the larval period, but procurrent caudal-ray formation is not completed until metamorphosis. Rays do not form in either the pectoral or ventral fins until metamorphosis.

Photophores develop during metamorphosis, at first as white photophores (prometamorphic stage), then as pigmented functional organs. Six or seven pairs of photophores form late, during the midmetamorphic and postmetamorphic stages. Photophore formation is completed and all photophores are pigmented by the end of metamorphosis.

Development is traced from larva to adult for changes in body form, in pigmentation, in sequence of formation of teeth, gill rakers, and other structures.

Distribution of the larvae of *Vinciguerria lucetia* within the area surveyed by cruises of the California Cooperative Oceanic Fisheries Investigations is shown for 2 years, 1951 and 1952. Larvae increase in abundance from southern California to southern Baja California; they are taken throughout the year. The wider distribution in the eastern Pacific, between 14° S. latitude and 35° N. latitude is illustrated, and variation in photophore number with latitude is pointed up. The range in mean number of photophores per side in different localities was from 78.50 to 83.40.

Two other species of *Vinciguerria* occur in the eastern Pacific: *V. nimbaria* and *V. poweriae*. Both occur on the fringes of the area routinely surveyed on CCOFI cruises. Characters used to separate the three species at different stages of development are given.

DEVELOPNENT AND DISTRIBUTION OF *VINCIGUERRIA LUCETIA* AND RELATED SPECIES IN THE EASTERN PACIFIC

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In the extensive area being surveyed routinely in the eastern North Pacific Ocean by the California Cooperative Oceanic Fisheries Investigations (CCOFI), the larvae of three species of fishes commonly occur that might be confused with larvae of *Sardinops caerulea*, the Pacific sardine; these are the larvae of *Vinciguerria lucetia*, *Engraulis mordax*, and *Leuroglossus stilbius*. All three are at least as abundant as sardine larvae, and they often occur together in collections. The larvae of the four species undoubtedly compete for food. In order to be able to recognize the larvae of these four species at all stages of development, even in samples where larvae are poorly preserved, we have made a detailed study of the development of each species. This paper is concerned largely with the development and distribution of *Vinciguerria lucetia*.

Vinciguerria lucetia, family Gonostomatidae, is one of the most abundant pelagic fishes in the eastern North Pacific Ocean; however, it is unlikely that it will ever become a commercially important species. It attains too small a size (2 to 2½ inches) to be esteemed for human food in America. Because of its great abundance, however, it is an important forage fish. This is not entirely speculation; we have examined several stomachs of albacore and skipjack off Baja California and Mexico that were filled with this species alone. Several records of *Vinciguerria*, including the material used by Hildebrand (1946) in describing *V. pacifici* (which we consider to be a synonym of *V. lucetia*), and our record from off the Columbia-Ecuador border, were obtained from stomach contents of tuna.

V. lucetia has a very extensive distribution. We have examined material from the eastern Pacific from 35° N. latitude to about 14° S. latitude. It has been reported from many other regions.

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Although *V. lucetia* is the only species of this genus occurring commonly in the area routinely surveyed on cruises of CCOFI, two other species occur on the fringes of the area: *V. nimbaria* and *V. poweriae*. The latter species has not been reported previously for the eastern Pacific. Characters used to separate the species and records of their occurrence are given in a later section.

We are not attempting a critical review of the species of *Vinciguerria*, as we have seen no material from regions other than the eastern Pacific. This paper will deal principally with *V. lucetia*, but for completeness some attention will be given to the two other species, *V. nimbaria* and *V. poweriae*.

The larvae of *V. lucetia* may not have been described previously. Regan (1916: pl. 5, figs. 6, 7) figured a larva and a metamorphosing individual that he called *Vinciguerria lucetia*. Since these figures show no distinguishing characters, it is impossible to identify the species represented. The larvae of *V. attenuata* and *V. poweriae* were described by Sanzo (1913, 1931). Jespersen and Tåning (1919, 1926) described larvae of *V. nimbaria* (*sanzoi*) and gave excellent descriptions of *V. attenuata* and *V. poweriae* as well. The differences between the larvae of the four species are discussed later in this paper (p. 399).

Most of the material used in this study was collected on cruises of the California Cooperative Oceanic Fisheries Investigations, a program sponsored by the Marine Research Committee of the State of California and carried out cooperatively by the Scripps Institution of Oceanography of the University of California, the Bureau of Marine Fisheries of the California Department of Fish and Game, the California Academy of Sciences, the Hopkins Marine Station of Stanford University, and the South Pacific Fishery Investigations of the United States Fish and Wildlife Service.

Dr. Carl L. Hubbs generously placed at our disposal the extensive collections made on expeditions by vessels of the Scripps Institution of Oceanography, and offered useful suggestions throughout the progress of the work. The illustrations of eggs, larvae, and other stages of *Vinciguerria* were prepared by George Mattson, and the charts and graphs by Andrew M. Vrooman and James R. Thrailkill. Several hundred persons have aided in the collection of material at sea.

Vinciguerria lucetia (Garman)

Maurolicus lucetius Garman, 1899. Mem. Mus. Compar. Zool. (Harvard), vol. 24, p. 242, pl. J, fig. 2 (original description).

Vinciguerria lucetia Brauer, 1906. Deutsche Tiefsee-Exped., vol. 15 (1), pp. 97–98, fig. 40 (material with symphyseal photophores referred to *V. lucetia*; probably mixture of *lucetia* and *nimbaria*). Jespersen and Tåning, 1926. Rept. Danish Ocean. Exped. 1908–1910, vol. 2 (Biology), A 12, pp. 26–29 (comparisons of adult characters of *V. lucetia* with 3 other species). Parr, 1931. Bull. Bingham Ocean. Coll., vol. II, No. 4, p. 11 (a number of records from eastern Pacific between 24°30′ N. and 11°05′ N.). Horsburgh, 1935. Proceed. California Acad. Sci. (4th series), vol. 21, pp. 227–229 (fairly detailed description of *lucetia* based on study of 30 specimens).

All of these references, with the exception of Jespersen and Tåning and Parr contain errors, but all pertain wholly or partly to *Vinciguerria lucetia*. Several errors or omissions occur in the original description of *lucetia*. Branchiostegals are invariably 12, not 9 as reported by Garman (1899); the upper opercular photophore is not mentioned. The symphyseal pair of photophores is not referred to by Garman in the text, but is shown in the figure. The isthmian group is given as 8 per side, hence we assume that the symphyseal pair is included in this count. Brauer (1906) referred 37 specimens from the Atlantic and Indian Oceans to *V. lucetia*. He was dealing with metamorphosing material (12 mm.-17.6 mm. long) in which the lateral series of photophores between ventral and anal fins was incomplete. His material probably was a mixture of *lucetia* and *nimbaria*. The record of Zugmayer (1911: 56, pl. II, fig. 4) is inaccurate; his description and figure apparently refer to *V. attenuata*. Unfortunately, this figure was copied as an illustration of *V. lucetia* by Weber and de Beaufort (1913: 119–120, fig. 44). The record of Gilbert (1908: 237) for the Marquesas Islands (Albatross station 3798) was checked by Horsburgh (1935: 229). A comparison of numerable characters of *V. lucetia* as given by various workers is summarized in table 1. Horsburgh (1935) gave modal and range values of morphometric characters for 22 adults and 8 juveniles. He did not include measurements of individual specimens, so we have not been able to compare his morphometric data with ours. We do not substantiate his observation that no great importance can be attached to the presence or absence of symphyseal photophores. We have never found this pair absent in adults, and consider its presence or absence to be diagnostic in separating *lucetia* and *nimbaria* from *attenuata* and *poweriae*.

TABLE 1.—*Numerable characters of* Vinciguerria lucetia *as reported by various workers*

Character	Garman (1899)	Brauer (1906)	Jespersen and Tåning (1926)	Horsburgh (1935)	Our material
Fins:					
Dorsal	14	13–14	13–14	14–15	13–16
Anal	15	14–15	14–16	14–16	13–17
Pectoral	9	8–9	9–10	10	10
Ventral	7	7	7	7	7
Caudal:					
Principal	—	—	19	—	19
Secondary	—	—	7–9+4–5	—	7–10+4–5
Gill rakers	—	—	9–10+19–20	27–35	8–10+18–23
Branchiostegals	9	11	—	—	12
Photophores:[1]					
Head:					
Orbital	2	2	2	2	2
Opercular	2	3	3	3	3
Symphyseal	1	1	1	1	1
Branchiostegal	8	8	8	8	8
Isthmian	7	7	7	7	7
Ventral:					
IV	14	14–16	14–15	14–16	13–16
VA	10	8–10	9–10	9–10	8–12
Lateral:					
OV	11	11–13	11–12	11–12	10–13
VA	11	5–9	10–11	10–11	9–12
Anal-caudal	14	12–13	13–14	12–16	12–16

[1] Photophore groups are discussed later in this paper (see p. 386). Different workers have used different methods of grouping photophores; we have put the counts of the several workers on a comparable basis.

DEVELOPMENT OF *VINCIGUERRIA LUCETIA*

EGGS

The egg of *Vinciguerria lucetia* is moderately small, spherical, lacks an oil globule, and has a segmented yolk. It is colorless in life and light straw colored in formalin. The shell membrane is double. The thin, inner membrane lies close to the thicker, outer membrane and is irregular in outline; neither membrane is sculptured.

Segmentation of the yolk is quite variable, and this is especially noticeable in early-stage eggs. The yolk in some eggs is nearly homogeneous; in

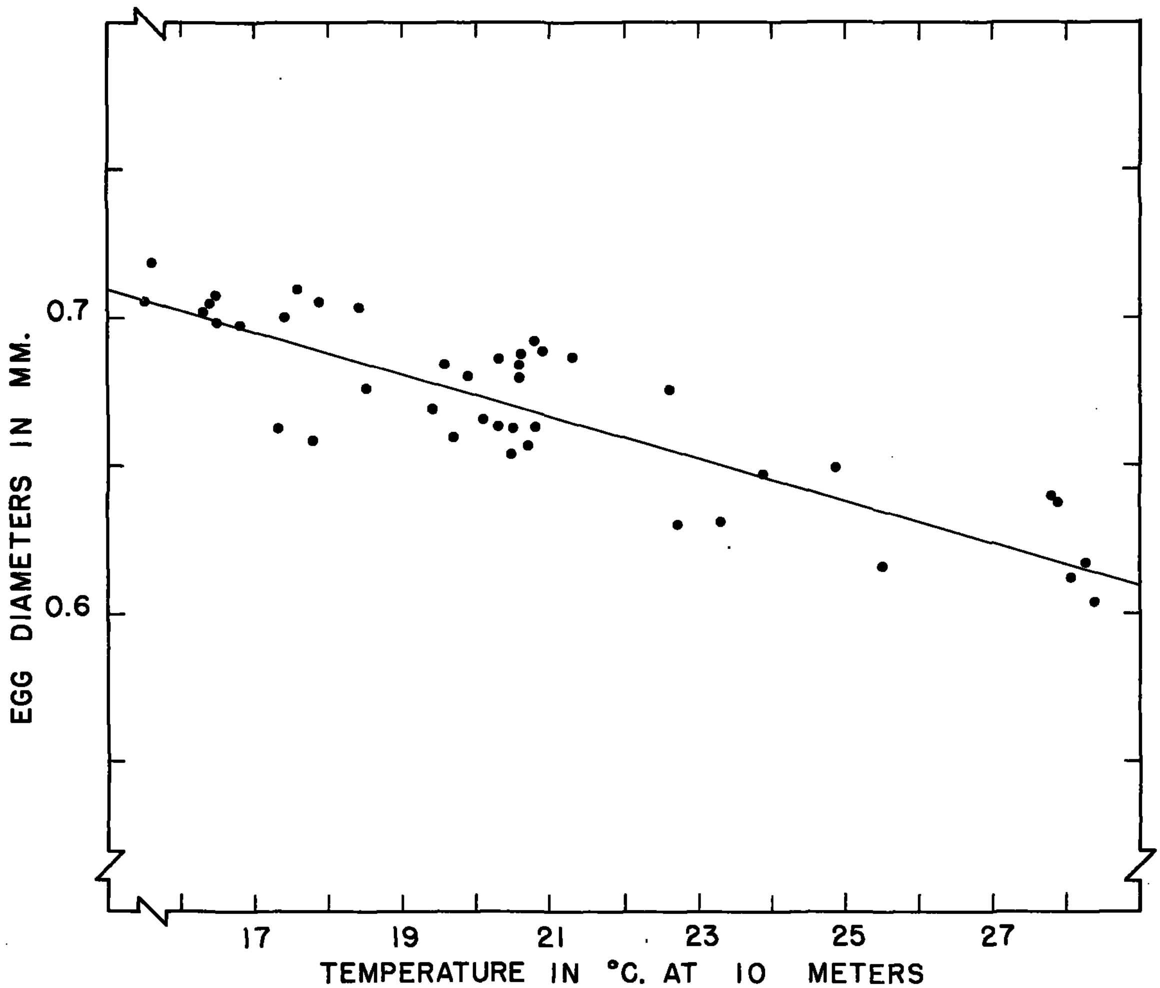

FIGURE 1.—Regression of egg size on temperature in degrees Centigrade, at 10 meters. The line is fitted by the method of least squares. The statistics for the line are as follows: $\bar{x}=20.68$; $\bar{y}=0.67$; $b=-0.0071$; $a=0.816$; $sy \cdot x=0.0155$.

others, partly segmented; in still others, completely segmented. The individual segments are globular, usually variable in size, and relatively few. Occasionally, eggs contain numerous small globules of yolk. The perivitelline space is rather narrow.

Eggs were measured from 42 localities between 32° N. latitude and 10° S. latitude (table 2). The range in diameters of eggs, measured at the outer shell membrane, was from 0.58 to 0.74 millimeters. The range in mean diameters of eggs in different localities was from 0.603 to 0.718 millimeters. There is a cline in egg size with latitude. The relation is probably one of temperature. A plot of egg size against temperature (° C.) is shown in figure 1. The 10-meter temperature is considered representative of the temperature in the upper mixed layer. The larger eggs are taken at the lower temperatures.

The egg of this species has not been described previously, but the eggs of two Mediterranean species, *V. attenuata* and *V. poweriae*, were described by Sanzo (1931). The eggs of these species differ from those of *V. lucetia* in at least two important respects: they have an oil globule and are larger.

The development of *Vinciguerria lucetia* eggs may be divided into the following stages:

1. Early, from fertilization to closure of the blastopore (fig. 2, *a* and *b*);
2. Middle, from closure of the blastopore to the time that the tail begins to curve laterally away from the embryonic axis (fig. 2, *c*); and
3. Late, from the time that the tail curves out of

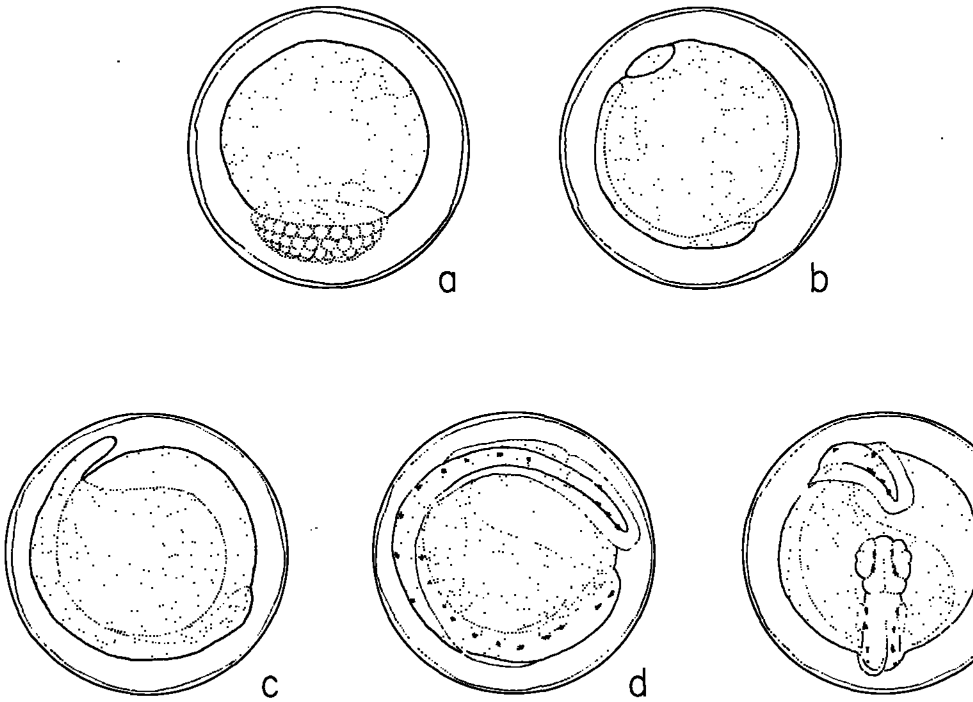

FIGURE 2.—Development of the egg of *Vinciguerria lucetia*: *a*, early stage, at development of blastodermal cap; *b*, early stage, immediately preceding blastopore closure; *c*, middle stage, with separating tail in same plane as embryo; *d*, late stage, just before hatching, lateral view; *e*, late stage, dorsal view.

plane of the embryonic axis to the time of hatching (fig. 2, *d* and *e*).

Early-stage eggs

The vitelline membrane must be quite delicate, for it had been broken in most early-stage eggs studied. The yolk granules remain intact and, as a consequence, the eggs do not become cloudy or opaque as happens when this membrane is ruptured in eggs of hake (Ahlstrom and Counts, 1955: 296) and jack mackerel (Ahlstrom and Ball, 1954: 210). The characters that aid in distinguishing early-stage eggs are (1) size, 0.58–0.74 millimeters, smaller than most pelagic fish eggs; (2) double-shell membrane, although the inner membrane may easily be overlooked; (3) lack of an oil globule; and (4) irregularly segmented yolk.

The embryo at blastopore closure is faintly outlined, but the eye has not yet developed, pigment is not present, and myomeres have not formed.

Middle-stage eggs

The conspicuous changes in development that occur during this stage include (1) eye formation; (2) division of body into myomeres; and (3) appearance of body pigmentation at about the mid-point of the stage. The pigment on middle-stage eggs is relatively simple—a row of dorsal spots on either side of the body; there is no ventral pigment and no pigment on the yolk membrane. The most striking feature about the rows of pigment spots is their dorsolateral placement. The embryos of many fishes, including the sardine, jack mackerel, and Pacific mackerel, have a row of dorsal pigment spots on either side of the notochord, but it is rather unusual for the row to be placed as far laterally as in *Vinciguerria lucetia* embryos. This character is a definite aid in identifying eggs of this species.

Late-stage eggs

It is always easier to identify eggs in the late stage than in the two earlier stages. The embryo is now more fully developed, and such features as total number of myomeres and length of intestine can be used in identification. At least 40 myomeres can be distinguished on late-stage eggs. The intestine extends approximately 0.7 of the body length. The yolk is pulled back into a wedge along the intestine—a feature observed commonly in late-stage eggs of stomiatid fishes, as well.

TABLE 2.—*Diameters of eggs of* Vinciguerria lucetia *from 43 localities in the eastern Pacific*

Station	Latitude	Longitude	Date	Number of eggs measured	Egg diameter (mm.)		Temperature (° C.) at 10 meters
					Mean	Range	
5205-93.70	31°27.9′ N	120°17.8′ W	V-15-52	6	0.706	0.70-0.72	15.5
5205-90.90	31°25′ N	121°59′ W	V-10-52	19	.718	.68-.74	15.6
5408-100.60	30°40.5′ N	118°47′ W	VIII-31-54	50	.703	.66-.74	18.4
5205-97.80	30°36.9′ N	120°29′ W	V-15-52	50	.702	.68-.74	16.3
5308-100.80	30°01′ N	120°07′ W	VIII-17-53	50	.700	.66-.74	17.4
Norpac 96	29°41′ N	120°43.5′ W	IX-16-55	17	.675	.65-.71	18.5
5205-103.80	29°26′ N	119°42′ W	V-22-52	50	.707	.68-.74	16.5
5206-107.65	29°23.5′ N	118°25′ W	VI-20-52	50	.698	.66-.74	16.5
5206-110.55	29°05.2′ N	117°18′ W	VI-19-52	50	.705	.66-.74	16.4
5408-113.40	29°02′ N	115°58.5′ W	VIII-28-54	7	.685	.66-.70	20.3
Norpac 110	28°56′ N	117°38′ W	IX-20-55	29	.679	.65-.70	20.6
5205-107.80	28°52.5′ N	119°20.5′ W	V-25-52	18	.697	.65-.74	16.8
5206-110.80	28°15′ N	118°58′ W	VI-19-52	50	.709	.66-.74	17.6
5206-113.70	28°02′ N	117°55′ W	VI-17-52	50	.705	.66-.74	17.9
Norpac 111	27°56′ N	119°35′ W	IX-18-55	25	.683	.66-.71	19.6
5308-120.50	27°32.5′ N	115°52.5′ W	VIII-12-53	50	.659	.61-.68	19.7
5206-117.70	27°24′ N	117°38′ W	VI-17-52	50	.662	.61-.70	17.3
Norpac 118	27°13.5′ N	116°30.5′ W	VIII-11-55	9	.668	.64-.69	19.4
5401-127.40	26°44.5′ N	114°25′ W	I-16-54	50	.657	.63-.68	17.8
5308-120.80	26°31′ N	117°45′ W	VIII-13-53	50	.665	.63-.70	20.1
5308-130.45	25°59′ N	114°27′ W	VIII-10-53	50	.663	.63-.70	20.8
Norpac 120	25°52.5′ N	119°06′ W	VIII-12-55	17	.691	.66-.73	20.8
5308-130.50	25°49′ N	114°44.5′ W	VIII-10-53	50	.662	.63-.68	20.5
5308-130.60	25°29.5′ N	115°21′ W	VIII-10-53	50	.656	.61-.68	20.7
Norpac 134	25°09′ N	116°02′ W	VIII-11-55	50	.686	.65-.72	21.3
Norpac 121	25°02′ N	120°45′ W	VIII-12-55	50	.683	.64-.73	20.6
5401-140.40	24°27′ N	112°59′ W	I-3-54	50	.663	.63-.68	20.3
5401-150.40	22°43′ N	111°58′ W	I-11-54	50	.653	.63-.68	20.5
Shellback 8	22°37′ N	123°25′ W	V-21-52	50	.679	.65-.70	19.9
Norpac 139	21°53′ N	127°38′ W	VIII-16-55	14	.687	.67-.70	20.6
Shellback 9	21°43′ N	123°58′ W	V-22-52	50	.688	.65-.71	20.9
Norpac 162	20°22′ N	116°19.5′ W	IX-13-55	150	.648	.61-.68	24.9
Norpac 148	19°59.5′ N	124°06′ W	IX-10-55	25	.675	.61-.70	22.6
Shellback 67	15°46′ N	100°35′ W	VI-14-52	12	.611	.59-.62	28.1
Shellback 65	14°00′ N	101°34′ W	VI-13-52	6	.616	.60-.65	28.3
Shellback 64	13°11′ N	102°07′ W	VI-13-52	7	.603	.58-.63	28.4
Shellback 77	6°50′ N	98°07′ W	VI-21-52	4	.638	.60-.68	27.9
Shellback 53	3°57′ N	108°08′ W	VI-9-52	50	.639	.60-.66	27.8
Shellback 47	1°00′ S	111°24′ W	VI-6-52	6	.629	.60-.65	22.7
Shellback 35	2°19′ S	116°50′ W	VI-2-52	3	.615	.60-.64	25.5
Shellback 87	3°03.5′ S	96°18.5′ W	VI-25-52	11	.62)	.60-.66	23.3
Shellback 95	9°30′ S	94°08.5′ W	VI-29-52	28	.646	.61-.67	23.9

Dashes of pigment in two lines extend from the forward part of the head between the eyes to the back of the head, and continue behind the head as two rows of dorsolateral pigment spots. Pigment extends to the tip of the notochord, and there are some discrete spots on the ventral margin posterior to the anus. In the caudal area, some pigment may extend into the fin-fold in 2 or 3 streaks.

By the time the embryo is ready to hatch, the tail encircles the head. The fin-fold is wide in the free part of the tail, but narrows anteriorly and ends at the back of the head.

POSTEMBRYONIC STAGES

Postembryonic development has been divided into six stages, which can be characterized as (1) larval, from hatching to photophore formation; (2) prometamorphic, the white photophore stage; (3) midmetamorphic, the stage of rapid change in body proportions, including a marked increase in depth and a change in eye shape from oval to round; (4) postmetamorphic, from the time that the eye becomes round until photophore formation and pigmentation are completed; (5) juvenile, between metamorphosis and sexual maturity; and (6) adult, sexually mature individuals.

The terminology for the stages of metamorphosis is not intended to be general, but clearly separates the stages in the metamorphosis of *Vinciguerria*.

The various stages of development of *Vinciguerria lucetia* were available from newly hatched larvae through mature adults. We have studied a series of specimens of each of the six stages. Development is discussed in the following sequence:

1. Changes in body form from larva to adult;
2. Changes in pigmentation during development;
3. Sequence of calcification, including vertebrae, gill rakers, teeth, branchiostegals, fin formation, supporting structures of fins; scales; and
4. Photophore development.

Changes in body form from larva to adult

In addition to standard length, measurements were made of six body parts: length of head,

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depth at pectoral, width of eye, distance from snout to anus, distance from snout to origin of dorsal fin, and distance from snout to insertion of ventral fins.

The number and size range of specimens used in studying body proportion in the various stages of development were as follows:

Stage	Number of specimens measured	Size range (mm.)	Illustrations
Larval	100	2. 2–18. 2	Figure 3, *a* to *d*.
Prometamorphic	22	13. 2–19. 2	Figure 8.
Midmetamorphic	49	13. 5–19. 2	
Postmetamorphic	46	13. 2–20. 2	Figure 9.
Juvenile and adult	51	19. 2–56. 0	Figures 12 and 13.

We had the opportunity to study changes in body form during all stages of development, and we found it desirable to treat each stage separately. At least as regards this species, we cannot agree to the statement of Parr (1956: 392) that "One of the primary purposes and needs of taxonomy is to develop expressions that describe a species or other systematic unit as a whole." This is neither possible nor desirable in a species such as *V. lucetia*, that has a marked metamorphosis for, as will be shown, marked changes occur in body proportions during metamorphosis at a time when there is little or no change in standard length; when, in fact, an actual shrinkage has been postulated (Sanzo 1913, 1931). Any function that could express in one equation growth during the larval period, metamorphosis, and later development of *V. lucetia* would be so complex that it would have little meaning.

We have plotted the actual measurements of a body part on standard length for each stage of development. Nearly all of the plots of measurements can be adequately fitted by a straight line using the method of least squares ($y=a+bx$), without further transforming the values. Such regressions have the advantages of simplicity in determining the statistics describing the regressions, and in having an easily comprehended biological interpretation. The slope of the regression (b) gives the rate of growth of the body part with respect to length during the stage of development that is being considered. A number of these regressions are presented in figures, and the statistics describing the series of regressions are given in table 3. All measurements are of preserved material. One of the sources of variation in our measurements results from differences in "relaxation" of specimens at time of preservation. Another source is the preservative used, as specimens in alcohol preserve somewhat differently from those in formaldehyde.

TABLE 3.—*Statistics describing regressions of body measurements on standard length for* Vinciguerria lucetia

Body proportion	Standard length	$\bar{x}$	$\bar{y}$	n	b	a	$s_{y \cdot x}$
Head length:	*Mm.*						
Larval	2. 2–18. 2	8. 15	1. 73	100	0. 214	0. 012	0. 1219
Prometamorphic	13. 2–19. 2	16. 82	3. 52	22	. 173	. 605	. 1604
Midmetamorphic	13. 5–19. 2	16. 58	3. 69	50	. 159	1. 043	. 1425
Postmetamorphic	13. 2–20. 2	16. 47	4. 33	45	. 261	. 029	. 1395
Juvenile and adult	19. 2–56. 0	31. 91	8. 53	51	. 263	. 140	. 3193
Body at depth pectoral:							
Larval	2. 2–18. 2	8. 22	. 67	97	. 098	–. 137	. 0727
Prometamorphic	13. 2–19. 2	16. 82	1. 67	22	. 082	. 292	. 1736
Midmetamorphic	13. 5–19. 2	16. 58	2. 00	50	. 097	. 397	. 1768
Postmetamorphic	13. 2–20. 2	16. 50	2. 61	46	. 180	–. 360	. 1724
Juvenile and adult	19. 2–56. 0	31. 91	5. 81	51	. 174	. 240	. 3189
Eye width:							
Larval	2. 2–18. 2	8. 50	. 34	91	. 039	. 007	. 0340
Prometamorphic	13. 2–19. 2	16. 82	. 70	22	. 041	. 001	. 0566
Midmetamorphic	13. 5–19. 2	16. 58	. 76	50	. 042	. 068	. 0871
Postmetamorphic	13. 2–20. 2	16. 95	1. 27	51	. 116	–. 687	. 1317
Juvenile and adult	19. 2–56. 0	----------	----------	----------	----------	----------	----------
Snout to ventral:							
Larval	2. 2–18. 2	13. 78	6. 97	11	. 469	. 506	. 1352
Prometamorphic	13. 2–19. 2	16. 82	8. 37	22	. 469	. 475	. 2718
Midmetamorphic	13. 5–19. 2	16. 58	7. 91	50	. 495	–. 297	. 1726
Postmetamorphic	13. 2–20. 2	16. 50	7. 75	46	. 445	. 396	. 1279
Juvenile and adult	19. 2–56. 0	31. 91	15. 50	51	. 521	–1. 132	. 3725
Snout to dorsal:							
Larval	2. 2–18. 2	11. 08	7. 01	57	. 565	. 739	. 1887
Prometamorphic	13. 2–19. 2	16. 82	10. 30	22	. 586	. 436	. 2095
Midmetamorphic	13. 5–19. 2	16. 58	9. 76	50	. 588	. 007	. 2240
Postmetamorphic	13. 2–20. 2	16. 50	9. 25	46	. 504	. 938	. 1149
Juvenile and adult	19. 2–56. 0	31. 91	17. 98	51	. 592	. 912	. 4307
Snout to anus:							
Larval	2. 2–18. 2	8. 15	6. 00	100	. 734	. 020	. 2044
Prometamorphic	13. 2–19. 2	16. 82	11. 98	22	. 665	. 804	. 2307
Midmetamorphic	13. 5–19. 2	16. 56	11. 12	48	. 697	–. 424	. 2071
Postmetamorphic	13. 2–20. 2	16. 50	10. 58	46	. 607	. 564	. 1255
Juvenile and adult	19. 2–56. 0	31. 91	20. 97	51	. 710	–1. 668	. 5464

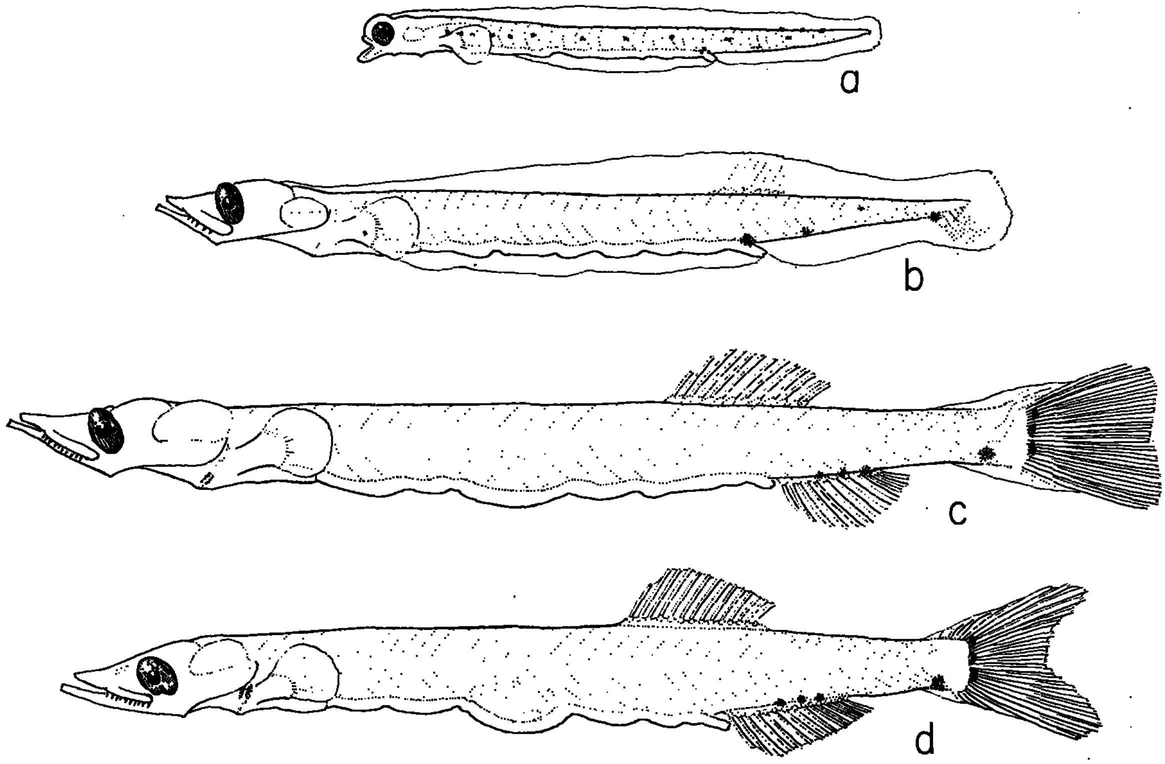

FIGURE 3.—Development of the larva of *Vinciguerria lucetia*: *a*, larva, 2.2 mm. long; *b*, larva, 6.0 mm. long; *c*, larva, 9.0 mm. long; *d*, larva, 13.1 mm. long.

From our study of larval growth in a number of species, we found that a simple size-on-size regression is preferable to a ratio-on-size regression. The regression line will seldom pass through the origin, and for a very simple reason. A body part must have some size at its differentiation. When the head differentiates on an embryo, for example, the embryo is already a millimeter or so in length. It often happens that the head at formation will constitute a different proportion of the standard length than it does subsequently. Whenever this happens, a rectilinear regression of size-on-size will have a y-intercept different from 0. But this line has more validity than one that would pass through the origin, for it will pass through the point representing the size of the part at its initial formation. For this reason, we believe that Parr (op. cit.: 378) is mistaken when he states that a regression curve must pass through the origin.

Larvae.—The larvae (table 4, fig. 3) are thin and threadlike at hatching. The head is moderate in length and width; head length about 20 percent of the standard length; head width slightly greater than body width. The regression of head length on standard length is somewhat curvilinear (fig. 4). For simplicity we have fitted a straight line to the regression by the method of least squares. The regression of head length on standard length for *V. nimbaria* and *V. poweriae* does not appear to be curvilinear. Original measurements of larvae and other stages of development of *V. lucetia* are given in an appendix. The rate of increase in head length during the larval period as thus determined is 0.215 millimeters per 1.0-millimeter increase in standard length.

In very young larvae, the depth (at pectorals) is only about 7 percent of the standard length. The increase in depth during the larval period is at a faster rate than this, being slightly less than 0.1-millimeter for each 1.0-millimeter increase in length (fig. 5).

The eyes are approximately spherical in newly hatched larvae and pigment forms almost immediately. In larvae about 3 millimeters long the eye has become oblong and slightly stalked. In measuring the oblong eye, the width was taken directly across the narrower dimension. The eyes increase

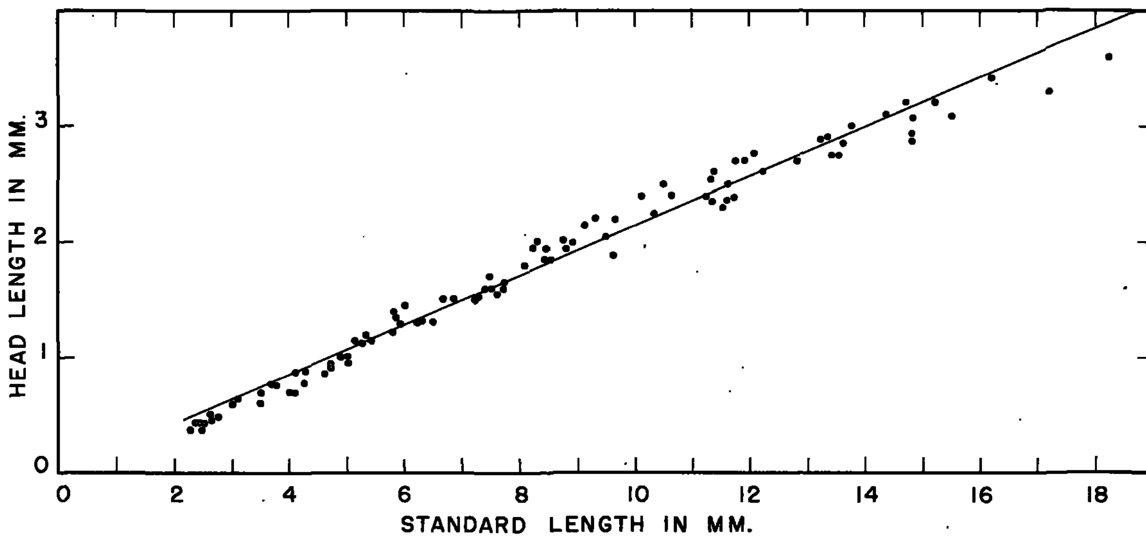

FIGURE 4.—Regression of head length on standard length for *Vinciguerria lucetia* larvae. The measurements were made on 100 specimens, shown in the figure as individual dots. The regression line is fitted to the data by the method of least squares. (Refer to table 3 for statistics describing the line).

in width approximately 0.04 millimeter for each 1.0-millimeter increase in standard length (fig. 6).

The digestive tract underlies much of the body (the distance from snout to anus is over 70 percent of the standard length). The regression of the distance of snout to anus on standard length appears to be slightly curvilinear; however, it is so nearly straight that for practical purposes it can be considered to be a straight line. The regression of the distance from snout to anus on standard

TABLE 4.—*Average counts and measurements of larvae of* Vinciguerria lucetia

[D—dorsal; V—ventral; LP—larval pectoral]

Standard length	Number of specimens	Average body measurements (mm.)							Meristic counts							
		Standard length	Head length	Eye width	Depth at pectoral	Snout to anus	Snout to dorsal	Snout to ventral	Vertebrae	Dorsal fin	Anal fin	Pectoral fins	Ventral fins	Caudal fin		
														Principal	Secondary	
															D	V
2.0–2.4 mm	6	2.4	0.4	0.12	0.17	1.6	------	------	------	------	------	LP	------	------	------	------
2.5–2.9 mm	4	2.6	.5	.12	.17	1.7	------	------	------	------	------	LP	------	------	------	------
3.0–3.4 mm	3	3.0	.6	.14	.19	2.1	------	------	------	------	------	LP	------	------	------	------
3.5–3.9 mm	5	3.6	.7	.15	.22	2.6	------	------	------	------	------	LP	------	------	------	------
4.0–4.4 mm	5	4.1	.8	.16	.26	3.0	------	------	------	------	------	LP	------	------	------	------
4.5–4.9 mm	5	4.8	.9	.18	.36	3.5	------	------	------	------	------	LP	------	------	------	------
5.0–5.4 mm	6	5.2	1.1	.21	.35	3.9	------	------	------	------	------	LP	------	------	------	------
5.5–5.9 mm	4	5.8	1.3	.22	.40	4.4	------	------	------	------	------	LP	------	5	------	------
6.0–6.4 mm	3	6.2	1.4	.25	.47	4.8	------	------	------	------	------	LP	------	14	------	------
6.5–6.9 mm	3	6.7	1.4	.27	.47	5.0	4.5	------	------	4	------	LP	------	19	------	------
7.0–7.4 mm	4	7.4	1.6	.28	.52	5.6	5.0	------	(*)	5	------	LP	------	19	------	------
7.5–7.9 mm	4	7.6	1.6	.30	.55	5.7	5.0	------	(*)	6	------	LP	------	19	------	------
8.0–8.4 mm	5	8.3	1.9	.33	.67	6.4	5.5	------	(*)	11	5	LP	------	19	1	1
8.5–8.9 mm	4	8.7	2.0	.33	.69	6.4	5.6	------	(*)	11	7	LP	------	19	1	1
9.0–9.4 mm	2	9.2	2.2	.38	.78	6.9	6.0	------	(*)	10	9	LP	------	19	1	1
9.5–9.9 mm	3	9.6	2.0	.37	.79	7.2	6.2	------	(*)	12	11	LP	------	19	1	1
10.0–10.9 mm	4	10.4	2.4	.40	.99	7.8	6.6	5.5	(*)	13	12	LP	Bud	19	2	2
11.0–11.9 mm	11	11.5	2.5	.48	.94	8.9	7.2	------	(*)	13	12	LP	Bud	19	2	2
12.0–12.9 mm	3	12.4	2.7	.49	1.02	9.1	7.7	6.2	(*)	14	12	LP	Bud	19	2	2
13.0–13.9 mm	6	13.5	2.9	.55	1.21	9.8	8.3	6.9	32	15	15	LP	Bud	19	4	3
14.0–14.9 mm	5	14.7	3.0	.61	1.38	10.7	9.1	7.4	36	15	16	LP	Bud	19	5	4
15.0–15.9 mm	2	15.4	3.2	.58	1.40	11.2	9.2	7.7	38	15	15	LP	Bud	19	6	4
16.0–16.9 mm	1	16.2	3.4	.66	1.60	11.6	10.2	------	41	14	15	LP	Bud	19	4	4
17.0–17.9 mm	1	17.2	3.3	.60	1.60	12.5	10.4	------	41	15	15	LP	Bud	19	5	4
18.0–18.2 mm	1	18.2	3.6	.65	1.60	13.1	11.2	9.0	42	16	16	LP	Bud	19	6	4

*Uroneurals associated with urostyle and hypurals are present.

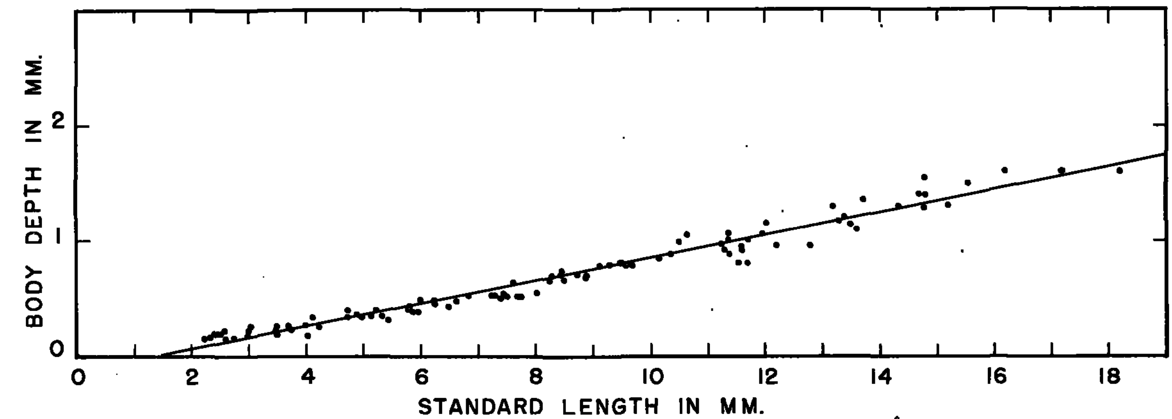

FIGURE 5.—Regression of body depth on standard length for *Vinciguerria lucetia* larvae, fitted by method of least squares (refer to table 3 for statistics describing the line).

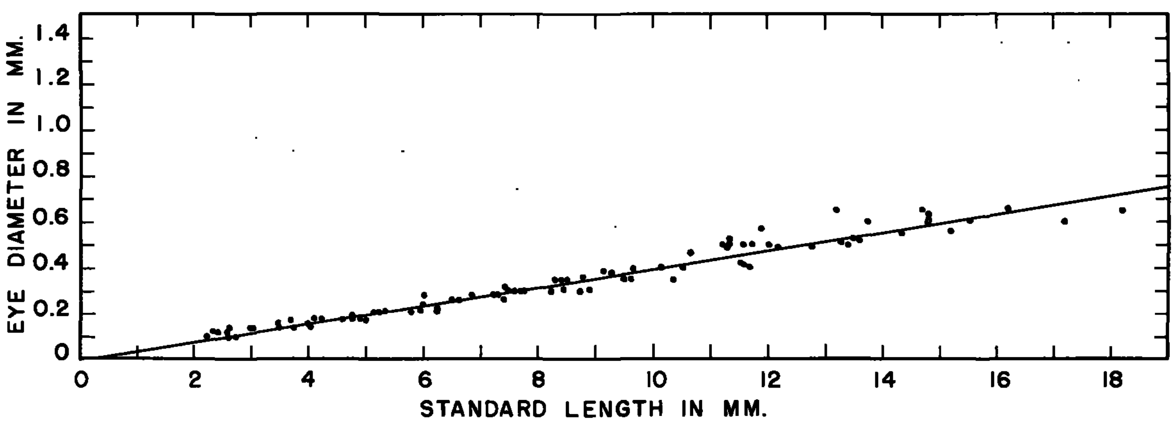

FIGURE 6.—Regression of eye diameter on standard length for *Vinciguerria lucetia* larvae, fitted by method of least squares (refer to table 3 for statistics describing the line).

length when fitted by the method of least squares gives a rate of increase of 0.73 millimeter for each 1.0-millimeter increase in length (fig. 7).

The measurements involving fins, such as the distance from snout to origin of dorsal or snout to insertion of ventrals, are available only for larger larvae. The dorsal fin forms soon after the caudal, and measurements of distance from snout to dorsal are available for most larvae longer than 6.5 millimeters. The ventral fins form at the very end of the larval period; the preventral measurement was available for only 11 larvae out of 100 studied. The snout-dorsal distance increases approximately 0.58 millimeter for each 1.0-millimeter increase in length during the larval period. The snout-ventral distance increases approximately 0.47 millimeter for each 1.0-millimeter increase in length.

Metamorphosing individuals.—Metamorphosis may be characterized as the period during which marked changes occur in body proportions and body structures without any marked increase in standard length. The length may not increase at all, or it may even diminish.

The degree of ossification that takes place during the larval period will have a marked bearing on changes in standard length that can occur during metamorphosis. If the vertebral column, for example, is completely formed before metamorphosis, the standard length cannot decrease to any appreciable extent. In *Vinciguerria*, the vertebral column ossifies immediately prior to metamorphosis. The individual centra are separated from each other by a narrow unossified space. Some compression does occur at these points, but it does not seem reasonable to us that as much shrink-

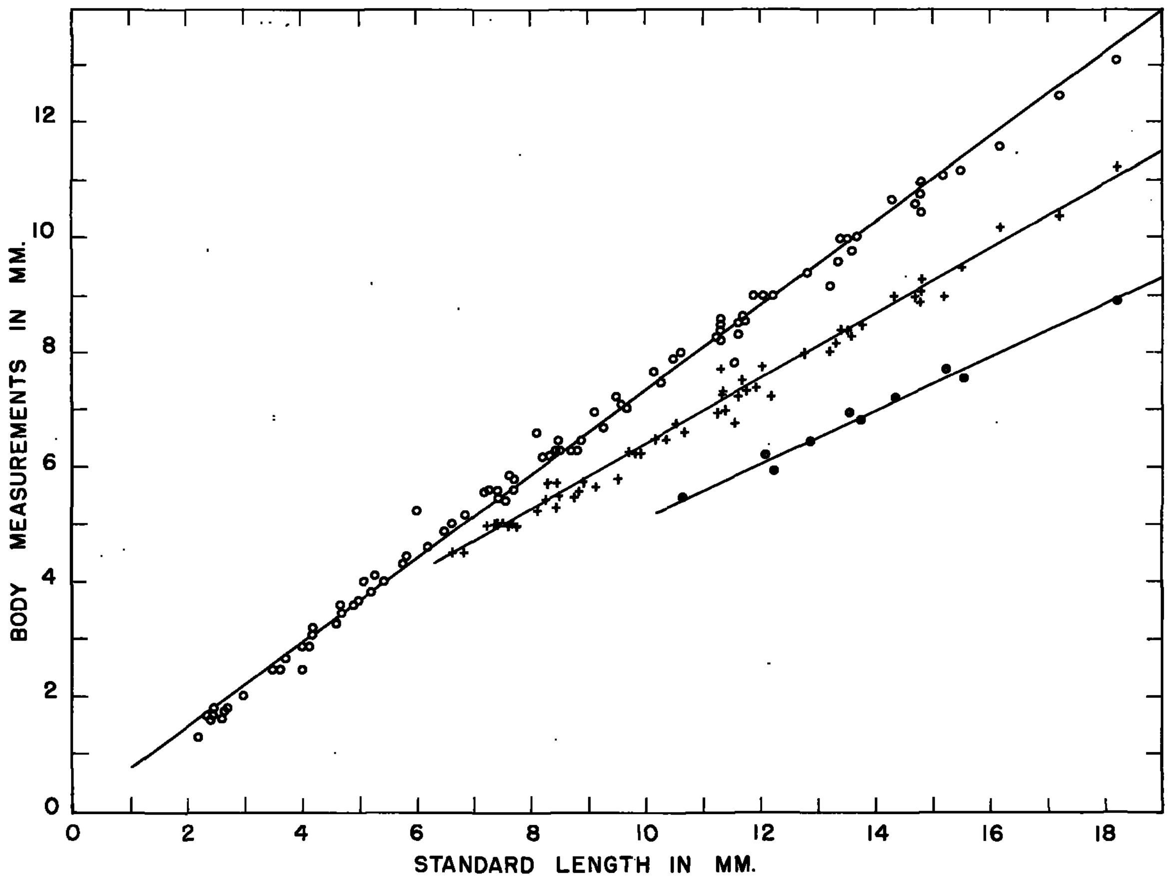

FIGURE 7.—Regression on standard length of distance from snout to anus (open circles), of distance from snout to origin of dorsal (+), and of distance from snout to insertion of ventrals (closed circles) for *Vinciguerria lucetia* larvae. The lines are fitted by the method of least squares. (Refer to table 3 for statistics describing the three lines.)

age could occur as has been postulated by Sanzo. Any species, such as the fresh-water eel, that shrinks markedly during metamorphosis does so before the vertebral column ossifies.

As mentioned previously, metamorphosis of *Vinciguerria* naturally falls into three stages (a prometamorphosing individual in the white photophore stage is shown in figure 8; midmetamorphosis is not illustrated; a postmetamorphosing specimen is shown in figure 9). Regressions of three body measurements on standard length are illustrated in figure 10 for the prometamorphic stage, and in figure 11 for the postmetamorphic.

Specimens of *V. lucetia* metamorphose at a smaller size in the area south of 25° N. latitude than in the northern part of its range. The smallest specimens examined of each of the three stages of metamorphosis in the two regions were as follows:

Stage	Southern Baja California (20°–25° N. latitude)	Southern California and northern Baja California (30°–35° N. latitude)
Prometamorphic	13.2 mm	17.2 mm.
Midmetamorphic	13.5 mm	17.4 mm.
Postmetamorphic	13.2 mm	16.5 mm.

The extent of the changes in body proportion that occur in each of the three stages of metamorphosis can be seen by comparing the average proportions of individuals of the same standard length (table 5). Two sizes have been chosen: 13.5 millimeters, which is at the lower end of the size range of all three stages, and 19.0 millimeters, which is at the upper end.

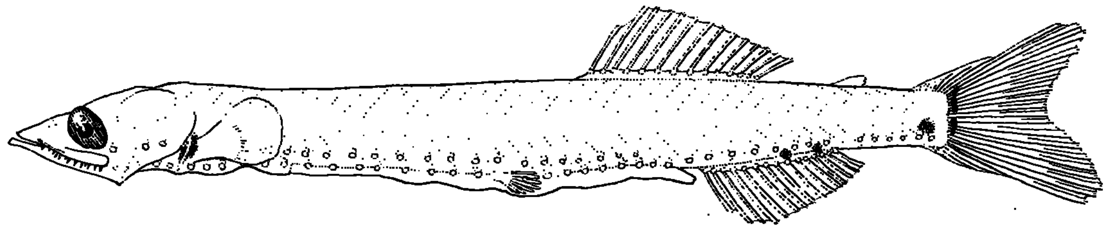

FIGURE 8.—Prometamorphosing specimen of *Vinciguerria lucetia* 15.0 mm. long, collected near Cape San Lucas, Baja California (station 157.10).

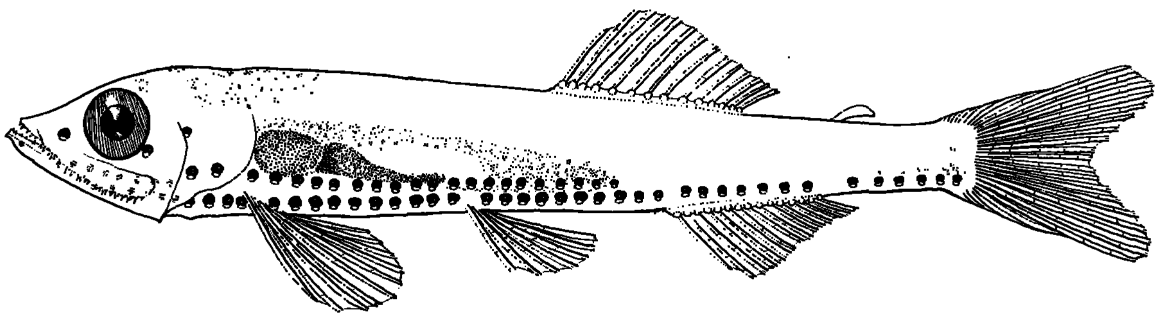

FIGURE 9.—Postmetamorphosing specimen of *Vinciguerria lucetia* 16.0 mm. long, from off southern Baja California (station 153.20).

The following changes occur in the body proportions studied:

Head length: Relative length of the head increases about 20 percent between the larval stage and the postmetamorphic. Prometamorphosing individuals are quite similar to larvae.

Eye diameter: A marked increase in eye diameter occurs between the larval and postmetamorphic stages, amounting to about 80 percent. The eye changes in shape from oval to approximately round, and loses its semistalked condition.

Body depth: A striking increase in body depth results during metamorphosis, amounting to about 80 percent in postmetamorphosing individuals. There is a simultaneous increase in the depth of the abdominal cavity, accompanied by a marked augmentation of pigment in the peritoneal tissues.

Distance from snout to insertion of ventral fins: A slight decrease in this dimension occurs during metamorphosis, amounting to somewhat less than 10 percent.

Distance from snout to origin of dorsal fin: The proportionate distance from snout to origin of dorsal fin is about 10 percent longer in larvae than in postmetamorphosing specimens of the same size.

Distance from snout to anus: There is a greater difference in this dimension between larval and postmetamorphic stages than in the preceding dimension; the decrease during metamorphosis

TABLE 5.—*Average body dimensions and proportions of developmental stages of* Vinciguerria lucetia *at two selected lengths*

[All values based on regression lines]

Stage	Average body measurements (in mm.)						Body proportions as percentage of standard length					
	Head length	Eye width	Depth at pectoral	Snout to ventral	Snout to dorsal	Snout to anus	Head length	Eye width	Depth at pectoral	Snout to ventral	Snout to dorsal	Snout to anus
13.5 mm.:												
Larval	2.88	0.54	1.19	6.84	8.37	9.91	21.33	4.00	8.81	50.67	62.00	73.41
Prometamorphic	2.94	.56	1.40	6.81	8.35	9.78	21.78	4.15	10.37	50.44	61.85	72.44
Midmetamorphic	3.19	.63	1.70	6.38	7.95	8.98	23.63	4.67	12.59	47.26	58.89	66.52
Postmetamorphic	3.55	.97	2.07	6.41	7.74	8.80	26.30	7.19	15.33	47.48	57.33	65.19
19.0 mm.:												
Larval	4.05	.75	1.73	9.42	11.48	13.95	21.32	3.95	9.11	49.58	60.42	73.42
Prometamorphic	3.90	.79	1.85	9.39	11.57	13.43	20.53	4.16	9.74	49.42	60.89	70.68
Midmetamorphic	4.07	.86	2.24	9.10	11.18	12.82	21.42	4.53	11.79	47.89	58.84	67.47
Postmetamorphic	4.99	1.41	3.06	8.86	10.51	12.09	26.26	7.42	16.11	46.63	55.32	63.63
Juvenile	5.14	1.65	3.56	8.77	10.34	11.81	27.05	8.68	18.74	46.16	54.42	62.16

amounts to between 13 and 18 percent, depending on size. Some of the decrease in this dimension is due to an actual shortening of the intestine. The intestine, including the anal papilla, extends beyond the origin of the anal fin in late-larval and prometamorphosing individuals, but contracts into a more anterior position, usually between the last two pairs of ventral VA photophores during metamorphosis.

Very little change occurs in total length during metamorphosis. We found the size range of individuals in the three metamorphic stages to be

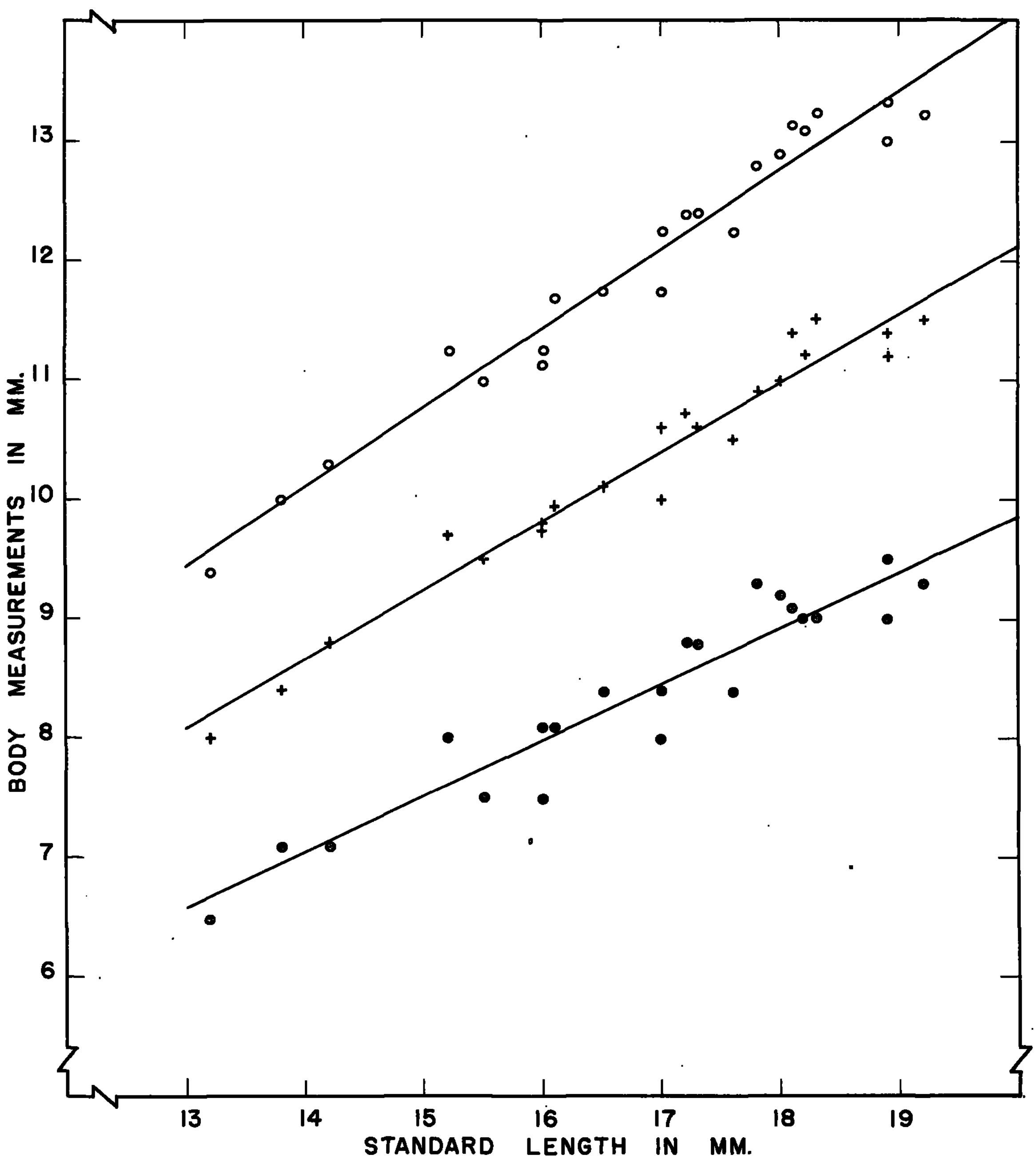

FIGURE 10.—Regressions on standard length of the distances from snout to anus (open circles), from snout to the origin of dorsal fin (+), and from snout to insertion of ventral fins (closed circles) of the prometamorphic stage of *Vinciguerria lucetia*. The lines are fitted by the method of least squares (see table 3).

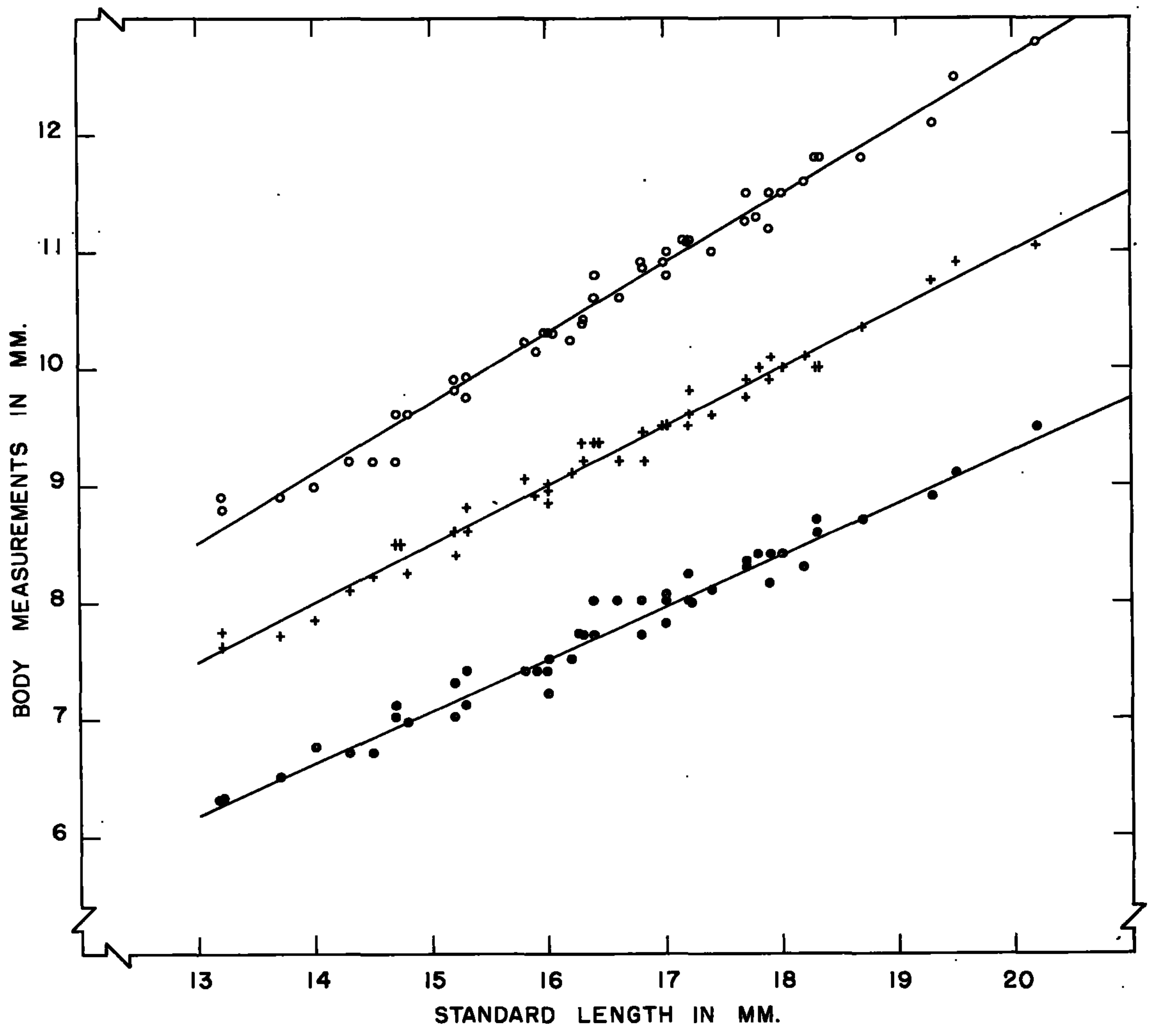

FIGURE 11.—Regression on standard length of the distance from snout to anus (open circles), from snout to the origin of dorsal fin (+), and from snout to insertion of ventral fins (closed circles) of the postmetamorphic stage of *Vinciguerria lucetia*. The lines are fitted by the method of least squares (see table 3).

almost identical. Although there is little increase in length, there is no evidence of an actual decrease (shrinking) in total length during metamorphosis. A decrease in length of *V. poweriae* and *V. attenuata* during metamorphosis has been claimed by Sanzo and by Jespersen and Tåning.

Juveniles and adults.—The rate of growth of body parts appears to be the same during the juvenile and adult stages (figs. 12 and 13), hence these two stages have been combined in our morphometric studies. During metamorphosis, three proportions increased relative to standard length (head length, eye diameter, and body depth), and three decreased (distances from snout to ventrals, snout to dorsal base, and snout to anus). The growth rate of the head during the juvenile and adult stages is about the same as during postmetamorphosis—an increase of slightly over 0.26 millimeter for each 1.0-millimeter increase in standard length. The depth of body also increases at a rate that is similar to that found for postmetamorphosing individuals—0.174-millimeter increase in depth for each 1.0-millimeter increase in standard length.

We have not attempted to fit a curve to the eye measurements, but the size-on-size plot is markedly curvilinear. The eye diameter in larger adults is proportionately less than in juveniles. Hildebrand (1946) has emphasized the proportionately smaller eye diameter in his description of *Vinci-*

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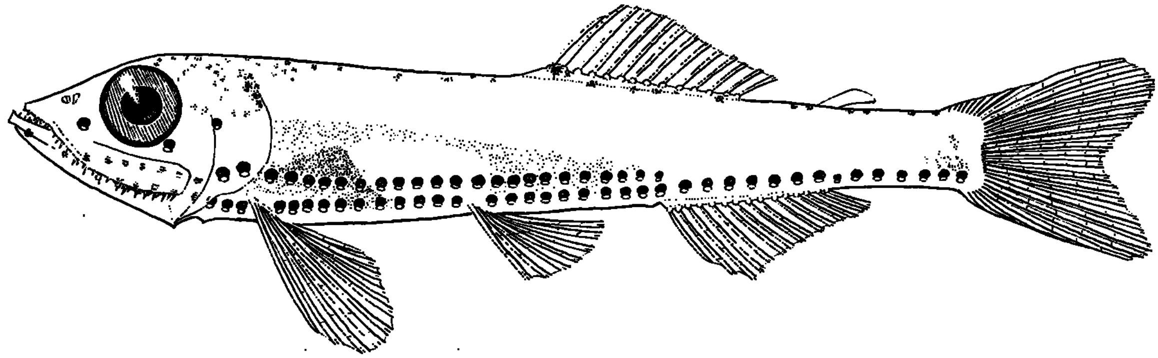

FIGURE 12.—Early juvenile of *Vinciguerria lucetia*, 19.5 mm. long, from off Point Abreojos, Baja California (station 130.35).

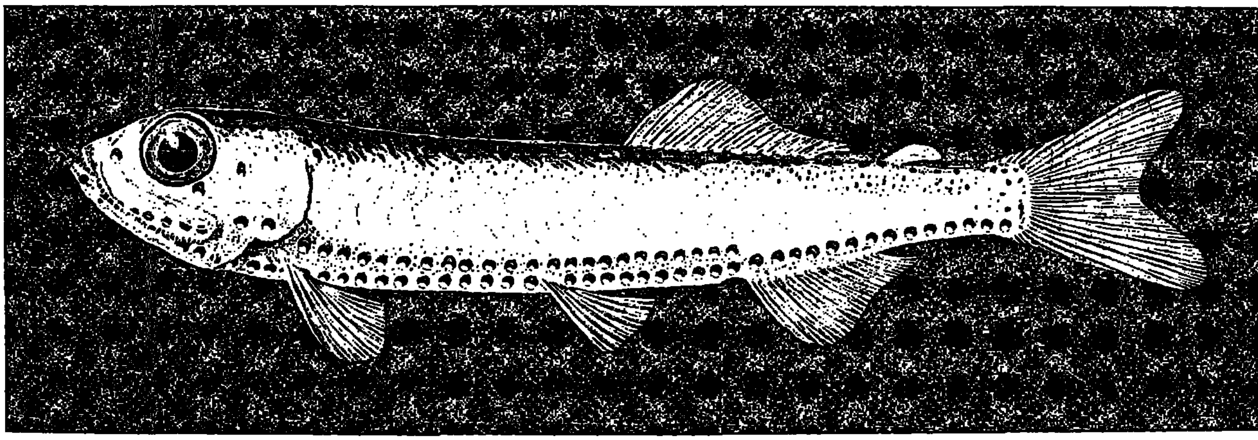

FIGURE 13.—Adult of *Vinciguerria lucetia*, 43.5 mm. long, from off Guadalupe Island.

guerria pacifici, based on large adult specimens, but this apparent difference from *V. lucetia* has not held up.

The distance from snout to anus increases 0.71 millimeter per 1.0 millimeter of growth—only slightly less than during the larval period. The distance from snout to origin of the dorsal fin, which showed a proportionate decrease during metamorphosis, again increases at a rate which is similar though slightly higher than that determined for the larval period. The same applies to the distance from snout to ventral fin bases (fig. 14).

The body parts that showed an increase in growth rate relative to standard length during metamorphosis, retained the higher rate during the juvenile and adult stages. The three measurements that showed a decrease in growth rate during metamorphosis did not continue at the decreased rate during later life, but reverted to a rate that was similar to that obtaining during the larval period.

Changes in pigmentation during development

Larval pigmentation.—The pigmentation of newly hatched larvae (approximately 2.0 mm. in length) and of larvae up to about 4.0 millimeters in length (fig. 3, *a*) differs markedly from that in larger larvae. At time of hatching, pigmentation is similar to that described for late-stage eggs, i. e., the principal feature is a line of dorsolateral pigment spots on either side of the body. In addition, there are a few ventral spots posterior to the anus and often 2 or 3 streaks of pigment in the caudal fin-fold. In larvae between 2.0 and 4.0 millimeters in length, the pigment migrates ventrally and the number of discrete pigment spots markedly decreases. For example, in yolk-sac larvae between approximately 2.0 and 2.5 millimeters in length there are 10 to 12 lateral spots between the head and anus, 2 or 3 ventral spots behind the anus, as well as streaks of pigment in the caudal fin-fold. Thereafter, until about 4.0 millimeters in length, the number of lateral spots is gradually reduced, after which size none is to be observed. If lateral spots represent migrating pigment, which is likely, the migration must occupy a considerably longer time than similar pigment movements in the larvae of the sardine, jack mackerel, Pacific mackerel, and other species that we have observed. At about 4 millimeters in length, the larvae show very little pigmentation. The usual pigmentation consists of only about three inconspicuous spots: one behind the pectoral fin (postpectoral spot), one above the anus (anal spot), and the other about midway between the anus and the end of the notochord (precaudal spot).

Throughout the remainder of the larval period (fig. 3, *b–d*), the pigment is usually confined to eight spots (or patches). These are (1) prepectoral spot—near base of pectoral fin; (2) postpectoral spot—approximately 1 millimeter behind pectoral fin; (3) anal spot—pigment spot above anus; (4) anal-base pigment—one to three pigment spots above posterior half of anal base; (5) precaudal spot—a lateral pigment spot midway between anus and end of notochord (or base of caudal fin); (6) caudal spot—located approximately 1 millimeter before end of notochord (or immediately before caudal base after flexion of notochord); (7) pigment at base of upper caudal rays; and (8) pigment at base of lower caudal rays.

A detailed study was made of the pigmentation of 79 specimens of larvae that measured between 4.3 mm. and 17.3 mm. in standard length. Pigmentation of a selected group of these larvae is given in table 6. The eight pigmented areas were never observed on any one individual, and only about 10 percent of the specimens examined had more than five of the pigmented areas developed.

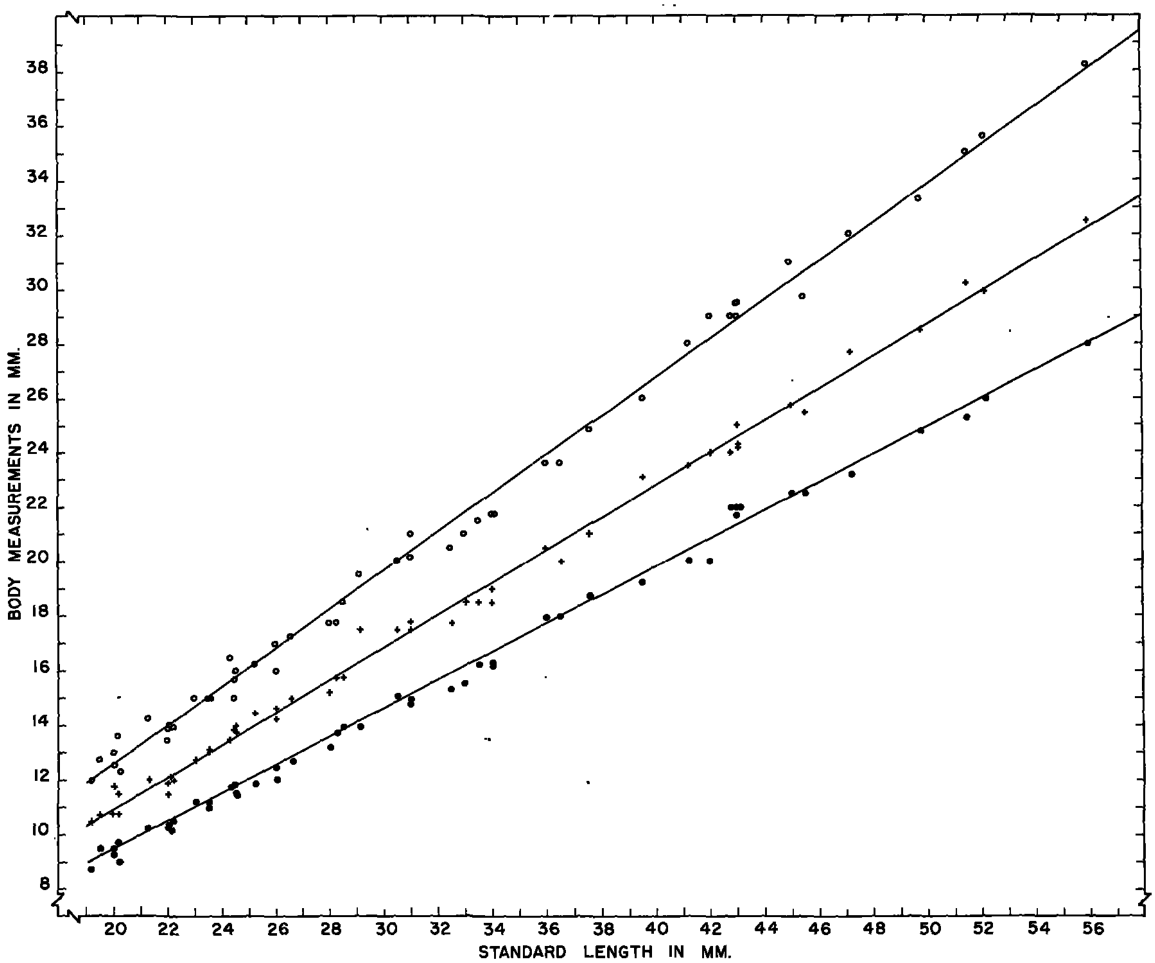

FIGURE 14.—Regressions on standard length of the distance from snout to anus (open circles), from snout to the origin of dorsal fin (+), and from snout to insertion of ventral fins (closed circles), of juveniles and adults of *Vinciguerria lucetia*. The lines are fitted by the method of least squares (see table 3).

Three of the pigment spots occurred only on larvae smaller than 9.0 millimeters. These were the postpectoral, anal, and precaudal spots. The anal spot was observed on only 8 individuals, the postpectoral spot on 14, and the precaudal spot on 24. The caudal spot was the only one found on larvae of all sizes. Seventy-six of the 79 individuals examined had this spot. The prepectoral spot was not observed on any larva smaller than 6.2 millimeters, was found on approximately half those between 6.2 and 9.0 millimeters, and on nearly all those longer than 9.0 millimeters. The pigmentation above the base of the anal fin usually was not present until after fin formation, however it was found on all larvae of more than 7.5 millimeters in length. At first formation, only a single pigment spot was present in this area; the number increased to 2, 3, or occasionally 4 spots on older larvae. The pigment at the base of the caudal fin rays formed initially soon after caudal-fin formation in the upper part of the caudal fin. Pigment along the base of the lower part of the fin was not consistently present until larvae were more than 8.5 millimeters in length. The pigment on the caudal fin consisted of elongated dashes rather than spots.

TABLE 6.—*Location of pigment area in* Vinciguerria lucetia *larvae of more than 4 millimeters standard length*

Standard length	Prepectoral	Pectoral	Anal	Anal-fin base [1]	Precaudal	Caudal	Pigmentation at base of caudal rays	
							Upper	Lower
4.3 mm	------	------	------	------	X	X	------	------
4.8 mm	------	------	------	------	X	------	------	------
5.3 mm	------	X	X	------	X	X	------	------
5.6 mm	------	------	X	------	X	X	------	------
6.3 mm	------	X	------	1	X	X	X	------
6.8 mm	X	X	------	------	X	X	X	------
7.3 mm	X	------	X	2	------	X	X	X
7.8 mm	X	X	------	1	X	X	X	------
8.3 mm	X	X	------	2	------	X	X	------
9.2 mm	X	------	------	2	------	X	X	X
9.7 mm	X	------	------	2	------	X	X	X
10.6 mm	X	------	------	2	------	X	X	X
11.5 mm	X	------	------	3	------	X	X	X
12.5 mm	X	------	------	2	------	X	X	X
13.3 mm	X	------	------	2	------	X	X	X
15.3 mm	X	------	------	3	------	X	X	X
16.2 mm	X	------	------	5	------	X	X	X
17.3 mm	X	------	------	4	------	X	X	X

[1] Number of discrete pigment spots above anal-fin base.

The caudal pigment spot, located just anterior to the end of the notochord before caudal-fin formation and just anterior to the base of the caudal fin after caudal formation, is perhaps the most diagnostic pigmentation in *Vinciguerria* larvae. The location of the caudal spot is of taxonomic value in separating the species: in *V. attenuata* and *V. poweriae* the caudal spot is on the lateral midline, whereas in *V. lucetia* and *V. nimbaria* the spot is close to the ventral margin.

Pigmentation changes during metamorphosis.—Pigmentation in the three stages of metamorphosis is separately discussed.

Prometamorphic stage: At the initiation of metamorphosis, when photophores are in the white or colorless stage, the pigmentation remains the same as in larger larvae (fig. 8).

Midmetamorphic stage: The principal augmentation of pigment during the period of rapid change in body proportion is in two areas, the head and the peritoneal wall. The pigment on the head is embedded on the back of the cerebellum and some extends over the crown. During this stage there is a rapid increase in the depth of the body cavity and the simultaneous appearance of considerable peritoneal pigment, particularly in the dorsal wall and in the posterior portion of the abdominal cavity. By the end of the stage there is a light stippling of pigment between the ventral photophores, a streak of pigment on the border of the eye just above the posterior ocular photophore, and a few pigment spots on the operculum.

Postmetamorphic stage: During this stage there is a marked increase in body pigmentation, particularly along the back from the head to the tail. On postmetamorphosing individuals, various stages in the development of dorsal pigmentation have been observed. The dorsal pigment appears just behind the head (fig. 9) and then gradually extends back. It usually is not developed along the entire length of the back until the very end of this stage. Simultaneously, there is an increase in the pigmentation on the crown of the head, a spread of pigment laterally on the nape, an augmentation of the peritoneal pigment, including a lateral spreading, and an increase in the stippling of pigment between the ventral photophores (IV and VA groups). The caudal pigment spot is still observable during this stage and embedded pigment appears in this region. The line of pigment at the base of the caudal rays intensifies and some pigment extends distally a short distance between the rays.

Juvenile and adult pigmentation.—The pigmentation described here for juveniles and adults was observed on preserved specimens that had lost their scales. Obviously, it will not apply to living specimens. The basic pattern of pigmentation is laid down during postmetamorphosis, and subsequent pigmentation mostly serves to intensify this pattern. However, during the juvenile and adult stages various minor but characteristic pigment marks appear. Several of these are on the head; 2 spots appear on the snout between the 2 anterior ocular photophores, a dash appears on the lower jaw just anterior to each SO photophore, and stippling forms along the premaxillary and anterior border of the maxillary. There is a spread of the pigment bordering the eye, and an increase in the amount of pigment on the crown and operculum. From the nape the pigment spreads to below the midline, but along the caudal portion of the body it does not spread below the midline. However, embedded pigment can be observed on some specimens above the anal base and the amount of embedded pigment in the vicinity of the urostyle and ultimate vertebra increases in juveniles and adults. On adults, pigment has been observed extending between and outlining the principal caudal rays, but no pigmentation of the other fins has been observed.

Sequence of calcification

As noted previously, our study was made on cleared and stained material. Bone material stains red with alizarin, hence the sequence of calcification can be readily followed.

Calcification proceeds more slowly in *Vinciguerria* larvae than in most other species we have studied in detail. During much of the larval period, the only structures that show ossification, other than the unpaired fins, are parts of the head, the pectoral girdle, and the structures associated with the urostyle. The cleithrum takes the stain almost immediately in the newly hatched larva. The mouth parts and the head bones gradually differentiate during the larval period. The uroneurals first stain in larvae about 7.5 millimeters long, but no ossification of vertebral centra or spines is discernible until the larvae are approximately 11 millimeters or more in length.

Vertebral development.—The uroneurals and hypurals associated with the urostyle develop considerably earlier than the remainder of the vertebral column. The uroneurals take stain in some specimens about 7.5 millimeters long, and the hypurals form soon after. As pointed out later, there are at first 7 hypural elements, but these are subsequently reduced by fusion to 5.

The vertebral column does not begin to ossify until near the end of the larval period. Ossification of vertebrae is also delayed in other deep-sea fishes (*Leuroglossus stilbius*, for example) but not in most fishes.

The centra of vertebrae ossify before the neural or haemal spines. The first vertebral centra to ossify are some distance back of the head. They appear in about the center of the precaudal group and ossification of centra then proceeds in both directions. The complete group of precaudal centra sometimes ossifies before any of the caudal centra, but usually the anterior 1 or 2 centra form after some caudal centra can be distinguished. Differentiation of the caudal group, with the exception of the urostyle, proceeds posteriorly. Before the ultimate centrum forms, its haemal spine can be distinguished. Differentiation of haemal and neural spines, unlike that of the centra, begins at the ultimate centrum and proceeds forward. A centrum does not ossify along its entire length at initial formation, rather, a narrow band of each centrum forms first and ossification then gradually spreads throughout its length.

The size of larvae at which the vertebrae ossify varies with locality. In areas where metamorphosis begins at about 13 or 14 millimeters the vertebrae begin to ossify at about 11 millimeters. In localities where metamorphosis begins at larger sizes (16 to 19 mm.), vertebral development is correspondingly delayed. Initial ossification of centra is usually complete by the prometamorphic stage, but the neural and haemal spines form during metamorphosis.

The range in number of vertebrae, including urostyle, is from 39 to 42. The number of precaudal vertebrae varies from 22 to 24. The total number of vertebrae shows a definite latitudinal variation which parallels a variation in number of photophores (table 7).

The average number of vertebrae is 41.2 for areas where photophores average 83 per side, while in areas with low average photophore counts (between 80.1–80.6 per side) the average number of vertebrae is 40.3, approximately 1 vertebra fewer.

Gill rakers.—Gill rakers were counted on both stained and unstained material, but more readily on the stained material, especially during the larval period. Gill rakers are more difficult to count on *Vinciguerria* than on fishes that attain a larger

TABLE 7.—*Number of vertebrae in 89 specimens of* Vinciguerria lucetia, *by area of capture*

Area	Number of specimens with—				Total number of specimens	Average number of vertebrae	Average number of photophores per side
	39 vertebrae	40 vertebrae	41 vertebrae	42 vertebrae			
30°-35°N., 122°-134°W	------	2	17	5	24	41.1	83.0
27.5°-30°N., 119°-129°W	------	1	19	8	28	41.2	83.2
25°-27.5°N., 115°-117°W	------	------	2	------	2	41.0	81.3
20°-25°N., 124°W	------	------	3	2	5	41.4	83.1
20°-25°N., 111°-118°W	3	6	10	1	20	40.4	80.6
10°-15°N., 103°W	1	8	1	------	10	40.0	80.1
All specimens	4	17	52	16	89	40.9	82.2

size. The anterior rakers on the lower limb are especially difficult to get into position for counting on juveniles and adults, and, as a consequence, we may have undercounted the rakers on some specimens. The full complement consists of 8 to 10 rakers on the upper limb, and 18 to 23 on the lower.

Gill rakers form on the lower limb during the larval period, but do not appear on the upper limb until metamorphosis. Nubbins were first observed on larvae approximately 8 millimeters long. A group of rakers, usually about 10, differentiates simultaneously. Two or three are still lacking at the posterior end of the lower limb, and between 7 to 10 at the anterior end. Fifteen or sixteen rakers are formed on the lower limb by the close of the larval period, when only the anteriormost rakers have not formed (see table 30).

The rakers were counted on a number of prometamorphosing specimens. The lowest count was 0+16, the highest 4+22. Most individuals had either 2 or 3 rakers developed on the upper limb and 17 or 18 on the lower.

Midmetamorphosing individuals usually had 3 to 5 rakers on the upper, and 17 to 21 on the lower limb; postmetamorphosing specimens usually had 6 to 9 on the upper limb, 18 to 23 on the lower. All juveniles or adults counted had either 8, 9, or 10 rakers on the upper limb, 18 to 23 on the lower.

No geographical variation was noted in numbers of gill rakers in juvenile and adult specimens of *Vinciguerria lucetia*.

Development of teeth.—Larval teeth (table 8) form first on the maxillaries, which are the first jaw bones to ossify. One or two maxillary teeth per side were observed on larvae just under 5 millimeters in length. Subsequently, teeth are gradually added along the maxillaries until there are approximately 13 per side at metamorphosis. Most of the maxillary teeth are straight and needlelike. The posterior teeth are usually a little longer than the anterior ones.

TABLE 8.—*Development of teeth in larval* Vinciguerria lucetia

Standard length	Number of specimens	Average number of teeth per side			
		Maxillary	Premaxillary	Mandibular	
				Outer	Inner
4-4.9 mm	3	1.3	0	0	0
5-5.9 mm	7	2.5	0	0	0
6-6.9 mm	8	4.1	0	0	0
7-7.9 mm	6	5.3	0	0.8	0
8-8.9 mm	10	7.6	0	2.8	0
9-9.9 mm	9	7.7	0	3.4	0
10-10.9 mm	5	9.4	0	4.2	0
11-11.9 mm	15	10.2	0	4.2	0
12-12.9 mm	7	11.1	0	4.6	0.6
13-13.9 mm	6	11.5	1.9	4.3	1.3
14-14.9 mm	1	11.0	3.0	5.0	2.0
15-15.9 mm	2	13.0	2.5	5.0	1.0
17-17.9 mm	1	12.5	4.0	5.0	2.0

The mandibular teeth form in two rows. Those in the outer row form first; they are directed laterally along the anterior part of the lower jaw. They can be observed in larvae of about 7 millimeters standard length and increase in number to 3 to 5 teeth (averaging 3.4) per side in 9-millimeter larvae. During the late larval period, the average number increases to 5, with a range of 4 to 6. The mandibular teeth of the inner row form on the anterior part of the dentaries and are directed at right angles to those of the lateral row. They first form on specimens of about 12 millimeters standard length, and 1 to 3 inner teeth are developed per side before metamorphosis. They are short, wide-based, and of unequal size.

The premaxillaries calcify late and the teeth are observed soon after, when the larvae are about 13 millimeters long. About 3 or 4 unevenly spaced teeth per side usually form before metamorphosis.

During prometamorphosis, the teeth do not differ from those described for larvae, but by late postmetamorphosis the dentition is similar to that of juveniles and adults. During metamorphosis, therefore, a marked increase in the number of teeth on the maxillary, premaxillary, and mandible occurs, as well as changes in the shape and arrangement of the teeth (refer to comments under *V. poweriae*, page 404, for a discussion of changes that occur in maxillary teeth during midmetamorphosis). The increase in number of teeth at

TABLE 9.—*Number of teeth present at various stages in development of* Vinciguerria lucetia

Stage	Number of specimens	Number of teeth per side		
		Premaxillary	Maxillary	Mandibular
Late larval	8	1- 4	11-13	5- 7
Prometamorphic	14	4- 6	12-16	5- 9
Postmetamorphic	8	11-18	14-28	13-30
Juvenile	4	13-15	26-32	25-30
Adult	5	12-17	50-65	38-48

different stages in the development of *V. lucetia* is summarized in table 9.

In late-metamorphosing individuals, juveniles, and adults the teeth develop as follows:

Premaxillary teeth apparently do not increase in number after metamorphosis. The highest number found, 17 on one side and 18 on the other, was on a postmetamorphosing individual. Premaxillary teeth are moderately wide based, sharply pointed, unequal in size and uneven in spacing. Usually 5 or 6 are longer and heavier than the others. The premaxillary teeth are uniserial and curve inward at their tips.

Maxillary teeth apparently increase in number throughout life, and adults have twice as many as postmetamorphosing individuals. Maxillary teeth are in a single row. There are two principal kinds of maxillary teeth: (1) straight teeth, set perpendicular to the jaw and curved slightly inward at their tips, and (2) oblique teeth, directed forward at an angle of about 45° and shaped somewhat like a flattened S. An anterior group of straight teeth precede the insertion of the first oblique tooth and the number in this group increases markedly between the postmetamorphic and adult stages. Postmetamorphosing individuals have an anterior group of 4 to 14 straight teeth, while the adult specimens examined had from 26 to 34 teeth in this group (fig. 15). The oblique teeth are interspersed singly between groups of 2 to 5 straight or nearly straight teeth. A group of 3 or 4 straight teeth ends the series; one to three of the teeth in this group are not in line with other maxillary teeth, but originate laterally on the maxillary rather than on its lower surface. The number and

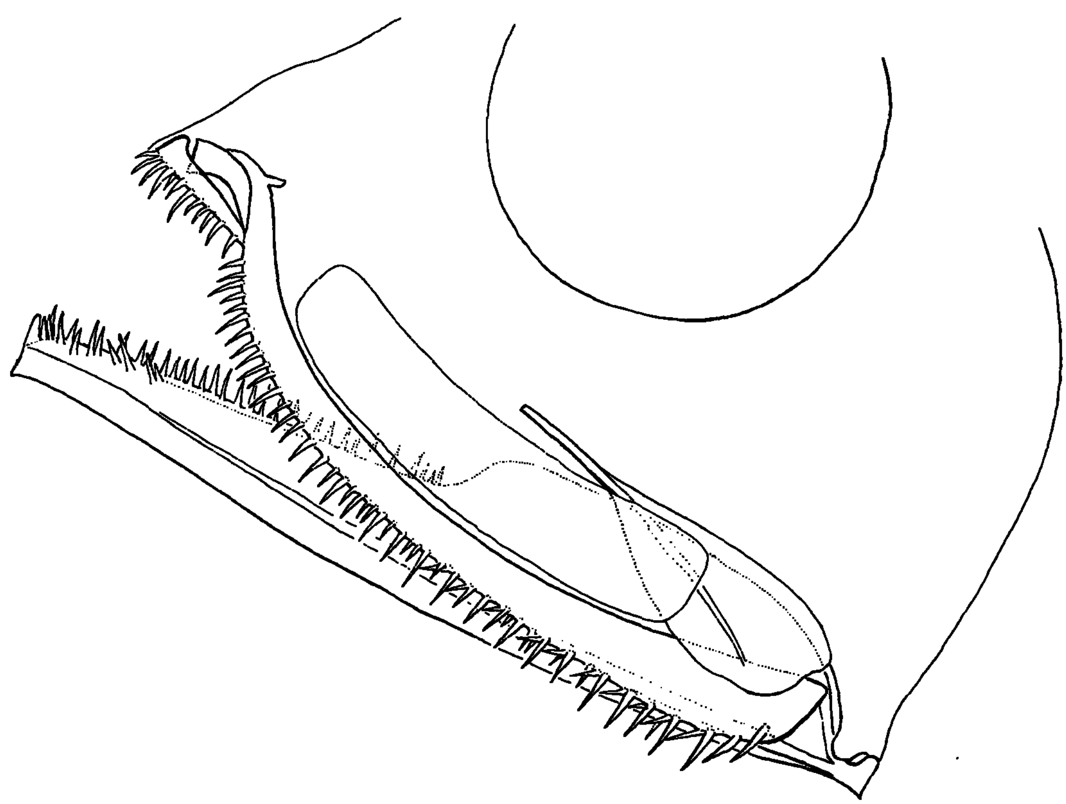

FIGURE 15.—Jaws of specimen of *Vinciguerria lucetia*, 42 mm. in length, collected off Guadalupe Island.

TABLE 10.—*Comparison of maxillary teeth on selected specimens of* Vinciguerria lucetia, *by stage of development*

Standard length	Number of straight teeth in anterior group		Number of oblique teeth		Total number of teeth	
	Left side	Right side	Left side	Right side	Left side	Right side
Postmetamorphic:						
16.75 mm	5	4	4	4	17	16
17.25 mm	3	4	5	4	15	14
17.55 mm	5	4	4	4	16	15
20.20 mm	10	13	6	5	24	26
Juvenile:						
19.50 mm	13	11	6	8	30	31
21.25 mm	10	7	7	7	26	28
24.45 mm	18	16	5	5	33	31
24.70 mm	16	16	5	6	30	32
Adult:						
29.20 mm	28	26	10	10	56	55
41.50 mm	33	32	10	10	65	63
43.00 mm	29	33	9	7	55	52
43.00 mm	28	31	7	7	50	52

arrangement of teeth vary on the two sides of the jaw (table 10).

Mandibular teeth also increase in number during growth from juvenile to adult. Mandibular teeth in the anterior part of the jaw are in two obliquely divergent rows. Teeth of the inner row are fewer and usually more uniform in size and spacing than are those of the outer row, where the teeth may be either evenly spaced or grouped in clusters of 2 or 3 teeth. The teeth in the posterior part of the lower jaw are uniserial and are more closely and uniformly spaced than the anterior group of teeth.

The palatine teeth form during the postmetamorphic stage. A specimen 16.75 millimeters long had 1 tooth on one side and 2 on the other, while a late postmetamorphosing individual, 20.2 millimeters long, had the full complement of 4 to 5 palatine teeth. The posteriormost tooth is largest, and the teeth decrease in size anteriorly.

The vomerine teeth, 1 on a side, also form during the postmetamorphic stage.

Branchiostegals.—Branchiostegals form during the late larval period just before metamorphosis. The size at which they form depends directly on the size the larva attains before metamorphosis. In some regions, branchiostegals are developed in larvae of about 12 millimeters, while in other areas they are not formed until the larvae are at least 16 millimeters long. The full complement of branchiostegals is 12, and all metamorphosing individuals had the full complement. As pointed out elsewhere, the first branchiostegal precedes the anterior branchiostegal photophore. The rays and photophores then alternate, except that the last four branchiostegals are posterior to the last photophore.

Fins.—The number of rays in fully developed fins is shown in table 11. The dorsal fin of *V. lucetia* has 13 to 16 rays (average, 14.59) and the anal fin has 13 to 17 (average, 15.14). In each fin the first ray is unsegmented, the second is segmented but unbranched, and the others are segmented and branched. We are following Jespersen and Tåning (1926) in counting the posterior two rays as separate. The bases of these rays are closer together than the bases of other rays, but they are always distinctly separated and have separate interneurals and interhaemals.

TABLE 11.—*Variation in number of rays in fully developed, unpaired fins of* Vinciguerria lucetia

Number of rays	Dorsal fin	Anal fin	Caudal fin		
			Principal rays	Dorsal secondary	Ventral secondary
4					65
5					1
7				5	
8				39	
9				20	
10				2	
13	3	1			
14	42	11			
15	48	62			
16	7	25			
17		1			
19			66		
Number of specimens	100	100	66	66	66
Average number of rays	14.59	15.14	19.00	8.29	4.02

In all specimens studied, each pectoral fin has 10 rays; the ventral (pelvic) fin has 7 rays. The uppermost ray and the lowermost ray in the pectoral are unbranched, all others are branched. All rays in the ventral fins are usually branched.

The caudal fin has 19 principal and 11 to 14 secondary rays. The principal rays are segmented, 17 are branched. The secondary (procurrent) rays are unsegmented and unbranched. Hollister (1936:259) applies the term "raylets" to such secondary rays. The secondary rays are unequally developed on the two parts of the tail, dorsal secondaries numbering 7 to 10 (average, 8.29), ventral secondaries 4 or 5 (average, 4.02).

We will discuss fins in the order of their formation: (1) Larval pectoral (without rays); (2) caudal; (3) dorsal; (4) anal; (5) ventrals (pelvics); and (6) pectoral (with rays).

Larval pectoral fins: The larval pectoral fins form almost immediately after hatching in larvae less than 2.5 millimeters in length. The fleshy base of the fin is narrow, and the membrane without rays is fan-shaped. Rays do not appear in the pectoral fins until metamorphosis (see below).

Caudal fin: The caudal fin of *V. lucetia* is a typical homocercal tail, and the development is essentially similar to that of many other isospondylous fishes.

The tail fin of isospondylous fishes typically has 19 principal rays (17 branched and the adjacent on either side unbranched). The rays are sharply divided into two groups: 10 upper and 9 lower. All 19 principal rays are ventral in origin, and all are associated with the urostyle except the lower unbranched ray in some species, in which it is attached to the haemal spine of the ultimate vertebra. This description applies to clupeids, engraulids, salmonids, osmerids, argentinids, et cetera.

The caudal fin is first evident as a ventral thickening forward of the tip of the notochord. The thickening has been observed on larvae as small as 4.5 millimeters. As usual, the first rays to form are always the central principal rays, and differentiation proceeds both anteriorly and posteriorly from this center; the rays which will constitute the upper group of 10 principal rays differentiate posteriorly, while those which will constitute the lower group of 9 principal rays differentiate anteriorly. The central caudal rays can be observed on larvae more than 5.5 millimeters long, and the full complement of 10+9 principal rays is found on larvae of more than 6.5 millimeters. The flexure of the posterior portion of the urostyle, bringing the rays into a terminal position, occurs almost simultaneously with principal-ray differentiation.

The secondary, or procurrent, caudal rays differentiate much more slowly than the principal rays. None were observed on larvae under 8.0 millimeters, and they are absent on some larvae approximately 8.5 millimeters long. The secondary rays form on either side of the principal rays, and differentiation proceeds anteriorly. The dorsal secondary rays are the only caudal rays that have a dorsal origin. The secondary rays form slowly. By the end of the larval period, 4 or 5 (occasionally 6) dorsal and 4 ventral secondary rays differentiate. This is the full complement of ventral secondary rays, but little more than half of the dorsal rays (there are 7 to 10 dorsal secondaries in the fully developed tail). Prometamorphosing individuals occasionally have the full number of dorsal secondary rays, but most of these lack 1 to 3 rays. Most midmetamorphosing individuals have the caudal secondary rays fully formed. Many isospondylous fishes with ventral light organs have fewer ventral secondary caudal rays than dorsal, hence this condition in *V. lucetia* is not unique.

The fully developed caudal fin is associated with the last three vertebrae. The development of the supporting skeletal structures for the caudal fin is discussed in a section following fin formation (p. 384).

Dorsal fin: The base of the dorsal fin can be seen on some larvae under 6.0 millimeters long, and rays are found on most larvae of more than 6.5 millimeters. Initially, a group of rays, usually six, in the central portion of the fin, differentiate at the same time, and differentiation then proceeds in both directions. The full complement of dorsal rays is 13 to 16, and the usual number is 14 or 15. Some individuals as small as 10.5 millimeters have 14 dorsal rays, and all of more than 12.0 millimeters in length have at least 14 rays; hence, dorsal-fin formation is completed during the larval period. Dorsal rays on larvae are unbranched.

Anal fin: Rays are not differentiated in the anal fin until larvae attain a length of at least 8.0 millimeters. As in the dorsal fin, the first rays to form are the median ones. Four or more rays appear simultaneously and differentiation then proceeds in both directions. The full complement of anal rays, 14 to 17, is found on all larvae longer than 13.0 millimeters.

Ventral fins: The buds of the ventral or pelvic fins can be seen on 11.0-millimeter larvae, but fin formation is not completed until metamorphosis, usually during the prometamorphic stage (table 12). The number of rays when fully formed is invariably 7.

Pectoral fins (with rays): Rays do not form in the pectoral fin until metamorphosis. Prometamorphosing specimens have from 0 to 6 rays in each fin. Since the complete complement is found on most midmetamorphosing individuals, we assume that ray formation is completed during the

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early part of midmetamorphosis. When fully formed, the number of pectoral rays is invariably 10 (table 12).

TABLE 12.—*Number of rays in pectoral and ventral fins of larval and metamorphosing specimens of* Vinciguerria lucetia

Stage	Number of rays									Total number of specimens
	0	1	3	4	5	6	7	8	10	
Larval:										
Pectoral fin	100	----	----	----	----	----	----	----	----	100
Ventral fin	100	----	----	----	----	----	----	----	----	100
Prometamorphic:										
Pectoral fin	10	1	2	2	1	4	----	----	----	20
Ventral fin	1	----	----	----	1	2	15	----	----	19
Midmetamorphic:										
Pectoral fin	----	----	----	----	----	----	2	1	22	25
Ventral fin	----	----	----	----	----	----	25	----	----	25
Postmetamorphic:										
Pectoral fin	----	----	----	----	----	----	----	----	25	25
Ventral fin	----	----	----	----	----	----	25	----	----	25

Adipose fin: The adipose fin is not evident on larvae, but can be observed on prometamorphosing individuals and is well-developed by the end of metamorphosis. The position and dimensions of this fin on adults is illustrated by morphometric measurements of three selected individuals:

Standard length	Snout to origin of dorsal	Snout to insertion of dorsal	Snout to adipose	Width of adipose at base	Length of adipose
Mm.	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*
26.2	14.7	19.8	22.1	0.3	1.5
40.6	23.1	30.2	34.3	0.6	2.3
56.0	32.5	42.5	48.0	0.8	3.8

The adipose fin has a moderately narrow base. The fin is directed obliquely backward, has a curved upper (anterior) margin and a fairly straight lower margin, and ends in a blunt point.

Supporting structures for dorsal and anal fins: The number of interneural spines associated with the dorsal fin is identical with or one less than the number of rays. In specimens having 1 less ray, the anterior interneural usually comprises 2 fused elements. Most of the interneurals in the anterior half of the fin are bifurcate at their proximal ends.

There are 13 to 15 free interneurals anterior to those associated with the dorsal fin. The first free interneural precedes the first neural spine, the second one lies between the 1st and 2d neural spines, and each remaining interneural is usually situated between two neural spines. There are no free interneurals posterior to the dorsal fin.

Interhaemal spines are similar to interneurals in having the anterior spines bifurcate at their proximal ends, and in having a similar relationship with fin rays. There are no free interhaemals either anterior or posterior to the anal fin.

Supporting structures for the caudal fin: We have taken a particular interest in the caudal fin and its supporting structures as an aid in the identification of larval fish. Surprisingly, there are more marked differences among gonostomatids in the supporting elements associated with the urostyle than in any family of which we have knowledge. In *Diplophos*, for example, the primitive and complete complement of 7 hypurals and 3 epurals persists. This is the basic number in many families of isospondylous fishes. In *Cyclothone*, on the other hand, the supporting structures are reduced to two hypurals and no epurals. *Vinciguerria* is intermediate, having five hypurals and a single epural.

It is interesting to note, however, that during formation of the caudal supporting structures in *V. lucetia*, 7 hypurals initially develop, which are subsequently reduced to 5 by fusion of elements. The uroneurals ossify before any other part of the vertebral column, and the hypurals form soon after, usually on larvae between 8 and 9 millimeters long. The elements that fuse are the 2 hypurals above and the 2 below the midpoint of the caudal fin. The beginning of fusion of the elements can be observed on some larvae 11.0 millimeters long, and fusion is completed before the end of the larval period. It is an interesting point that the outer hypurals, which remain separate, ossify before the inner ones.

The caudal fin is associated with the last three vertebrae, i. e., the urostyle and the two vertebrae with normal centra, anterior to the urostyle, which are designated "ultimate" and "penultimate." The neural spines are modified on the latter two vertebrae. They are wider than ordinary spines and truncate at their distal ends. The haemal spine is always truncate on the ultimate vertebra, but is ordinarily pointed on the penultimate. Several vertebrae anterior to the penultimate also have truncate neural spines, but normally pointed haemal spines. The condition found in 13 specimens examined for these characters is given in table 13.

The specimen illustrated in figure 16 has truncate neural spines on the last 4 vertebrae anterior

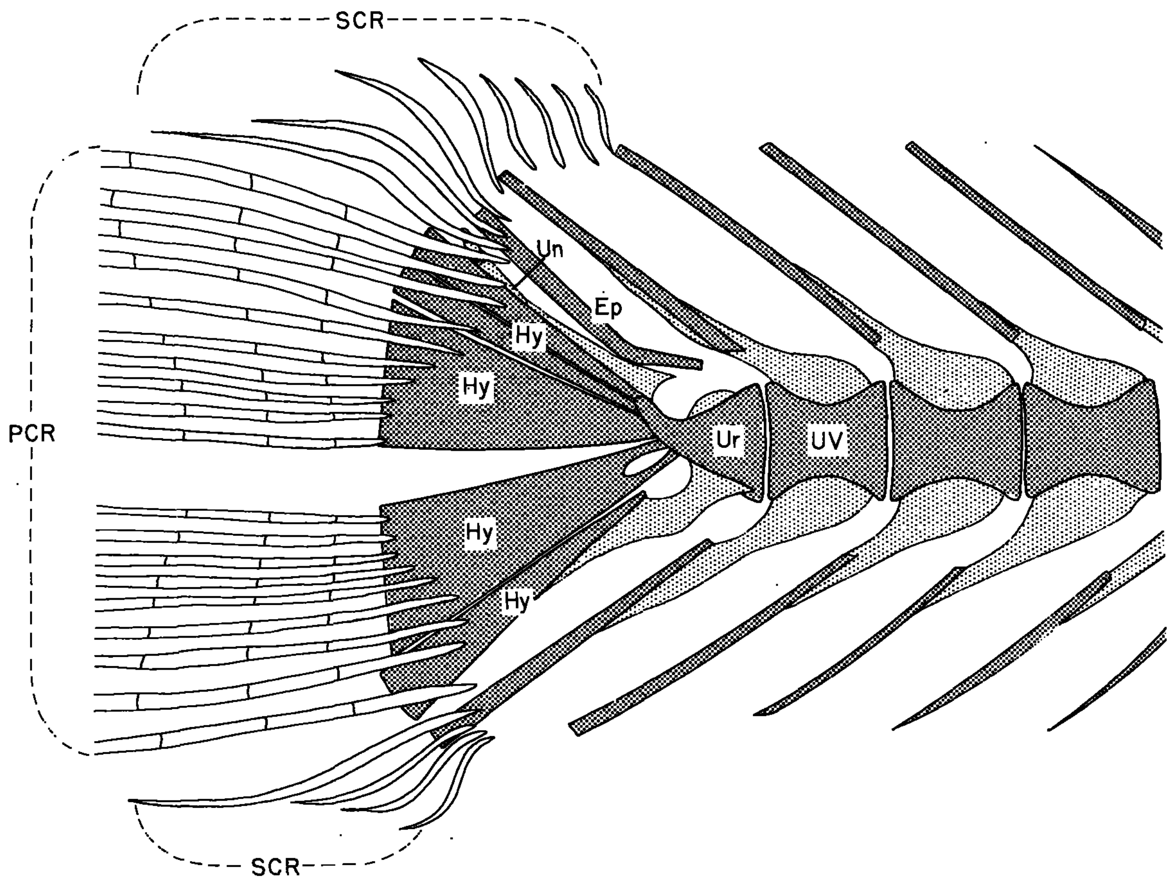

FIGURE 16.—Caudal portion of vertebral column, showing the supporting skeletal structures of the caudal fin. (Ep—epural; Hy—hypurals; PCR—principal caudal rays; SCR—secondary caudal rays; Un—uroneural; Ur—urostyle; UV—ultimate vertebra.)

TABLE 13.—*Types of neural and haemal spines on last six caudal vertebrae anterior to urostyle in* Vinciguerria lucetia

[Based on 13 specimens]

Vertebra	Number of specimens with spines—		
	Both truncate	Neural, truncate; haemal, pointed	Both pointed
I (ultimate)	13		
II (penultimate)	2	11	
III (antepenultimate)		13	
IV		9	4
V		1	12
VI			13

to the urostyle and truncate haemal spines on the last 2. As shown in table 13, the majority of specimens examined have 4 truncate neural spines, but only 2 individuals out of 13 have more than a single truncate haemal spine.

Scale formation

The scales of *Vinciguerria* are highly deciduous, so much so that specimens taken in plankton hauls or trawls seldom possess scales. As a consequence we have not been able to study scale formation. Some postmetamorphosing individuals showed scale pockets over the body, hence we assume that scales are laid down during metamorphosis. No attempt is made to show scales on our drawings. Some specimens dip netted off Guadalupe Island still retained a few scales.

Photophore development

The photophores of *Vinciguerria* are striking in appearance. The number and arrangement of these organs easily distinguish the genus from other gonostomatids. In live specimens taken by dip net at Guadalupe Island, Baja California, the organs gave off a luminescent, blue light when the specimens were held or stimulated. In adults, each photophore consists of a black base and a grayish-silver lens, which is directed downward.

Several methods of classifying photophores have been used (cf., Jespersen and Tåning, 1926;

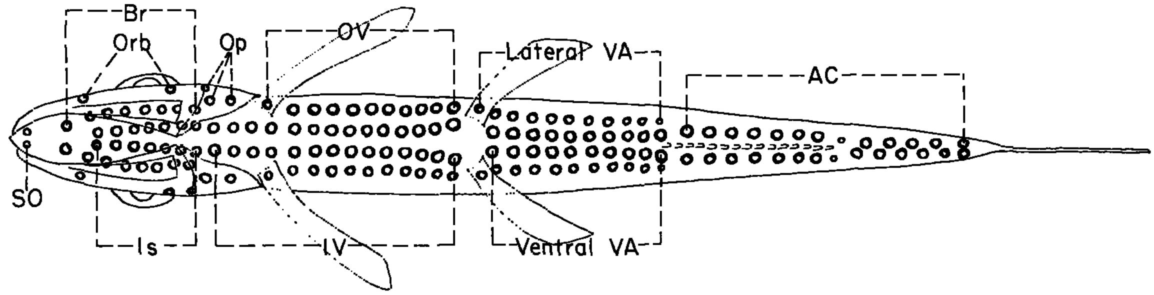

FIGURE 17.—Ventral view of juvenile *Vinciguerria lucetia*, showing the arrangement of photophore groups. (SO—symphyseal pair: Orb—orbital photophores; Op—opercular photophores; Br—branchiostegal photophores; Is—isthmian photophores; OV—lateral photophore group extending from operculum to ventral fin; lateral VA—lateral group extending from ventral fin to origin of anal fin; IV—ventral body photophores between isthmus and ventral fins; ventral VA—ventral group between ventral fins and origin of anal fin; AC—group between origin of anal fin and base of caudal fin.)

Horsburgh 1935). We are using a classification that differs slightly from previous classifications, but appears to us to be a natural system for grouping photophores in *Vinciguerria*.

The photophores have been grouped into 10 categories (see fig. 17). Five of these are used to classify the photophores on the head, 2 for lateral photophores on the body, and 3 for ventral body photophores. The head photophores are grouped as follows: (1) Symphyseal (SO)—one pair placed anteriorly on the underside of lower jaw; (2) orbital (Orb)—2 per side, 1 in front of eye, the other just under posterior portion of eye; (3) opercular (Op)—3 per side, 1 behind center of eye, 2 about on level with lateral row of photophores; (4) branchiostegal photophores (Br)—8 per side, spaced between anterior 9 branchiostegals; (5) isthmian photophores (Is)—7 per side, spaced along isthmus.

Head photophores seldom vary in number after development is complete. Less than 1 percent of the specimens examined had other than 8 branchiostegal photophores per side; 1 specimen had 9, 2 specimens had 9 photophores on one side and 8 on the other, and 1 specimen had 7 photophores on one side and 8 on the other. Only 3 individuals had other than 7 isthmian photophores per side; 2 specimens lacked a photophore on one side (7–6), the other had an additional photophore on one side (7–8).

The body photophores are alined on each side in two rows, a lateral row and a ventral row. The photophores in the lateral row are in two groups, one anterior to the ventral fins (OV), the other between the ventral and anal fins (VA). The OV group contains between 10 and 13 photophores (average, 11.34) and the VA group, when fully formed, contains 9 to 12 photophores (average, 10.88). The IV group of photophores (isthmus to ventral fins) in the ventral row is continuous with the isthmian group. The IV group contains 13 to 16 photophores (average, 14.34) on each side. The ventral series is interrupted by the ventral fins. The VA group of photophores in the ventral row begins just behind the ventral fins and extends to the origin of the anal fin; on each side there are 8 to 12, usually 9 or 10, photophores (average, 9.89). The anal-caudal (AC) group, situated between the origin of the anal fin and the base of the caudal fin, is intermediate in level between the lateral and ventral series; there are 12 to 16, usually 13 or 14, photophores on each side (average, 13.86).

Unlike the head photophores, the body photophores vary in number. The extent of this variation is shown for 586 specimens in table 14.

There is not only variation in the number of photophores per group on different individuals, but at times in the number of photophores per group on the two sides of the same individual. This asymmetry (different number per side) is more marked in the AC group than in the other body groups. The percent of individuals having asymmetry in photophore pairings is given in table 15.

The OV group of photophores in the lateral series is situated above the IV group of ventral-row photophores. The IV group extends farther

TABLE 14.—*Variation in number of body photophores, in 586 specimens of* Vinciguerria lucetia

[See text, p. 386 for explanation of symbols]

Number of photophores	Lateral row		Ventral row		AC group
	OV group	VA group	IV group	VA group	
8-9				2	
9-9		1		67	
9-10		1		45	
9-11				1	
10-10	5	70		438	
10-11	8	40		16	
11-12	369	441		16	
11-11	13	16		1	
12-12	178	17			
12-13	5				7
12-14					3
13-13	8		6		94
13-14			10		118
13-15					8
14-14			364		233
14-15			16		80
14-16					1
15-15			176		38
15-16			6		2
16-16			8		
Total number of specimens	586	586	586	586	584
Average number of photophores per side	11.34	10.88	14.34	9.89	13.86

TABLE 15.—*Asymmetry in photophore pairing in various photophore groups in* Vinciguerria lucetia

[Based on 586 specimens of table 14]

Photophore group	Frequency of specimens with photophore numbers—		Percentage of specimens with asymmetrical pairng of photophores
	Same on two sides of body	Different on two sides of body	
Head	580	6	1.0
Lateral OV	560	26	4.4
Ventral IV	553	33	5.6
Lateral VA	529	57	9.7
Ventral VA	521	65	11.1
Anal-caudal (AC)	365	219	37.5

forward than the OV group; the three anterior pairs of IV photophores have no counterparts in the OV group. Otherwise, the 2 series usually correspond photophore for photophore and the organs of the 2 series are regularly alined transversely. When asymmetry occurs, it is usually in both the IV and OV groups. Of 33 specimens that had asymmetry in the IV group, 26 showed asymmetry in the OV group as well. On the other 7 specimens, the OV group was symmetrical while the IV group had an uneven number on the two sides. Such asymmetry in the ventral IV group that is not shared by the lateral OV group is usually in the anterior three photophores. A similarly close relation obtains between the lateral VA and ventral VA series of photophores when photophore formation is complete. As is noted in the following section, a group of the lateral VA photophores is late-forming. The lateral VA group, when completely formed, averages one photophore per side more than the ventral VA group. The anterior pair of photophores of the lateral VA group, situated above the ventral fins, has no counterpart in the ventral VA group. Otherwise, the two groups have identical numbers of photophores. When asymmetry occurs, it is usually found in both groups. On only nine individuals was asymmetry in the ventral VA group not found in the lateral VA group as well. Asymmetry in the VA groups is more frequent than in the OV and IV groups, but is much less frequent than in the AC group. Hence, frequency of asymmetry seems to be definitely related to position of the photophore group on the body: least in the photophores associated with the head, and increasing posteriorly.

Late-forming photophores.—Most photophores appear simultaneously at the beginning of the transformation stage. At first formation, photophores are colorless, but the base soon becomes pigmented. Six, occasionally seven, photophores per side form late: the upper opercular, the 3 (or occasionally 4) posterior photophores of the lateral VA group, the symphyseal, and a median photophore of the AC group.

Upper opercular photophores: The pair of upper opercular photophores (Op) is usually the first of the late-forming light organs to appear, and the only ones that consistently develop during the midmetamorphic stage. These photophores are found on about 25 percent of the midmetamorphosing specimens and on all classed as postmetamorphosing. The largest individual lacking them was 19.0 millimeters long.

Posterior photophores of the lateral VA group: Three to four pairs of photophores of the posterior lateral group are lacking when the photophores initially appear. Approximately 10 percent of the specimens examined lacked 4 photophores on each side; the remainder lacked 3 photophores. Because of the relation between numbers of photophores in the lateral and ventral VA groups, it is possible to determine the number of "missing" photophores exactly. At formation, late-forming photophores are colorless and are smaller than the adjacent, earlier-formed ones.

Even when they become pigmented, they can be distinguished readily from those initially formed.

The late-forming photophores of the lateral VA group develop mainly during the postmetamorphic stage. On about 10 percent of the midmetamorphosing individuals examined, a single late-forming VA photophore or a pair of VA photophores had appeared. One pair of the lateral photophores almost always develops before the symphyseal pair, and the other 2 (or 3) pairs are added gradually. There is some variation in the sequence in which the late-forming AC pair of photophores appears in relation to the VA photophores (to be discussed later). Usually the posterior pair of lateral VA photophores is the last to form.

The largest specimen studied in which the photophores had not all formed was 22.3 millimeters in length; it lacked a VA and an AC photophore on one side. The smallest specimen with complete photophores measured 17.5 millimeters. We consider that metamorphosis terminates when the photophores are all laid down and the late-forming photophores are pigmented.

Symphyseal photophores: The pair of symphyseal (SO) photophores does not appear until the postmetamorphic stage. Of the 75 postmetamorphosing individuals used to trace photophore development, 26 still lacked these photophores. The largest individual that lacked symphyseal photophores was 19.0 millimeters long; the smallest specimen on which they were developed was 12.5 millimeters. In sequence of formation, symphyseal photophores are usually the third pair of late-forming photophores to appear.

Symphyseal photophores have been used as a diagnostic character in separating species of *Vinciguerria: lucetia* and *nimbaria* develop this pair, while *attenuata* and *poweriae* do not. However, owing to the circumstance that symphyseal photophores are late-forming, this character must be used with caution when dealing with metamorphosing individuals.

Anal-caudal photophores: The anal-caudal (AC) photophores are separated into two groups during most of the metamorphic period, but eventually become a continuous series by the addition of a pair of photophores between the two groups. The photophores in the two groups differ in spacing. In the anterior group, situated above the anal fin, the photophores of the two sides are rather widely separated and are arranged in pairs opposite one another; in the posterior group, the photophores of the two sides are too closely approximated to lie side by side, and alternate regularly, except for the posteriormost pair, or occasionally the last two pairs, which again show the transverse alinement (fig. 17). The anterior group of AC photophores usually consists of 6 or 7 photophores on a side (average, 6.78), the posterior group has 5 to 7 (average, 6.13).

The numbers of photophores in the two AC groups, based on 215 metamorphosing individuals, are given in table 16.

TABLE 16.—*Variation in number of photophores in the anterior and posterior anal-caudal groups during metamorphosis, in 215 specimens of* Vinciguerria lucetia.

[On both sides of body]

Number of photophores	Anterior group	Posterior group
5-5		8
5-6	2	38
6-6	36	86
6-7	37	58
7-7	126	25
7-8	8	
8-8	5	
8-9	1	
Average, per side	6.78	6.13

There is some variation in the sequence of development of the late-forming AC pair in relation to late-forming VA photophores; this is shown in table 17, based on 106 postmetamorphosing individuals. Usually the pair of late-forming AC photophores develop before the last pair of lateral VA photophores; 9 individuals having the AC light organs on both sides of the body still lack 1 or more pairs of VA photophores. On the other hand, 2 individuals with all VA photophores still lack the pair of AC light organs.

TABLE 17.—*Sequence of development of late-forming photophores of the lateral VA and the AC groups, in 106 specimens of* Vinciguerria lucetia

[On both sides of body]

Number of lateral VA photophores lacking	Number of AC photophores lacking		
	1-1	0-1	0-0
4-4	1	0	0
4-3	2	0	0
3-3	25	3	0
3-2	9	3	0
2-2	33	7	1
2-1	3	0	1
1-1	6	1	7
0-1	0	2	0
0-0	2	0	0
Total number of specimens	81	16	9

DISTRIBUTION OF *VINCIGUERRIA LUCETIA* IN THE EASTERN PACIFIC

Our data on the distribution of *Vinciguerria lucetia* have been derived from two sources: the survey cruises conducted by the California Cooperative Oceanic Fisheries Investigations (CCOFI), from which we have been able to derive detailed information on its distribution off California and Baja California, and the less frequent but wide-ranging cruises and expeditions that have covered much of the eastern North Pacific, such as "Norpac," "Northern Holiday," "Shellback," and "Eastropic" expeditions of the Scripps Institution of Oceanography and several tuna longline cruises conducted by the California Department of Fish and Game. Most of the material has been obtained from plankton-net collections, supplemented by an examination of collections obtained from midwater trawls, tuna stomachs, and occasionally dip netting.

DISTRIBUTION AND ABUNDANCE IN CCOFI SURVEY AREA

We shall first discuss the distribution and abundance of *V. lucetia* larvae and adults off California and Baja California, and then present such information as we have on the more extensive distribution of this wide-ranging species.

The distribution of larvae of this species in the CCOFI area in 1951 and 1952 is shown in figures 18 and 19. In each of these, the cruises extended only as far north as the California-Oregon State line. The area off northern California (station lines 40–57) was surveyed on two cruises each year: during July and August in 1951, and June and July in 1952. The area between San Francisco and Point San Juanico, Baja California (station lines 60–137) was surveyed on most cruises. The waters still farther south (station lines 140–157) were not routinely surveyed; the area was covered on three cruises in 1951 (March, June, and September), but only during the February cruise in 1952, and then only partially.

The northern extent of the distribution of *V. lucetia* has been fairly well delimited. There was only a single occurrence of larvae to the north of Point Conception in both 1951 and 1952—at station 60.80 in May 1951, and at station 77.55 in November 1952. In 1949, however, larvae were taken in several collections off central and northern California. The northernmost collection of larvae was at station 509 (37°21′ N. latitude, 130°36′ W. longitude); the northernmost collection of metamorphosing individuals was at station 704 (34°54′ N. latitude, 124°04′ W. longitude). Even so, the occurrences to the north of Point Conception have been sporadic, and the number of specimens obtained has been few.

The area off southern Baja California, unfortunately, cannot be completely compared in 1951 and 1952, owing to the fragmentary coverage in the latter season. This area appears to be the richest for *V. lucetia* of any in the CCOFI region. In 1951, when cruises extended to Cape San Lucas on three occasions, more than 50 percent of the larvae of this species were obtained on the station lines (140–157) off southern Baja California. The data are summarized in table 18.

TABLE 18.—*Census estimates of abundance (in billions of larvae) of* Vinciguerria lucetia *during three cruises in the CCOFI survey area in 1951*

Station lines	Cruise and month			Total estimated number of larvae	Percent of total
	5103 March	5106 June	5109 September		
60–77	0	0	0	0	0
80–93	139	163	68	370	3.33
97–107	28	188	639	855	7.69
110–120	700	194	1,273	2,167	19.49
123–137	116	1,193	457	1,766	15.88
140–157	1,040	1,716	3,205	5,961	53.61
Total	2,023	3,454	5,642	11,119	100.00

In the area regularly covered (station lines 60 to 137), the cumulative census estimates of larvae for comparable cruises during the 2 years (December 1951 was omitted, since there was no December cruise in 1952) are quite similar: 18,384 billion as compared to 19,020 billion (table 19). As explained in a previous publication (Ahlstrom and Counts, 1955), a census estimate is one that integrates standard haul estimates over area but not over time. Size is not taken into account. It is a comparative estimate of abundance, rather than an estimate of actual abundance, which must take into account size, growth rate, and other factors (Ahlstrom 1954), some of which are not known as yet for this species. However, for comparative purposes, census estimates are valid measures of relative abundance.

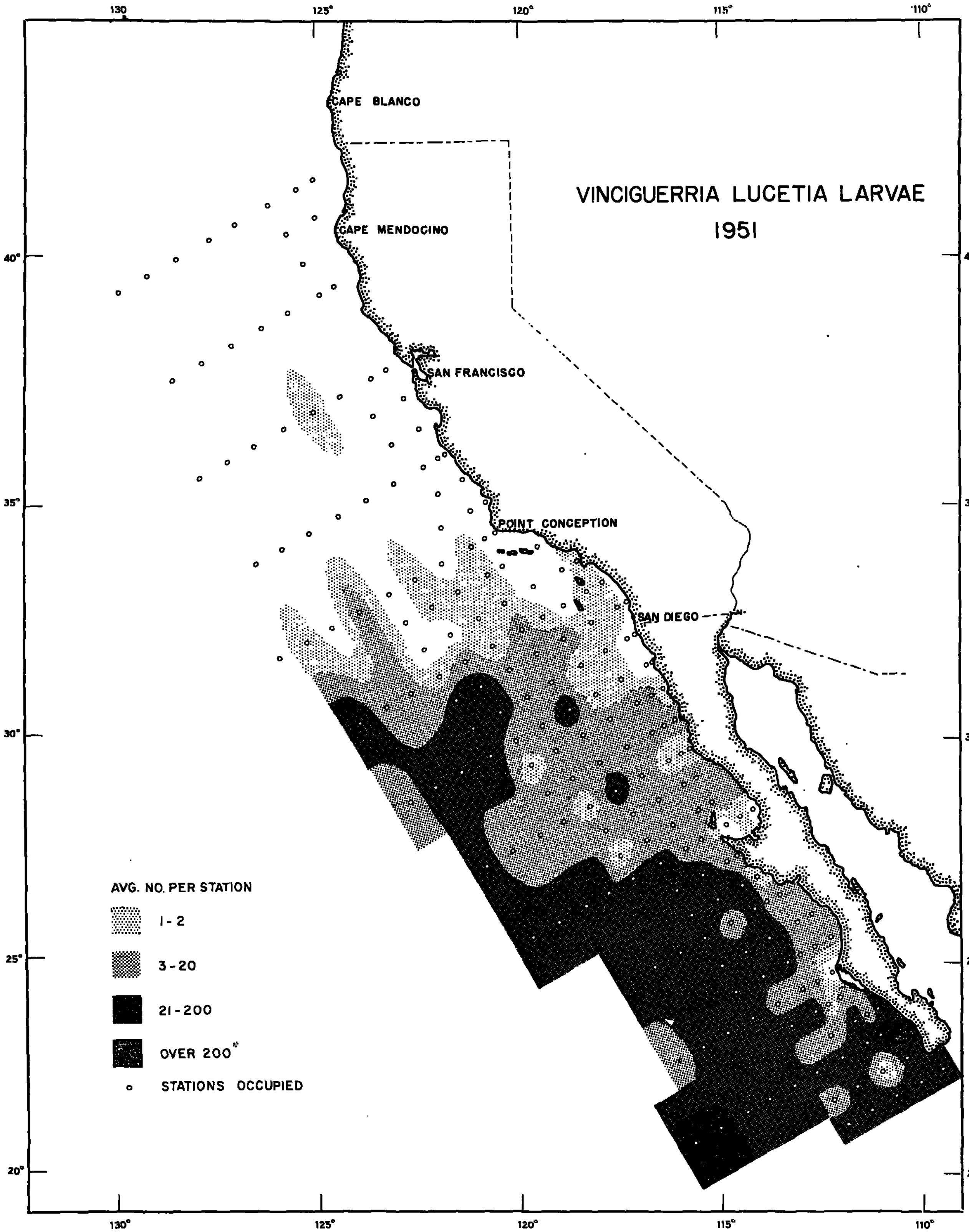

FIGURE 18.—Distribution and abundance of *Vinciguerria lucetia* larvae on survey cruises of the California Cooperative Oceanic Fisheries Investigations in 1951.

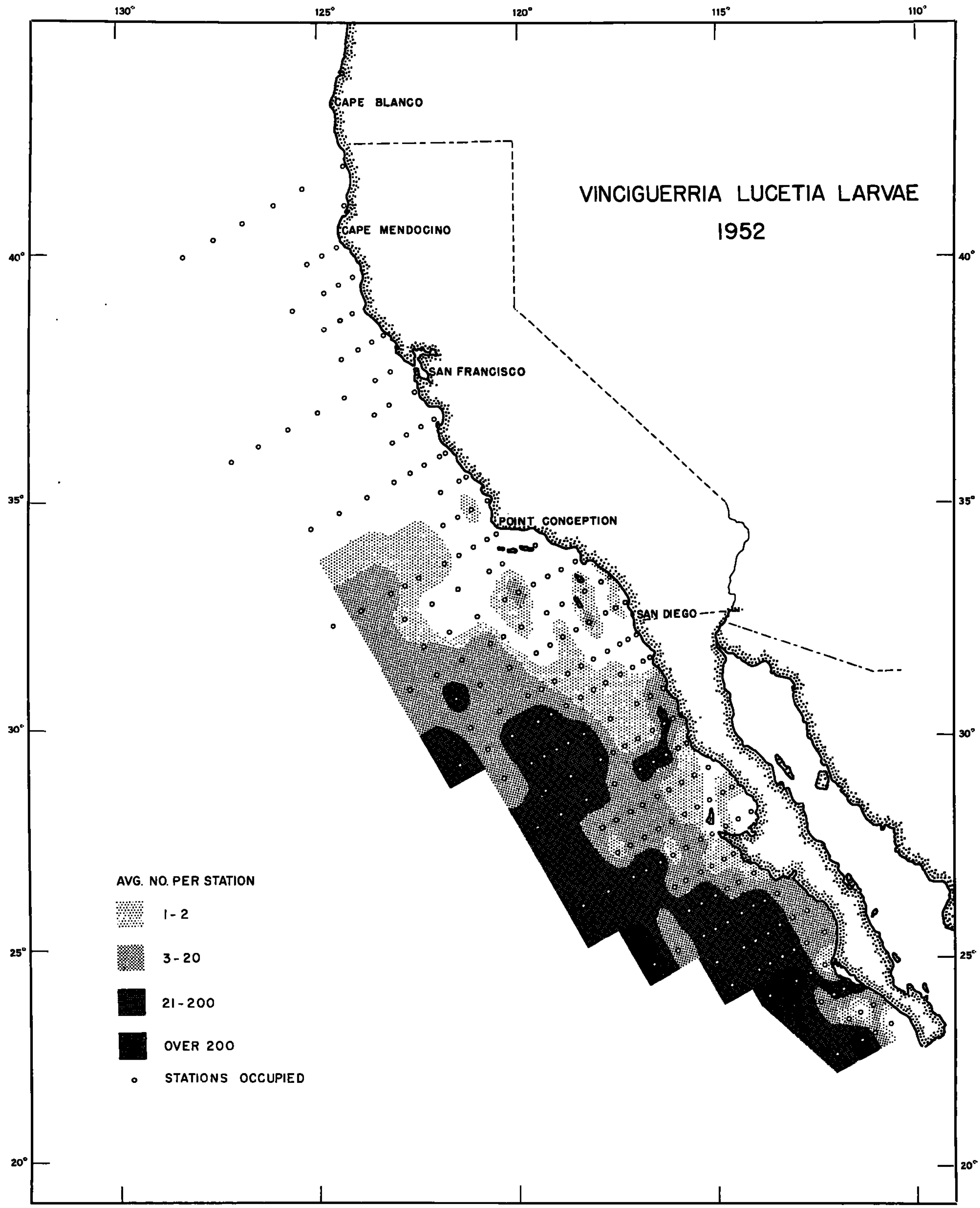

FIGURE 19.—Distribution and abundance of *Vinciguerria lucetia* larvae on survey cruises of the California Cooperative Oceanic Fisheries Investigations in 1952.

TABLE 19.—*Census estimates of abundance (in billions of larvae) of* Vinciguerria lucetia *in the CCOFI survey area during the monthly cruises of 1951 and 1952*

Station lines	Cruise and month												Total estimated number of larvae (billions)
	5101 Jan.	5102 Feb.	5103 Mar.	5104 Apr.	5105 May	5106 June	5107 July	5108 Aug.	5109 Sept.	5110 Oct.	5111 Nov.	5112 Dec.	
1951													
60–77	0	-------	-------	0	12	0	0	0	0	0	0	0	12
80–93	1	14	139	160	254	163	94	128	68	42	11	47	1,121
97–107	90	18	28	603	354	188	396	630	639	945	204	175	4,270
110–120	643	72	700	482	359	194	79	610	1,273	2,510	546	877	8,345
123–137	311	445	116	447	839	1,193	564	575	457	647	141	10	5,745
140 and below	-------	-------	1,040	-------	-------	1,716	-------	-------	3,205	-------	-------	-------	5,961
Total	1,045	549	2,023	1,692	1,818	3,454	1,133	1,943	5,642	4,144	902	1,109	25,454

Station lines	Cruise and month												Total estimated number of larvae (billions)
	5201 Jan.	5202 Feb.	5203 Mar.	5204 Apr.	5205 May	5206 June	5207 July	5208 Aug.	5209 Sept.	5210 Oct.	5211 Nov.	5212 Dec.	
1952													
60–77	-------	-------	-------	0	0	0	0	0	0	0	3	-------	3
80–93	12	1	19	52	17	48	147	177	47	145	46	-------	711
97–107	54	32	103	307	106	161	373	400	301	1,245	220	-------	3,302
110–120	536	224	265	261	874	607	1,365	616	1,303	2,152	1,553	-------	9,756
123–137	965	166	375	1,314	207	558	907	104	340	204	108	-------	5,248
140 and below	-------	474	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	474
Total	1,567	897	762	1,934	1,204	1,374	2,792	1,297	1,991	3,746	1,930	-------	19,494

The relative abundance of *V. lucetia* larvae in different parts of the CCOFI survey area is shown in table 20. The regular survey area has been divided into five subareas, two located off California (lines 60–77 and 80–93), and three located off Baja California (lines 97–107, 110–120, and 123–137). In neither season was as much as 6 percent of the total taken off California.

TABLE 20.—*Relative abundance (in billions of larvae) of* Vinciguerria lucetia *in different sections of the CCOFI survey area, 1951 and 1952*

[Cumulative census estimates; see table 19]

Station lines	1951		1952	
	Estimated number	Percent of total	Estimated number	Percent of total
California:				
60–77	12	0.06	3	0.02
80–93	1,121	5.75	711	3.74
Baja California:				
97–107	4,270	21.91	3,302	17.36
110–120	8,345	42.81	9,756	51.29
123–137	5,745	29.47	5,248	27.59
Total	19,493	100.00	19,020	100.00

Larvae were taken throughout the year in all parts of the distribution off southern California and Baja California (table 21). They increased in numbers in late summer and early autumn, and in both years the greatest abundance occurred in October.

TABLE 21.—*Abundance (in billions of larvae) of* Vinciguerria lucetia *in the area surveyed by CCOFI (lines 60–137), by months, 1951 and 1952*

Month	1951		1952	
	Estimated number	Percent of year's total	Estimated number	Percent of year's total
January	1,045	5.36	1,567	8.24
February	549	2.82	423	2.22
March	983	5.04	762	4.01
April	1,692	8.68	1,934	10.17
May	1,818	9.33	1,204	6.33
June	1,738	8.92	1,374	7.22
July	1,133	5.81	2,792	14.68
August	1,943	9.97	1,297	6.82
September	2,437	12.50	1,991	10.47
October	4,144	21.26	3,746	19.70
November	902	4.63	1,930	10.15
December	1,109	5.69	-------	-------
Total	19,493	100.01	19,020	100.01

Although these population estimates are based solely on larvae, specimens in older stages of development (metamorphosing individuals, juveniles, and adults) were taken in all parts of the CCOFI area below Point Conception.

WIDER DISTRIBUTION IN EASTERN PACIFIC

The northern limits of the distribution of *Vinciguerria lucetia* have been adequately delimited by the CCOFI survey cruises, but the southward and westward limits have not. Information is available on the wider distribution of this species from special cruises.

V. lucetia is not only abundant off Baja California, but throughout the area between 20° N. and 14° S. latitude (the southern limit of our collections, rather than the southern limit of distribution of the species). Throughout this wide range, *V. lucetia* is taken in some stage of development in most plankton collections. It is probably the most ubiquitous and abundant species of fish in plankton collections from the eastern Pacific. It has been taken in most hauls made with midwater trawls between 35° N. and 14° S. latitude. It is occasionally taken in dip-net collections, but the only locality where it has been consistently taken by this means is Guadalupe Island, off Baja California. Some of our best adult material has been obtained from this locality.

An unusual occurrence of *V. lucetia* should be noted. On February 10, 1956, Dr. George E. Lindsay, Director of the San Diego Museum of Natural History, found large numbers of dried individuals in windrows on the beach at San Benedicto Island. It is possible that the fish were killed by subterranean volcanic action and washed ashore, as there has recently been considerable volcanic activity on these islands. A number of these specimens were examined by us. They had the usual photophore counts for individuals from that area (80–82 photophores per side), and ranged in size from 29 to 51 millimeters in standard length. The collection contained only *V. lucetia*. This occurrence parallels the mass mortality of *Tarletonbeania crenularis* reported by Aughtry (1953).

V. lucetia is abundant in the southern portion of the Gulf of California. Distribution in the gulf during cruise 5602 is shown in figure 20.

The farthest westward that we have obtained specimens of *Vinciguerria lucetia* has been about 134° W. longitude. Above 20° N. latitude, it is replaced to the west of 134° by *V. nimbaria* and *V. poweriae*, which are discussed later in this paper. Our collections below 20° N. latitude have seldom extended this far westward, so they are inadequate to delimit the westward distribution of the species in the tropical Pacific. We have a record of *V. lucetia* from 14°21′ N. latitude, 133°05′ W. longitude. The distribution of *V. lucetia*, based on collections we have examined, is shown in figure 21.

The westward distribution of the species of *Vinciguerria* in the central Pacific could be clarified from the collections made by the Pacific Oceanic Fishery Investigations. We are not including published records of *V. lucetia* from other parts of the Pacific, as it is not often possible to verify the records from figures or description. Furthermore, it is beyond the scope of this paper.

RELATION OF PHOTOPHORE NUMBER TO LATITUDE

In studying variation in photophore number in different parts of its distribution in the eastern Pacific, 586 specimens of *Vinciguerria lucetia* were examined from 162 collections obtained between 34°55′ N. and 14°00′ S. latitude and between 78°10′ and 134°25′ W. longitude.

There are marked differences in the average total number of photophores per side in different parts of the range. To show these differences, the collections have been grouped into subareas, each comprising 5 degrees of latitude and 10 degrees (or less) of longitude. The results are summarized in table 22, and illustrated in figure 22.

The average number of photophores per side of the composite material was 81.31; the range of means for the subareas was from 78.50 to 83.40, a difference of 4.90 photophores per side.

In the CCOFI area there is a marked cline of photophore number with latitude. Fish taken north of 27°30′ N. latitude average nearly 2.5 photophores per side higher than fish taken between 20° and 25° N. latitude, while those taken between 25° and 27°30′ N. latitude have an intermediate number of photophores per side. The numbers of photophores in the head and VA groups are similar in all areas; the difference in photophore number results from reduction in the number of lateral OV and ventral IV photophores by approximately 1 photophore in each group per side and of AC photophores by about 0.5 photophore per side.

It is an interesting finding that the specimens taken offshore from southern Baja California between 119° and 126° W. longitude had counts that were similar to those found in the northern portion of the distribution (average number of photophores per side, 82.94). The temperature distribution found on "Norpac" affords an explanation: surface temperatures in the offshore area were lower than off southern Baja California.

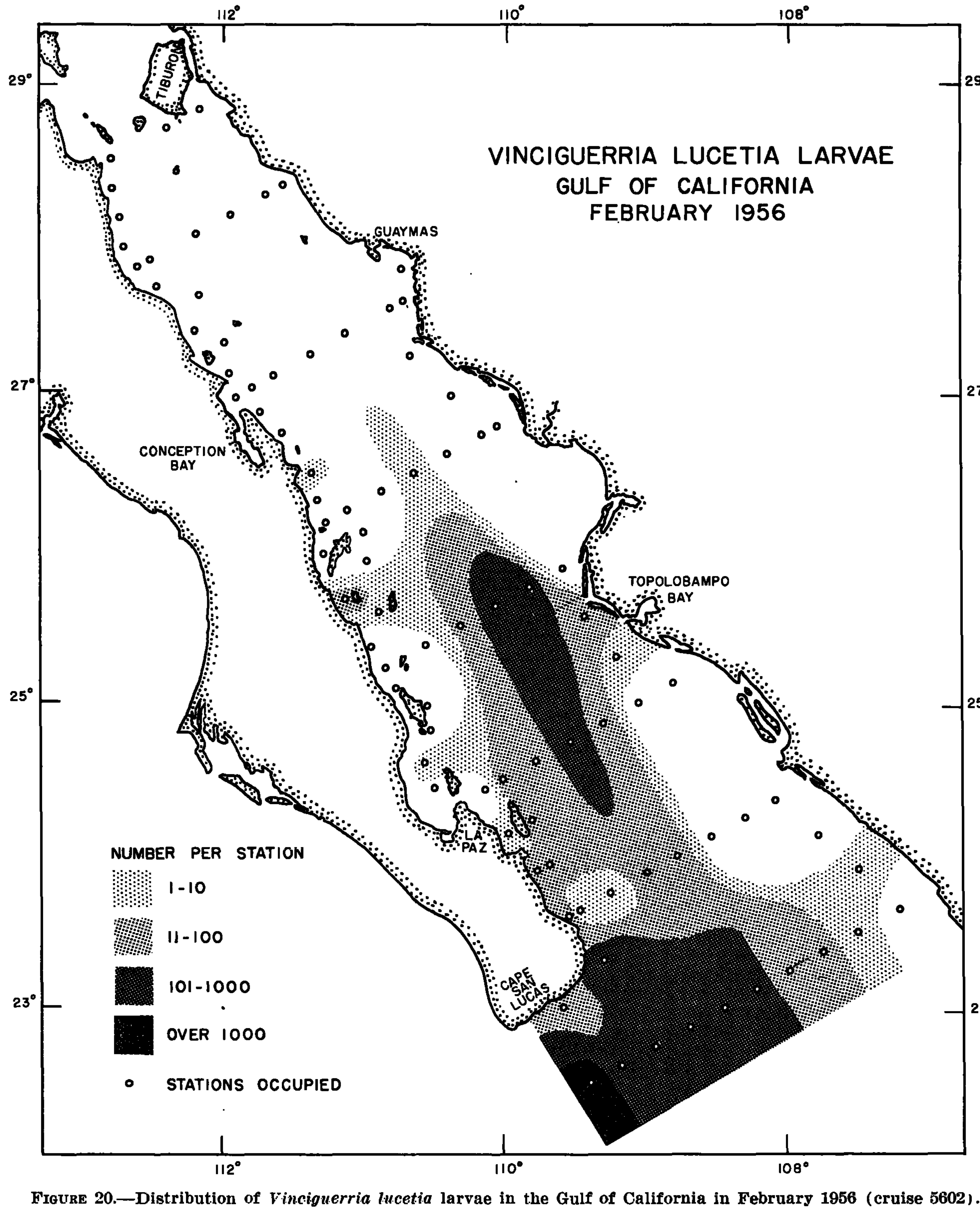

FIGURE 20.—Distribution of *Vinciguerria lucetia* larvae in the Gulf of California in February 1956 (cruise 5602).

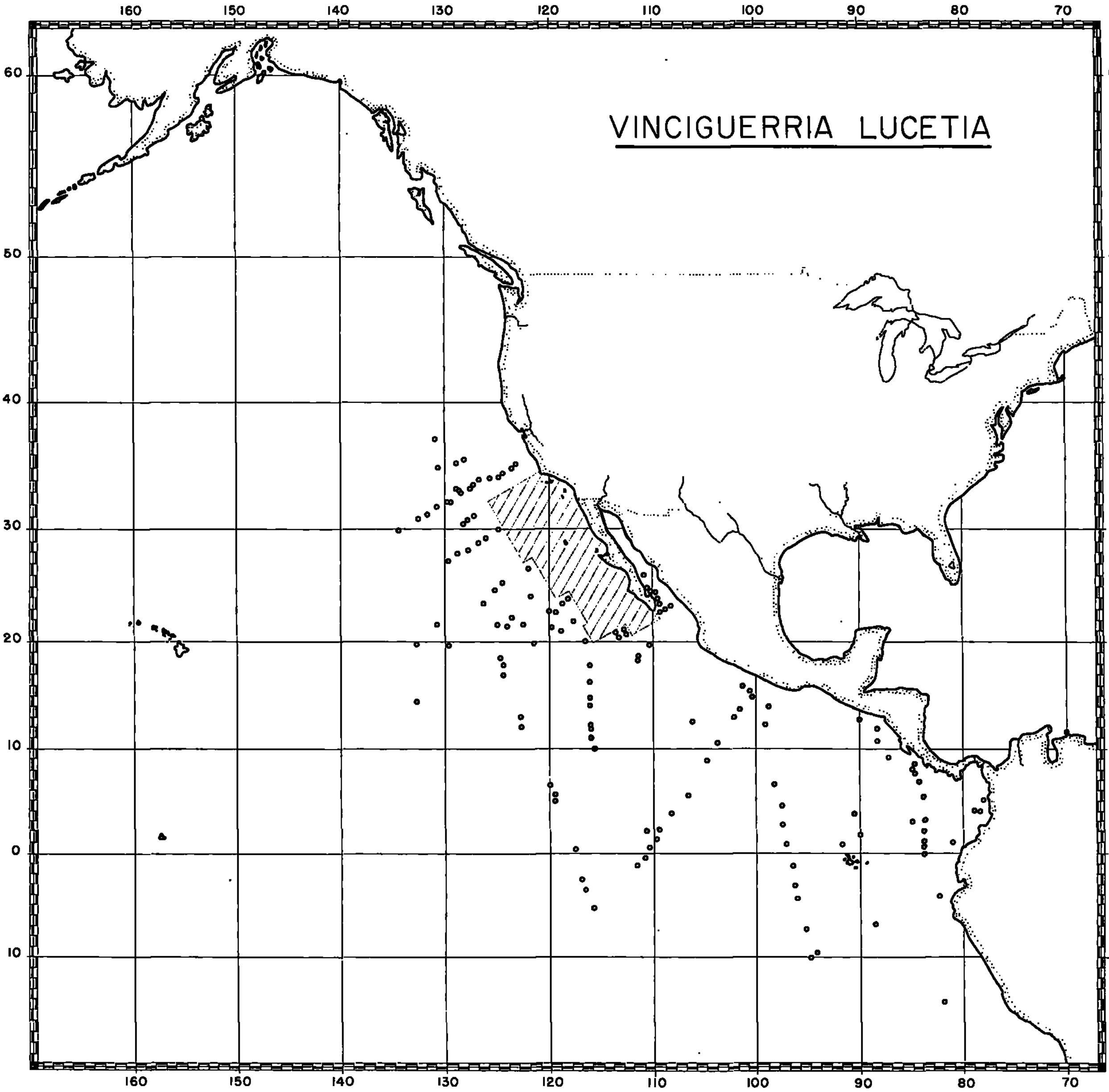

Figure 21.—Distribution of *Vinciguerria lucetia* larvae in the eastern Pacific. Bar shading shows the area covered by CCOFI survey cruises of 1951 and 1952 (see figs. 18 and 19).

The CCOFI survey area extends only to the tip of Baja California. Throughout the extensive area to the south, average counts are low, approximating those found off southern Baja California. The range of mean values for subareas south of 20° N. latitude was from 78.50 to 82.00 photophores per side. When the comparisons are based on all individuals taken in each 5 degrees of latitude, the results are as follows:

Latitude	Number of specimens	Average number of photophores per side
15°–20° N	50	80.55
10°–15° N	79	80.28
5°–10° N	92	80.38
0°–5° N	56	80.67
0°–5° S	16	81.07
5°–10° S	11	81.05
10°–15° S	5	81.00

TABLE 22.—*Variation in number of photophores per side on* Vinciguerria lucetia *collected in the eastern Pacific*

[Area: 35° N.–14° S. lat., 78°–134° W. long.]

Area	Average number photophores per side						Total number of photophores per side	Number of specimens	Number of collections
	Head	Lateral row		Ventral row		AC group			
		OV group	VA group	IV group	VA group				
30°–35° N.:									
117°–120° W	21.0	11.83	11.00	14.83	10.00	14.20	82.86	12	6
120°–130° W	21.0	12.03	10.89	15.03	9.89	14.19	83.03	31	13
130°–134° W	21.0	12.00	10.80	15.00	9.80	14.20	82.80	5	3
27°30′–30° N.:									
117°–120° W	21.0	12.00	10.89	15.01	9.90	14.24	83.04	56	15
120°–129° W	21.0	12.04	10.94	15.04	9.94	14.44	83.40	26	11
25°–27°30′ N.: 113°–120° W	21.0	11.26	10.96	14.26	9.95	13.85	81.28	50	18
20°–25° N.:									
109° W. and Gulf	21.0	10.91	11.00	13.91	10.00	13.72	80.54	16	5
110°–118° W	21.0	11.08	10.85	14.09	9.85	13.77	80.64	50	18
119°–126° W	21.0	11.89	10.92	14.89	9.92	14.32	82.94	31	7
15°–20° N.:									
102° W	21.0	11.00	10.00	14.00	9.00	13.50	78.50	1	1
111°–116° W	21.0	11.05	10.95	14.05	9.97	13.47	80.49	32	5
124°–125° W	21.0	11.29	10.79	14.29	9.79	13.62	80.78	17	2
10°–15° N.:									
88° W	21.0	11.06	10.96	14.06	9.94	13.75	80.77	26	2
90°–99° W	21.0	11.00	10.60	14.00	9.60	13.80	80.00	5	3
101°–106° W	21.0	11.04	10.69	14.04	9.71	13.62	80.10	26	5
115°–116° W	21.0	10.94	10.74	13.94	9.74	13.59	79.95	17	5
122° W	21.0	11.00	10.75	14.00	9.75	13.50	80.00	4	1
133° W	21.0	11.50	10.50	14.50	9.50	14.00	81.00	1	1
5°–10° N.:									
78° W	21.0	11.00	10.86	14.00	9.84	13.62	80.32	25	1
84°–87° W	21.0	11.00	10.87	13.98	9.89	13.64	80.38	59	6
105° W	21.0	11.00	10.50	14.00	9.50	13.25	79.25	4	1
119°–120° W	21.0	12.12	10.88	15.12	9.88	13.00	82.00	4	3
0°–5° N.:									
79° W	21.0	11.08	10.82	14.08	9.78	13.86	80.62	25	1
80°–90° W	21.0	11.00	11.00	13.97	10.00	13.72	80.69	16	8
92°–98° W	21.0	10.94	10.94	13.94	9.94	13.56	80.32	9	4
109°–110° W	21.0	11.00	11.00	14.00	10.00	14.25	81.25	2	2
111°–117° W	21.0	11.75	10.50	14.75	9.62	13.75	81.37	4	3
0°–5° S.:									
82° W	21.0	11.00	11.00	14.00	10.00	14.00	81.00	4	1
96°–97° W	21.0	11.25	10.92	14.25	9.92	13.58	80.92	6	2
111°–117° W	21.0	11.67	10.75	14.67	9.75	13.50	81.26	6	4
5°–10° S.:									
89° W	21.0	11.00	11.00	14.00	10.00	13.80	80.80	5	1
94°–95° W	21.0	11.12	11.38	14.12	10.38	13.88	81.88	4	3
116° W	21.0	11.00	10.50	14.00	9.50	14.00	80.00	2	1
10°–14° S.: 82° W	21.0	11.00	11.00	14.00	10.00	14.00	81.00	5	1
All areas	21.0	11.34	10.88	14.34	9.89	13.86	81.31	586	162

The lowest average counts were obtained between 10° and 15° N. latitude, but even these specimens average only about 0.4 photophore less than specimens taken off southern Baja California. Specimens obtained from south of the Equator average about 0.4 photophore higher than the material from off southern Baja California.

MOVEMENT BETWEEN AREAS

The ubiquitous distribution of *Vinciguerria lucetia* has already been commented on. Over a very extensive area, it is taken in some stage of development in most plankton hauls that we have examined. In at least a part of its range, however, it can be shown that there must be little or no interchange between the populations in not too widely separated areas. The marked difference in the average number of photophores on specimens from northern and southern Baja California has already been noted. It may be interesting to examine photophore counts from these two regions in more detail. In figure 23, the distributions of photophore counts from northern Baja California (27°30′–30° N. latitude) and southern Baja California (20°–25° N. latitude) are shown. These areas are separated from each other by about 150 miles. It will be noted that there is little overlap in the two distributions—slightly over 20 percent. Thus, only 20 percent of the specimens in the two groups have similar photophore counts. This value may be assumed to represent the maximal amount of interchange (mixing) that could take place between the two populations, at least after the photophores have formed. It is exceedingly unlikely that all the overlap in the two distributions would be the result of mixing, and it is a distinct possibility that little or no interchange actually takes place between the two.

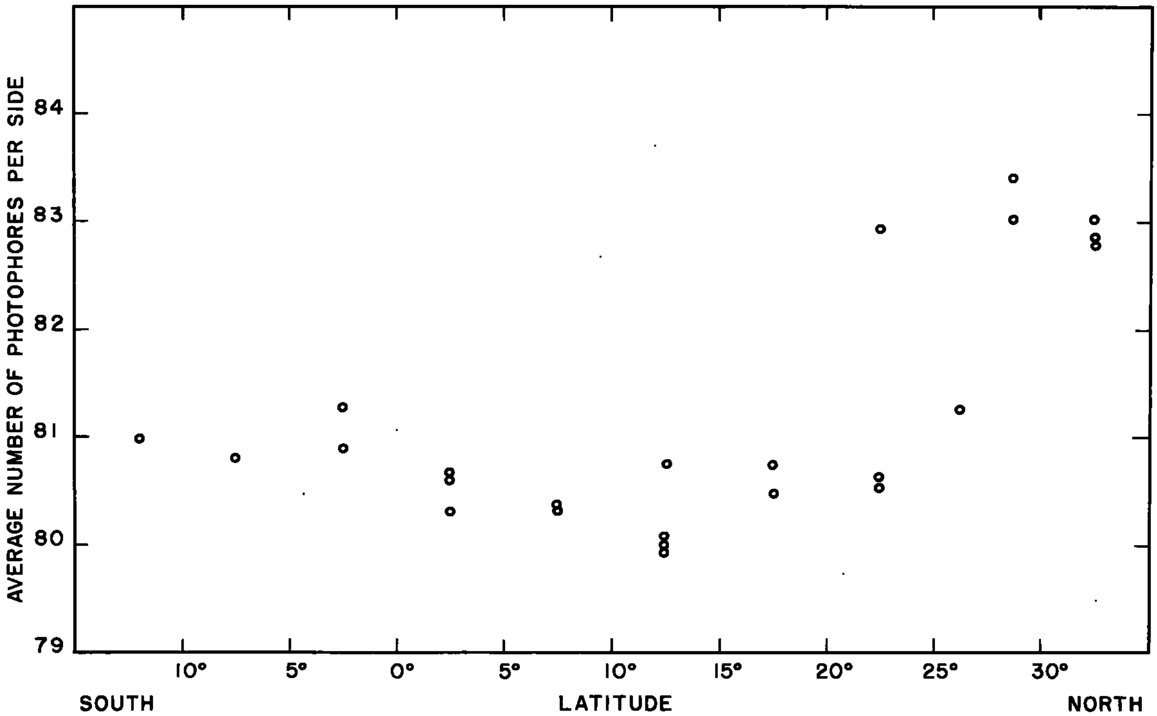

Figure 22.—Relation of average photophore number to latitude. This is a plot of photophore counts summarized in table 22. Only counts from areas having five or more specimens are included.

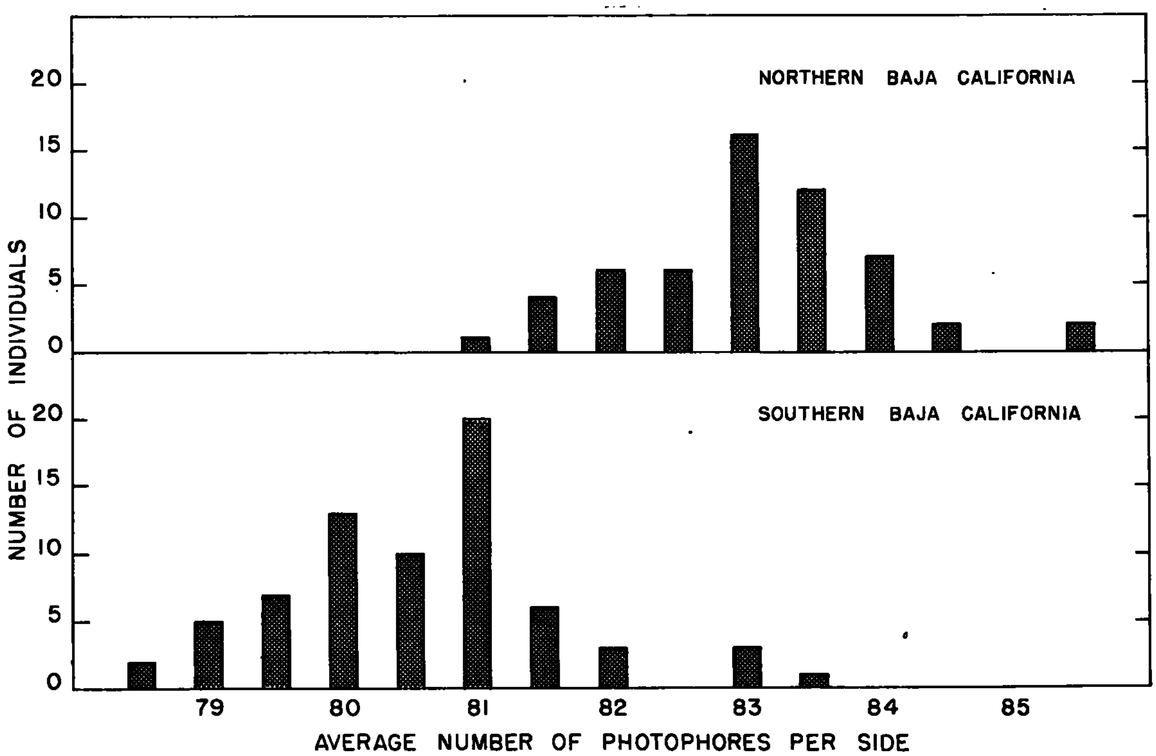

Figure 23.—Frequency of photophore counts per side in *Vinciguerria lucetia* from two regions: northern Baja California (27° 30′ N. to 30° N. latitude), and southern Baja California (20° to 25° N. latitude). For each individual the value plotted is the average of the photophore count on the two sides of the body.

Such a marked difference in photophore number as is shown in these two populations does not occur over much of the distribution of *V. lucetia*, hence the technique used here is applicable only to selected areas.

VERTICAL DISTRIBUTION OF EGGS AND LARVAE

Information on vertical distribution of larvae has been derived from two sources: (1) Vertical distribution series taken on cruises made especially for this purpose, and (2) deeper-level closing-net hauls taken during "Norpac."

Eggs and larvae of *V. lucetia* were taken in three series of vertically stratified horizontal net hauls made off central Baja California during April 1955, but only commonly in one series (station 130.60). The distribution of eggs and larvae at this station is shown in figure 24. This series was taken during the night. Larvae were distributed somewhat deeper in the two series taken during the daytime (stations 107.80 and 110.60), mostly between depths of 50 and 100 meters. The thermocline at all three stations was deep, between 75 and 100 meters. Obviously, these data are too sparse to permit any firm conclusions on vertical distribution of *lucetia* eggs and larvae, other than that they occur throughout the upper mixed layer, and to some extent in the thermocline.

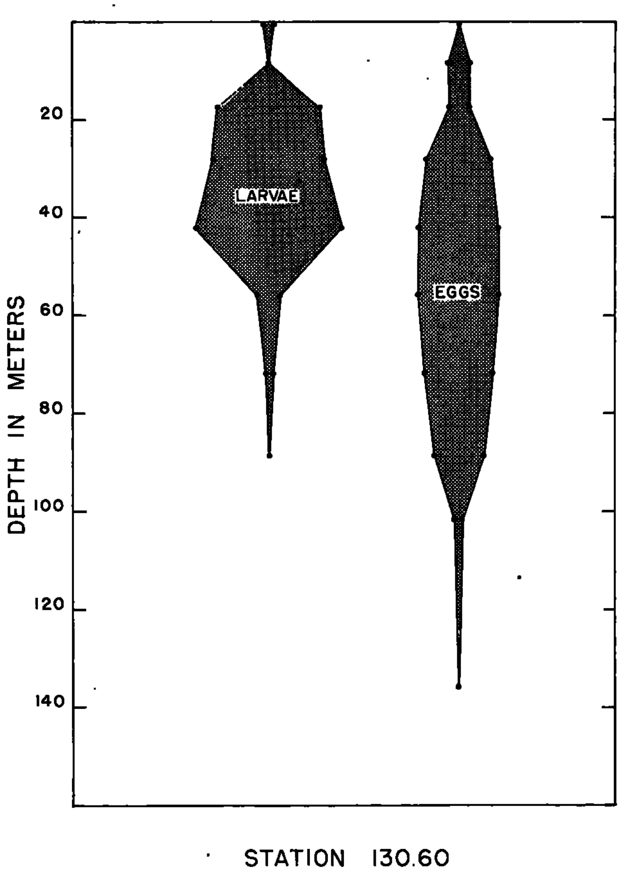

FIGURE 24.—Vertical distribution of eggs and larvae of *Vinciguerria lucetia* at station 130.60 (25°29′ N. lat., 115° 24′ W. long.) on April 21, 1955.

On "Norpac" (CCOFI cruise 5508), two net hauls were taken at most stations, an upper-net haul sampling the upper level from approximately 135 meters deep to the surface, and a closing-net haul sampling the level between approximately 270 to 135 meters deep.

Three species of *Vinciguerria* larvae were taken at 72 stations at which both nets were used. Only 1 upper-set haul in this group did not contain *Vinciguerria* larvae, while they were taken in only 12 closing-net hauls. The total number of *Vinciguerria* larvae taken in these upper-net hauls was 1,723, as compared with a total of 29 in closing-net hauls, or approximately 60 times as many. Hence, less than 2 percent of the larvae was taken by the closing net in the deeper layer sampled, which was of a thickness equivalent to the stratum sampled by the upper-net haul.

Although these results do not preclude the possibility that some *Vinciguerria* larvae may occur at depths below those sampled by the upper and closing nets, it seems unlikely that any significant quantity occurs at deeper levels.

OTHER SPECIES OF *VINCIGUERRIA* OCCURRING IN THE EASTERN PACIFIC

It should be noted that the generic name *Vinciguerria*, proposed by Jordan and Evermann (1896: 577), but first reported in Goode and Bean (1895: 513), has been accepted without a strict regard to priority. Bonaparte (1841) described a subgenus *Poweria* under *Ichthyococcus*, with *P. poweriae* as type species. Apparently this description was overlooked by Jordan and Evermann at the time they proposed the generic name of *Vinciguerria* with *V. attenuata* as the type species. However, in conformity with the principle of conservation (Hubbs 1956) adopted by the Fourteenth International Congress of Zoology for incorporation in the International Rules of Zoological Nomenclature, and in view of the fact that apparently no previous author has adopted the name *Poweria*, it seems permissible and proper to retain the familiar name *Vinciguerria.*

Norman (1930), in his monograph of the family Gonostomatidae, has listed six species of *Vinciguerria*, of which two were considered doubtful. The 4 species considered valid were the following: *attenuata*, *poweriae*, *sanzoi*, and *lucetia;* the 2 doubtful ones were *nimbaria* and *raoulensis.* As Horsburgh (1935) has shown, *sanzoi* is identical with *nimbaria.*

The species described by Waite (1910) under the name of *Gonostoma raoulensis* may be a synonym of *V. nimbaria*—the original description is inadequate. The fin formula was given as D. 10; A. 10; V. 6; P. 11; C. 8+15. These counts, if accurate, would set this species apart from all other species of *Vinciguerria*, which never have fewer than 13 dorsal, 12 anal, 7 ventral, and 19 principal and 11 to 14 secondary (procurrent) caudal rays. The caudal count given by Waite is obviously inaccurate, and we assume that little more reliance can be placed on the counts of other fins. The characters of *G. raoulensis* that suggest a close relationship to *nimbaria* are the following: (1) Gill rakers, 5+13 on first arch; (2) presence of a symphyseal pair of photophores; and (3) number of body photophores, especially a high IV number (16).

Vinciguerria pacifici, described by Hildebrand (1946) from off northern Peru, does not appear to us to be distinct from *lucetia.*

Narooma benefica Whitley (1935) is probably a synonym of *V. lucetia.* The description is based on a specimen that was washed ashore in southern New South Wales, Australia, and slightly attacked by beach crustacea before collection. The counts of rays in the dorsal (8+?) and anal (12) fins are probably incomplete. The total photophore number is approximately 80 on each side. The grouping as given by Whitley is probably inaccurate since he lists 6 isthmian, 16 ventral IV, and 12 lateral OV photophores on a side. However, *Vinciguerria* characteristically has 7 isthmian photophores and 3 less lateral OV than ventral IV photophores, hence the grouping probably should be 7 isthmian, 15 ventral IV, and 12 lateral OV photophores on a side. A symphyseal photophore is present. Gill rakers are described as slender and numerous, but an exact count is not given.

The four species of *Vinciguerria* fall naturally into two groups, which are easily separated both as larvae and as adults. One group contains *attenuata* and *poweriae*, the other group contains *lucetia* and *nimbaria.*

The two groups are easily distinguishable in the embryonic stage. The eggs of *attenuata* and *poweriae* have an oil globule, which is lacking in the eggs of *lucetia* and *nimbaria.*

The simplest character separating late-larval and early-metamorphic stages of the two groups is pigmentation, especially in the position of the caudal pigment spot. The spot has a mediolateral position in *attenuata* and *poweriae*, whereas it is just above the ventral margin in *lucetia* and *nimbaria.* There are other differences in pigmentation between the two groups. In *lucetia* and *nimbaria* the pigment at the base of the caudal fin usually consists of 2 dashes above and 1 below the midline. Also, there are generally 2 or 3 melanophores above the anal fin. Both of these pigment groups are lacking in *attenuata* and *poweriae.*

The two groups are readily separated in the adolescent and adult stages by the presence or absence of the symphyseal pair of photophores. This photophore group is developed in *lucetia* and *nimbaria* and lacking in *poweriae* and *attenuata.*

Sanzo (1913, 1931) and Jespersen and Tåning (1926) have called attention to several characters that are useful in separating the larvae of *poweriae* from *attenuata.* Both have the conspicuous axial caudal pigment spot, but this is the only pigmentation on larvae of *poweriae. V. attenuata*, on the other hand, has pigment above the air bladder and sometimes has a small melanophore on the anal papilla.

An important difference between larvae of these two species is in the distance from snout to anus. The proportion is shorter in *attenuata* than in any of the other species of *Vinciguerria*, being less than 70 percent of the standard length. In larvae of *poweriae*, the distance from snout to anus averages about 75 percent of the standard length (range, 73–79 percent).

Larvae of *poweriae* have a "peculiar spot" (quoting Jespersen and Tåning, 1926) above the anal papilla. Both Sanzo and Jespersen and Tåning have called attention to this spot. It is not a pigment area, but a small, conspicuous oval structure that may be a part of the urinary system.

Three species of *Vinciguerria* occur in the eastern Pacific: *lucetia*, *poweriae*, and *nimbaria*. Brief descriptions of the developmental stages of the latter two species are given in following sections.

Vinciguerria poweriae (Cocco)

Gonostomus poweriae Cocco, 1838, Nuovi Ann. Sci. Nat. II, p. 167 (original description).

Ichthyococcus poweriae Bonaparte, 1841. Icon. Fauna Ital., F. 27, p. 138, fig. 8.

Maurolicus poweriae Günther, 1864. Cat. Fish., vol. 5, p. 390 (brief description).

Vinciguerria poweriae Sanzo, 1913. Mem. R. Com. Talassogr. Ital., vol. XXXV, pp. 3–7, figs. 6–9 (description of larvae). Sanzo, 1931. Fauna e Flora del Golfo di Napoli, Monogr. 38, pp. 71–75, figs. 50–53 (description of eggs and larvae). Jespersen and Tåning, 1919. Vidensk. Medd. Dansk Naturh. Foren., vol. 70, pp. 218–220, figs. 1 and 4 (prometamorphic stage and adult figured). Jespersen and Tåning, 1926. Rept. Danish Ocean. Exped., 1908–1910, vol. 2 (Biology), A 12, pp. 22–37, figs. 13–1, 14–1, 15–1, 16–1, 17–1 (comparison of *V. poweriae* with three other species).

The *poweriae* material available from the eastern Pacific consisted of eggs, larvae, and metamorphosing individuals. We obtained no material of either juveniles or adults. The distribution (occurrences) of the species on "Norpac" is shown in figure 25. Eggs from 21 localities were measured (table 23).

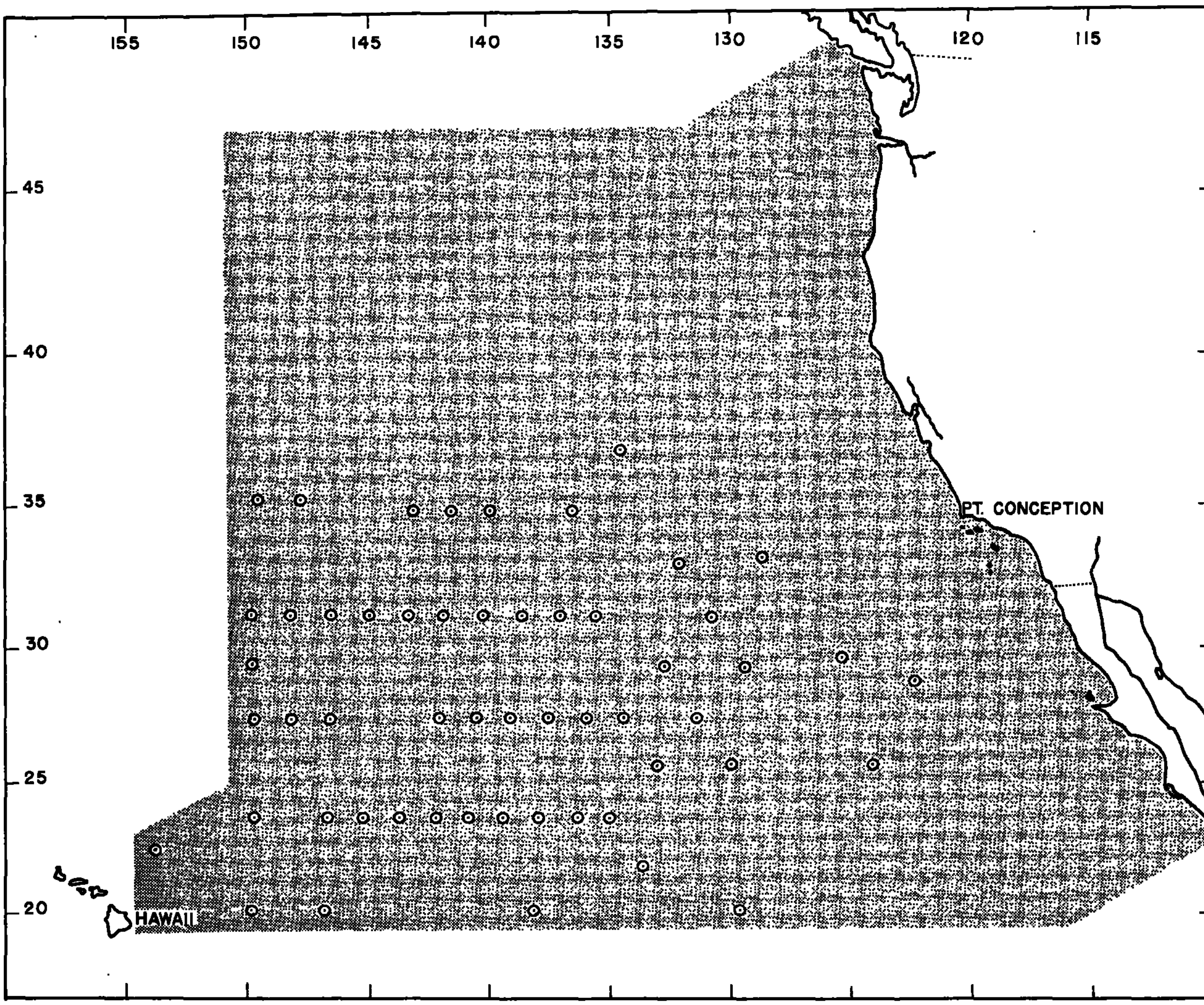

FIGURE 25.—Distribution of *Vinciguerria poweriae* on "Norpac," based on all stages of development obtained (eggs, larvae, metamorphosing individuals). Shading indicates the total area covered by agencies cooperating in the California Cooperative Oceanic Fisheries Investigations.

TABLE 23.—*Measurements of eggs of* Vinciguerria poweriae *collected at 21 stations in the eastern Pacific, in 1955*

Norpac station	North latitude	West longitude	Date	Number of eggs measured	Egg diameter (mm.)	
					Mean	Range
No. 59	34°53′	143°23′	VIII-17	20	0.813	0.76-.85
No. 60	35°08′	148°00′	VIII-23	11	.817	.78-.85
No. 61	35°07′	149°40′	VIII-23	9	.807	.79-.82
No. 68	33°02′	132°15′	VIII-21	18	.797	.75-.82
No. 78.5	31°11′	138°54′	VIII-28	8	.808	.78-.85
No. 79	31°09′	140°29′	VIII-28	5	.799	.76-.83
No. 79.5	31°10′	142°02′	VIII-27	5	.800	.78-.82
No. 81.5	31°10′	148°24′	VIII-26	7	.809	.80-.82
No. 89	29°34′	125°40′	IX-3	10	.803	.77-.83
No. 90	29°17′	129°45′	IX-1	5	.802	.78-.82
No. 91	29°17′	132°57′	VIII-31	7	.797	.76-.83
No. 101	27°26′	134°45′	VIII-19	18	.790	.76-.82
No. 101.5	27°28′	136°14′	VIII-19	14	.803	.78-.83
No. 102.5	27°26′	139°16′	VIII-20	14	.784	.75-.82
No. 126	23°43′	135°11′	VIII-20	14	.808	.78-.83
No. 127	23°40′	138°16′	VIII-21	5	.786	.77-.80
No. 127.5	23°40′	139°41′	VIII-21	24	.795	.76-.83
No. 128	23°40′	141°06′	VIII-22	9	.797	.76-.82
No. 128.5	23°38′	142°22′	VIII-22	5	.789	.76-.81
No. 129.5	23°46′	145°30′	VIII-23	9	.795	.76-.84
No. 130	23°48′	146°56′	VIII-23	10	.796	.78-.83

Measurements and meristic counts were made on 26 larvae, ranging in size from 8.3 to 18.5 millimeters in length (table 24), and on 12 metamorphosing specimens (table 25). Four stages of eggs are illustrated in figure 26, and a midmetamorphosing specimen is shown in figure 27.

The *poweriae* material obtained in the eastern Pacific differs in several respects from that collected in the Mediterranean, as characterized by Jespersen and Tåning (1926). The points of agreement, however, are more numerous and trenchant than the differences. We shall discuss three differences and then point up seven pertinent points of agreement between our material and that described by Jespersen and Tåning.

1. *Size at metamorphosis.*—We have studied six specimens of prometamorphosing *V. poweriae.*

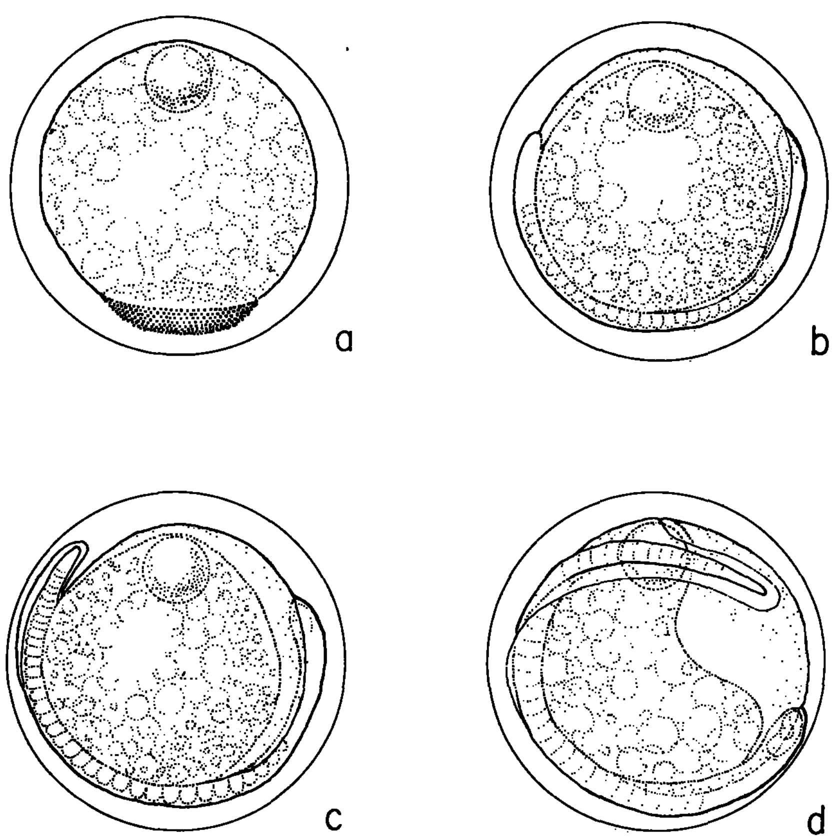

FIGURE 26.—Development of the egg of *Vinciguerria poweriae*: *a*, early stage, at development of blastodermal cap; *b*, middle stage, soon after blastopore closure; *c*, middle stage, with tail separating from yolk but still in same plane as embryo; *d*, late stage.

These ranged in size from 19.7 to 22.3 millimeters standard length. The size range given by Jespersen and Tåning for early metamorphosing individuals of this species was between 16 and 20 millimeters standard length.

2. *Number of vertebrae.*—The average number of vertebrae in Pacific material was 40.0, with a range of 39 to 41 vertebrae in 12 specimens. Jespersen and Tåning reported 38 or 39 vertebrae for Mediterranean material.

3. *Number of photophores.*—Photophore counts are given in table 26 for 12 specimens of metamorphosing *V. poweriae* collected from the eastern Pacific. There is close agreement in photophore counts between the material from the Pacific and from the Mediterranean, except in the number of AC photophores. Although our material is confined to metamorphosing individuals, it is a simple matter to determine from them what the full complement of AC photophores will be: it will aver-

TABLE 24.—*Measurements and meristic counts of larval* Vinciguerria poweriae *from the eastern Pacific*

[BF—base formed; U—urostyle]

Area	Body measurements (in mm.)						Meristic counts [1]					Number of gill rakers	Number of vertebrae ossified
									Caudal fin				
										Secondary			
	Standard length	Head length	Eye width	Depth at pectoral	Snout to anus	Snout to dorsal	Dorsal	Anal	Principal	D	V		
29°17′ N., 129°45′ W	8.3	1.54	0.28	0.52	6.20	-------	BF	BF	11	0	0	-------	-------
23°42′ N., 143°57.5′ W	9.1	1.87	.35	.70	7.00	-------	BF	BF	19	0	0	-------	-------
29°34′ N., 125°40′ W	10.5	2.11	.38	.68	8.00	-------	8	BF	19	0	0	-------	-------
33°02′ N., 132°15′ W	10.8	2.05	-------	.68	8.20	-------	6	BF	19	0	0	-------	-------
33°02′ N., 132°15′ W	11.5	-------	-------	-------	-------	-------	8	BF	19	0	1	-------	-------
31°09.5′ N., 148°24′ W	11.5	2.10	-------	.79	8.80	-------	10	6	19	1	1	-------	-------
29°34′ N., 125°40′ W	12.0	2.24	.40	.79	9.50	-------	8	BF	19	0	0	-------	-------
31°09.8′ N., 142°02′ W	12.0	2.16	.40	.72	9.10	-------	9	BF	19	0	0	-------	-------
19°57.5′ N., 129°44′ W	12.4	2.29	.44	.76	9.60	-------	11	9	19	2	1	0+7	-------
29°17′ N., 129°45′ W	12.5	2.39	-------	.74	9.40	-------	10	7	19	1	1	0+6	-------
27°25′ N., 150°00′ W	12.6	2.50	.51	.95	9.90	-------	10	6	19	2	1	0+7	-------
34°51′ N., 136°45′ W	12.7	2.43	.39	.85	9.75	8.70	-------	-------	-------	-------	-------	-------	-------
34°51′ N., 136°45′ W	13.3	2.60	.42	.91	10.20	9.10	-------	-------	-------	-------	-------	-------	-------
31°12′ N., 137°19′ W	14.0	-------	.42	.87	10.80	9.60	-------	-------	-------	-------	-------	-------	-------
21°52′ N., 133°51′ W	15.1	2.92	.46	.86	11.30	9.80	13	11	19	2	1	0+8	-------
29°17′ N., 132°57′ W	15.7	3.02	-------	1.18	11.70	-------	12	11	19	2	1	0+8	12+U
27°30.5′ N., 140°49′ W	15.9	3.03	.58	1.14	12.30	10.60	12	10	19	2	1	0+9	14+U
31°09.5′ N., 148°24′ W	16.0	2.89	.47	1.05	12.00	10.60	12	10	19	2	1	0+8	-------
34°51′ N., 136°45′W	16.1	2.80	.51	1.14	12.00	10.25	-------	-------	-------	-------	-------	-------	-------
25°34.5′ N., 124°21′ W	16.2	2.97	.47	1.26	12.50	10.80	12	9	19	2	1	0+9	8+U
23°40′ N., 141°06′ W	17.0	-------	-------	-------	-------	-------	15	14	19	3	2	0+12	40
31°08.5′ N., 130°59′ W	17.0	3.02	.63	1.16	12.60	10.90	13	12	19	2	1	0+9	21+U
29°34′ N., 125°40′ W	17.1	3.20	.60	1.19	12.90	11.40	13	12	19	3	2	0+10	18+U
31°11′ N., 145°10′ W	17.2	3.13	.52	1.18	12.95	11.10	12	12	19	5	3	0+10	-------
31°08.5′ N., 130°59′ W	17.9	3.28	-------	1.34	13.50	11.50	14	12	19	3	2	0+11	31+U
29°17′ N., 129°45′ W	18.5	3.69	.66	1.37	13.50	11.90	14	13	19	3	2	0+11	[2] 39

[1] No pectoral or ventral rays are formed during larval period. Larval pectorals are present on all specimens and ventral buds are developed on specimens over 15 mm. long.

[2] Penultimate vertebra still lacking; total number of vertebrae will be 40.

TABLE 25.—*Measurements and meristic counts in metamorphosing stages of* Vinciguerria poweriae *from the eastern Pacific*

Area	Body measurements (in mm.)							Meristic counts							Number of gill rakers	Number of vertebrae
												Caudal				
													Secondary			
	Standard length	Head length	Eye width	Depth at pectoral	Snout to ventral	Snout to dorsal	Snout to anus	Dorsal	Anal	Pectoral	Ventral	Principal	D	V		
Prometamorphic:																
31°12′ N., 150°07′ W	19.7	3.87	0.79	1.76	10.2	12.1	14.6	15	14	1	6	19	7	4	2+12	40
32°03′ N., 130°21′ W	21.1	4.00	.79	1.70	10.6	13.2	15.9	14	14	4	7	19	8	4	2+12	40
31°12′ N., 137°19′ W	21.2	3.85	.60	1.65	10.8	13.6	15.8	15	13	0	Rays?	19	6	4	0+12	41
31°12′ N., 137°19′ W	21.8	4.00	.86	1.87	10.9	13.3	15.7	15	13	0	5	19	9	4	2+12	40
31°08.5′ N., 130°59′ W	22.1	4.20	-------	1.76	11.0	13.5	15.5	14	14	0	6	19	8	4	1+12	39
29°21′ N., 126°13′ W	22.3	4.25	.86	1.80	11.0	13.7	16.2	14	14	2/3	7	19	8	4	1+12	40
Midmetamorphic:																
32°38′ N., 172°21′ W	17.2	-------	1.12	2.47	8.5	10.4	11.8	-------	-------	-------	-------	-------	-------	-------	-------	-------
20°07′ N., 138°22.5′ W	19.8	4.38	.89	2.08	10.6	12.2	14.3	14	12	10	7	19	7	4	2+12	41
29°21′ N., 126°13′ W	20.2	4.35	1.20	2.60	9.5	11.0	13.2	15	15	10	7	19	7	4	3+12	40
26°53′ N., 121°39′ W	22.9	4.30	.90	2.23	11.5	14.1	15.6	13	14	10	7	19	7	4	3+12	-------
Postmetamorphic:																
32°53′ N., 134°13′ W	17.9	4.25	1.43	2.94	8.9	9.8	12.0	14	14	10	7	19	8	4	3+12	39
32°52′ N., 131°58′ W	18.2	4.50	1.35	3.25	9.0	10.0	12.5	15	14	10	7	19	8	4	-------	40

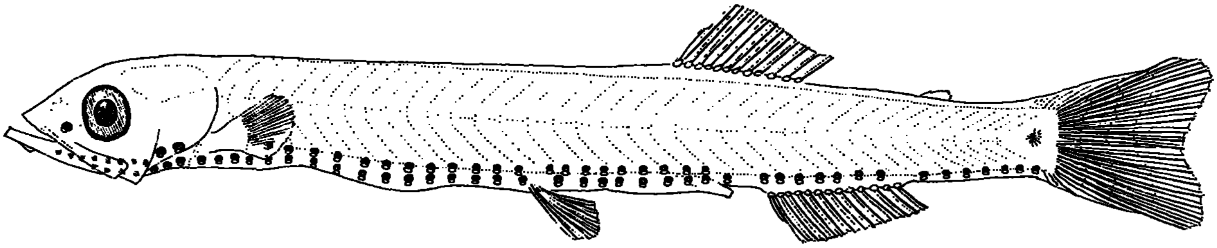

FIGURE 27.—Midmetamorphosing specimen of *Vinciguerria poweriae*, 22.9 mm. in standard length, from "Norpac" station 112D (26°53′ N., 121°39′ W.)

age 14.10 per side (range, 13–15), as compared to an average of 13.00 per side (range, 12–14) for Mediterranean specimens. Jespersen and Tåning did not report any variation in the number of ventral IV photophores (always 16) but did indicate variation in the number of lateral OV photophores (12 or 13). It is likely that variation in the number of IV photophores was overlooked by these workers, as we have found no specimen of this or of any other species of *Vinciguerria* in which there is variation in the number of photophores in the OV group but not in the IV group. The OV group averages three photophores less on a side than the IV group. The anterior three pairs of IV photophores have no counterparts in the OV group, but otherwise the two groups usually correspond photophore for photophore. In the material of *V. poweriae* we have studied, the lateral OV photophore group invariably had three photophores less on a side than the IV group. We found 15 to 17 photophores per side in the IV group (average, 15.96) and 12 to 14 photophores per side in the OV group (average, 12.96). Data on range and average counts of photophore groups in Pacific material of *V. poweriae*, *V. nimbaria*, and *V. lucetia* are given in table 27.

The points of agreement of *V. poweriae*, as described by Jespersen and Tåning from Mediterranean material, with our material from the eastern Pacific are rather numerous. We will call attention to seven:

1. *Eggs*.—The eggs of *V. poweriae* have been characterized by Sanzo (1931) as having an oil globule and being similar to the eggs of *V. attenuata*. We have had no difficulty in identifying the eggs of *V. poweriae* from the Pacific. The size range and average diameter of eggs from 21 localities were summarized in table 23. The range in size is from 0.75 to 0.85 millimeters. Eggs taken in the northern part of the distribution tend to be slightly larger than those taken farther south, but the difference is not as marked as that shown for *V. lucetia*. The single oil globule measures 0.17 to 0.19 millimeters in diameter. There is no evidence of the thin inner shell membrane that is found in eggs of *V. lucetia* and *V. nimbaria*.

TABLE 26.—*Number of photophores in metamorphosing stages of* Vinciguerria poweriae *from the eastern Pacific*

[Both sides of body given]

Station	North latitude	West longitude	Standard length	Head: Orb and Op	Head: SO	Head: Br	Head: Is	Lateral row: OV group	Lateral row: VA group	Ventral row: IV group	Ventral row: VA group	Anal-caudal (AC group)	Number of incomplete photophores	Total number of photophores
Prometamorphic:			*Mm.*											
Norpac 82D	31°12′	150°07′	19.7	4–4	0	8–8	7–7	13–13	8–8	16–16	9–9	6+7–6+7	4–4	82–82
5009–70.175D	32°03′	130°21′	21.1	4–4	0	8–8	7–7	13–13	9–9	16–16	9–9	6+7–6+8	3–3	82–83
Norpac 78	31°12′	137°19′	21.2	4–4	0	8–8	7–7	13–14	9–8	16–17	10–9	? ?	4–4	----------
Norpac 78D	31°12′	137°19′	21.8	4–4	0	8–8	7–7	13–13	8–8	16–16	9–9	5+7–6+7	4–4	81–82
Norpac 76D	31°08.5′	130°59′	22.1	4–4	0	8–8	7–7	12–13	8–7	15–16	9–8	6+7–6+7	4–4	80–80
5304–90.152	29°21′	126°13′	22.3	4–4	0	8–8	7–7	13–13	9–9	16–16	9–10	6+8–5+7	3–4	83–83
Midmetamorphic:														
Chinook 14	32°38′	172°21′	17.2	4–4	0	8–8	7–7	13–13	9–9	.6–16	9–9	6+7–6+6	3–3	81–82
Norpac 153D	20°07′	138°22.5′	19.8	4–4	0	8–8	7–7	13–13	9–9	16–16	9–9	6+7–7+7	3–3	82–83
5304–90.152	29°21′	126°13′	20.2	5–5	0	8–8	7–7	13–13	9–9	16–16	9–9	14–6+8	1–2	82–83
Norpac 112D	26°53′	121°39′	22.9	4–4	0	8–8	7–7	12–13	9–8	15–16	9–8	7+7–7+7	3–3	81–81
Postmetamorphic:														
N. Holiday 64	32°53′	134°13′	17.9	5–5	0	8–8	7–7	13–13	9–9	16–16	9–9	13–14	1–1	81–82
N. Holiday 65	32°52′	131°58′	18.2	5–5	0	8–8	7–7	13–13	8–8	16–16	9–9	? ?	2–2	----------

TABLE 27.—*Full complement of photophores per side in three species of* Vinciguerria *from eastern Pacific*

[Figures in parentheses indicate range]

Photophore group	*V. poweriae*		*V. nimbaria*		*V. lucetia*	
	Range	Average	Range	Average	Range	Average
Orb and Op	5	5.00	5	5.00	5	5.00
SO	0	0	1	1.00	1	1.00
Br	8	8.00	8	8.00	7-9	8.00
Is	7	7.00	7	7.00	6-8	7.00
Lateral:						
OV	(12-14)	12.96	(13-14)	13.08	(10-13)	11.33
VA	(9-11)	10.00	(10-12)	10.92	(9-12)	10.88
Ventral:						
IV	(15-17)	15.96	(16-17)	16.08	(13-16)	14.33
VA	(8-10)	9.00	(9-11)	9.92	(8-12)	9.89
AC	(13-15)	14.10	(12-15)	13.35	(12-16)	13.86
Total number of photophores per side	(81-84)	82.02	(84-87)	84.35	(78-86)	81.29

2. *Pigmentation of larvae.*—In both localities, larval pigment is confined to the centrally placed caudal pigment spot.

3. *Supra-anal structure.*—The structure or spot above the anal papilla was present in the material from both areas.

4. *Low number of maxillary teeth.*—Jespersen and Tåning called attention to the fact that *V. poweriae* has a lower number of maxillary teeth than other species of *Vinciguerria* of corresponding sizes. We have found the same situation in Pacific material. No larva of *V. poweriae* has been examined that had more than 10 maxillary teeth. Prometamorphosing individuals have only 8 to 12 maxillary teeth; the few midmetamorphosing individuals studied have had 8 or 9 maxillary teeth. It is characteristic of the development of maxillary teeth for marked changes to occur during midmetamorphosis. The oblique teeth first appear during this stage, and the remaining teeth are unequal in size, not subequal as in late larvae. This difference is even more marked in *V. nimbaria* than in *V. poweriae.* Some or most of the larval maxillary teeth must be resorbed or shed, to account for the reduction in number at a time when oblique teeth and small straight teeth are being added to the maxillary. The number of maxillary teeth in late larvae and metamorphosing stages of the three Pacific species of *Vinciguerria* are summarized in table 28.

The greater ranges in maxillary teeth shown for the late stages of *V. lucetia* probably reflect the greater abundance of material of this species. If more specimens of the other two species were available, the ranges would undoubtedly be greater.

TABLE 28.—*Comparison of the number of maxillary teeth in three species of* Vinciguerria *from the eastern Pacific*

Stage	*V. poweriae*	*V. nimbaria*	*V. lucetia*
Late larval	7-10	13-15	10-13
Prometamorphic	8-12	14-19	12-16
Midmetamorphic	8-9	11-13	12-20
Postmetamorphic	13-14	12-19	14-28

5. *Low anal-ray count.*—The anal-ray count in *V. poweriae* is the lowest of any of the four species of *Vinciguerria*, and this species is the only one in which the average number of anal rays is lower than the average number of dorsal rays. The ray counts of the Pacific material of *Vinciguerria* are summarized in table 29.

TABLE 29.—*Comparison of fin-ray counts in three species of* Vinciguerria *from the eastern Pacific*

Fin	*V. poweriae*		*V. nimbaria*		*V. lucetia*	
	Range	Average	Range	Average	Range	Average
Dorsal	14-15	14.50	14-15	14.09	13-16	14.59
Anal	12-15	13.70	14-15	14.64	13-17	15.14
Pectoral	10	10.00	10	10.00	10	10.00
Ventral	7	7.00	7	7.00	7	7.00

6. *Low gill-raker count.*—The Pacific specimens of *V. poweriae* have identical gill-raker counts with those reported by Jespersen and Tåning for Mediterranean material. The raker counts are much lower for comparable stages of development than the counts obtained from specimens of *V. nimbaria* and *V. lucetia* (table 30). It will be noted that *V. poweriae* obtains its full complement of rakers at an earlier stage of development than do the other Pacific species. The full complement of 12 rakers on the lower limb is developed before the end of the larval period, and the small group (three) on the upper limb is developed by midmetamorphosis. The full complement of gill rakers was not found on the lower limb of *V. nimbaria* until midmetamorphosis or on the upper limb until postmetamorphosis. The development of the full set of gill rakers on the upper limb of *V. lucetia* is even more delayed.

TABLE 30.—*Number of gill rakers on the first branchial arch in three species of* Vinciguerria *from the eastern Pacific*

Stage	*V. poweriae*	*V. nimbaria*	*V. lucetia*
Late larval	0+9-12	0+12-13	0+15-16
Prometamorphic	0-2+12	2-3+13-14	0-4+16-22
Midmetamorphic	2-3+12	3-4+13-15	3-5+17-21
Postmetamorphic	3+12	5+15	6-9+18-23
Juvenile and adult	No data [1]	5+15	8-10+18-23

[1] Jespersen and Tåning (1926) report 3 to 4+11 to 12 gill rakers for juvenile and adult material of *V. poweriae* from the Mediterranean.

TABLE 31.—*Number and location of late-forming photophores per side in four species of* Vinciguerria

[Figures in parentheses indicate range]

Location of late-forming photophores	Number of late-forming photophores in—									
	V. poweriae				*V. attenuata* [1]		*V. nimbaria* [2]		*V. lucetia* [2]	
	Eastern Pacific		Mediterranean [1]		Average number	Range	Average number	Range	Average number	Range
	Average number	Range	Average number	Range						
Opercular	1		1		1		1		1	
Symphyseal	0		0		0		1		1	
Lateral VA	1.70	(1-2)	2.05	(1-3)	3.93	(3-6)	3	(3)	3.10	(3-4)
Anal-Caudal	1		1		1		1		1	
Total	3.70		4.05		5.93		6		6.10	

[1] From Jespersen and Tåning (1926).
[2] From eastern Pacific.

7. *Late-forming photophores.*—*V. poweriae* has the lowest number of late-forming photophores of any species of *Vinciguerria.* Available information on late-forming photophores is summarized in table 31.

At the initial formation of the photophores *V. poweriae* usually lacks only four photophores on a side, while the other three species usually lack six. There is a slight, but probably not a significant, difference between the Pacific and Mediterranean material of *V. poweriae* in the number of late-forming photophores: 3.7 as compared with 4.05.

Differences in pigmentation between *poweriae* and *attenuata* on the one hand and *lucetia* and *nimbaria* on the other have already been commented on. Aside from pigmentation, the larva of *poweriae* is quite similar in appearance to that of *lucetia;* however, the larvae of the two species differ somewhat in body proportions. The differences are not marked, yet are greater than those between larvae of *lucetia* and *nimbaria.* Statistics describing the regressions of body proportions on standard length for *poweriae* larvae are given in table 32. In addition to standard length, measurements were made of five body parts: head length, depth at pectoral, width of eye, distance from snout to anus, and distance from snout to origin of dorsal fin. The body proportions of larvae of *poweriae* differ from those of larvae of *lucetia* in the following principal ways: (1) The head is about 10 percent shorter (fig. 28); (2) the body is more slender; depth at pectorals is about 15 percent less than in *lucetia* larvae of the same standard length; and (3) the eye is smaller, at least in width (the dimension taken).

TABLE 32.—*Statistics describing regression of body measurements on standard length for larvae of three species of* Vinciguerria

Body proportion	Size range	$\bar{x}$	$\bar{y}$	*n*	*b*	*a*	$s_{y \cdot x}$
Head length:	*Mm.*						
lucetia	2.2–18.2	8.15	1.73	100	0.214	0.012	0.1219
nimbaria	5.4–16.0	10.34	2.08	30	.199	.022	.1140
poweriae	8.3–18.5	14.00	2.64	24	.180	.125	.1245
Body depth:							
lucetia	2.2–18.2	8.22	0.67	97	.098	−.137	.0727
nimbaria	5.4–16.0	10.32	0.89	32	.103	−.173	.1060
poweriae	8.3–18.5	14.00	0.97	25	.082	−.177	.0933
Eye diameter:							
lucetia	2.2–18.2	8.50	0.34	91	.039	.007	.0340
nimbaria	5.4–16.0	10.95	0.43	27	.040	−.011	.0440
poweriae	8.3–18.5	14.08	0.47	20	.031	.035	.0497
Snout to dorsal:							
lucetia	6.6–18.2	11.08	7.01	57	.565	.739	.1887
nimbaria	10.1–16.0	12.90	8.17	16	.574	.764	.1281
poweriae	12.7–18.5	15.90	10.47	14	.539	1.896	.1725
Snout to anus:							
lucetia	2.2–18.2	8.15	6.00	100	.734	.020	.2044
nimbaria	5.4–16.0	10.30	7.77	31	.731	.242	.1417
poweriae	8.3–18.5	14.00	10.62	25	.725	.468	.1893

Vinciguerria nimbaria (Jordan and Williams)

Zalarges nimbarius Jordan and Williams, *in* Jordan and Starks, 1896. Proceed. California Acad. Sci., Ser. 2, vol. 5, p. 793, pl. 76 (original description).

Vinciguerria nimbaria Gilbert, 1908. Mem. Mus. Compar. Zool., vol. 26, p. 237 (description emended). Horsburgh, 1935. Proceed. California Acad. Sci. (Ser. 4), vol. 21, pp. 230–231 (description emended, *sanzoi* placed in synonymy).

Vinciguerria sanzoi Jespersen and Tåning, 1919. Vidensk. Medd. Dansk Naturh. Foren., vol. 70, pp. 218–220, figs. 2, 5 (original description). Jespersen and Tåning, 1926. Rept. Danish Ocean. Exped., 1908–1910, vol. 2 (Biology), A12, pp. 23–29 (*V. sanzoi* compared with other species of *Vinciguerria*).

?*Gonostoma raoulensis* Waite, 1910. Trans. New Zealand Inst., vol. 42, p. 373, pl. 35, fig. 1 (original description).

Gilbert (1908) first called attention to an inaccuracy in the original description by Jordan and Williams of *Zalarges nimbarius* with regard to the

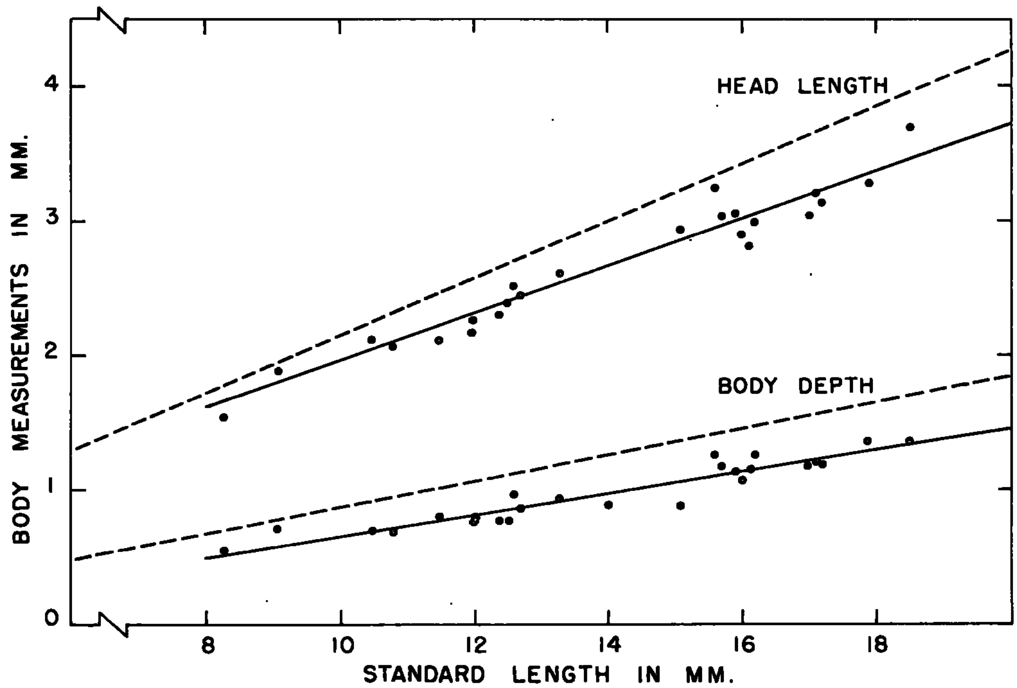

Figure 28.—Regressions of head length and body depth on standard length of larvae of *Vinciguerria poweriae*. Regression lines (solid) were fitted by the method of least squares (see table 32 for statistics describing the regressions). The broken line above each regression is the comparable regression line for *V. lucetia* larvae (see figs. 4 and 5).

number of dorsal rays, and Horsburgh (1935) reexamined the original material and further amended the description by pointing out the presence of an adipose fin and a pair of vomerine teeth. Horsburgh also examined material of *V. sanzoi* and concluded that it was identical with *V. nimbaria*. We concur in this disposition of *V. sanzoi*, as the Pacific material of *V. nimbaria* examined by us agrees in all particulars with the detailed descriptions of larvae, metamorphosing individuals, and adults of *V. sanzoi*, as described by Jespersen and Tåning.

V. nimbaria is closely related to *V. lucetia*, from which it can be rather readily separated after photophore formation, but the eggs and younger larval stages of the two species are practically identical.

In the eastern Pacific, *V. nimbaria* is an oceanic species, occurring mainly to the west of 133° W. longitude. The distribution of metamorphosing individuals, juveniles, and adults is shown in figure 29. One specimen (H50–104, Scripps Institution) was taken by explosives in the Scripps Submarine Canyon, near La Jolla, another at station 100.80 (30°01′ N., 120°07′ W.), but these are the only individuals thus far taken within the area routinely surveyed on CCOFI cruises. No attempt has been made to plot the distribution of eggs and larvae of *V. nimbaria*, because of the uncertainty of distinguishing them from *V. lucetia*. However, as no specimens of *V. lucetia* have been taken to the west of 134° W. longitude, there seems to be little overlap in the actual distributions of the two species.

We have assumed that eggs and larvae occurring in the area where later stages of *V. nimbaria* are found also belong to this species. Several collections contained larvae in various stages of development together with metamorphosing individuals and juveniles of *V. nimbaria*. This material has been carefully examined to determine characters that can be used to separate the eggs and larvae of *lucetia* and *nimbaria*. Measurements and meristic counts on 34 specimens identified as *V. nimbaria* larvae are given in table 33. Unfortunately, the only valuable diagnostic characters do not appear until near the end of the larval period. The eggs of the two species are almost identical in appearance and size, and both lack an oil globule. One tenuous difference is in the amount of

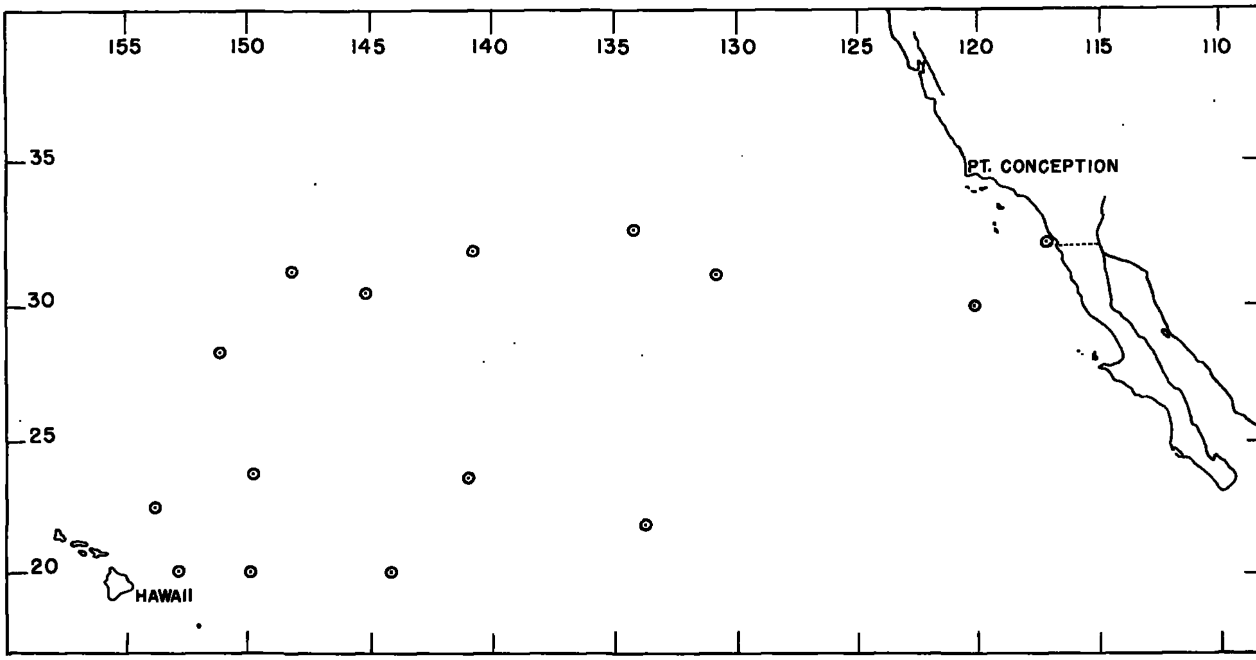

FIGURE 29.—Distribution (occurrences) of metamorphosing, juvenile, and adult *Vinciguerria nimbaria*, based on material studied from the eastern Pacific.

TABLE 33.—*Measurements and meristic counts of* Vinciguerria nimbaria *larvae from the eastern Pacific*

[BF—base formed; U—urostyle]

Area	Body measurements (in mm.)						Meristic counts [1]					Number of gill rakers	Number of vertebrae ossified
	Standard length	Head length	Eye width	Depth at pectoral	Snout to anus	Snout to dorsal	Dorsal	Anal	Caudal fin: Principal	Caudal fin: Secondary D	Caudal fin: Secondary V		
31°09.5′ N., 148°24′ W	5.4	1.07	0.18	0.40	4.00				0	0	0		
23°45′ N., 150°00′ W	5.4	0.94		.28	4.10				0	0	0		
20°03′ N., 150°01.5′ W	6.0	1.19		.44	4.70		BF		10	0	0		
19°57.5′ N., 144°15′ W	6.9	1.45	.26	.52	5.20		7		19	0	0		
23°45′ N., 150°00′ W	7.1	1.49	.32	.56	5.35		8	BF	19	0	0		
23°45′ N., 150°00′ W	7.3	1.38		.51	5.40		8	BF	19	0	0		
20°03′ N., 150°01.5′ W	7.3	1.59	.24	.72	5.50		10	BF	19	0	0		
32°53′ N., 134°13′ W	7.6	1.55		.68	6.00		6	BF	19	0	0		
31°11′ N., 145°10′ W	8.0	1.40	.30	.60	6.05		7	BF	19	0	0		
20°03′ N., 150°01.5′ W	8.2	1.77	.32	.65	6.40		11	BF	19	0	0		
20°03′ N., 150°01.5′ W	8.3	1.75		.66	6.40		10	BF	19	0	1	0+8	
20°03′ N., 150°01.5′ W	8.5	1.79	.35	.82	6.50		10	7	19	1	1	0+8	
23°45′ N., 150°00′ W	8.8	1.77	.35	.70	6.50		10	BF	19	1	1	0+8	
31°09.5′ N., 148°24′ W	9.1	1.24	.32	.72	7.05		10	BF	19	1	1		
23°45′ N., 150°00′ W	9.2	1.84	.38	.79	7.05		11	4	19	1	1	0+8	
31°11′ N., 145°10′ W	9.4						12	8	19	1	1	0+8	
23°40′ N., 141°06′ W	10.1	2.11	.38	.79	7.90	6.70	12	9	19	1	1	0+10	
19°57.5′ N., 144°15′ W	10.7	2.18	.42	1.05	8.10	6.95	14	13	19	3	2	0+11	
28°06.5′ N., 151°25′ W	10.7	2.28	.53	1.10	8.20	6.90	13	11	19	3	1	0+10	
20°03′ N., 150°01.5′ W	10.8		.44	.96			12	12	19	3	2	0+10	
23°45′ N., 150°00′ W	11.0	2.11	.36	.82	8.30	7.00	13	11	19	3	2	0+9	
31°11′ N., 145°10′ W	11.6	2.24	.47	.95	8.85	7.40	13	13	19	2	2	0+10	
20°03′ N., 150°01.5′ W	12.5	2.50	.51	1.21	9.20	8.00	13	14	19	4	3	0+11	27+U
28°06.5′ N., 151°25′ W	13.0	2.80	.54	1.28	9.50	8.00	13	12	19	4	3	0+12	31+U
31°09.5′ N., 148°24′ W	13.1	2.50	.51	1.21	9.85	8.20	13	12	19	4	2	0+11	22+U
31°11′ N., 145°10′ W	13.3	2.53	.49	1.08	9.90	8.50	13	14	19	3	2	0+10	
23°40′ N., 141°06′ W	13.6	2.71	.46	1.16	10.05	8.65	14	14	19	2	3	0+12	29+U
23°40′ N., 141°06′ W	13.7	2.80	.52	1.11	10.20	8.50	14	14	19	4	4	0+12	25+U
23°45′ N., 150°00′ W	14.1	3.00	.53	1.18	10.35	8.75	14	13	19	6	3	0+13	34+U
30°25′ N., 145°08′ W	14.2	3.00	.60	1.53	10.50	9.10	13	14	19	5	4	0+13	38+U
31°09.5′ N., 148°24′ W	14.2	2.71	.49	1.14	10.85	9.00	14	13	19	4	3	0+13	35+U
19°57.5′ N., 144°15′ W	14.5						15	15	19	6	4	2+13	42
28°06.5′ N., 151°25′ W	14.5	2.98	.66	1.53	11.00	8.90	13	15	19	6	4	0+13	42
31°09.5′ N., 148°24′ W	16.0	3.08	.63	1.39	11.95	10.10	14	14	19	5	4	0+13	42

[1] No pectoral or ventral rays are formed during larval period. Larval pectorals are present on all specimens and ventral buds are developed on most specimens over 10 mm. in length.

TABLE 34.—*Comparison of number of gill rakers in larvae of* Vinciguerria nimbaria *and* V. lucetia *from the eastern Pacific*

Standard length	*V. nimbaria*			*V. lucetia*		
	Number of specimens	Number of gill rakers		Number of specimens	Number of gill rakers	
		Range	Average		Range	Average
6–6.9 mm	4	0	0	5	0	0.
7–7.9 mm	3	0 or nubs	0 or nubs	5	0	0.
8–8.9 mm	4	0+8	0+8	4	nubs or 0+10	0+10.
9–9.9 mm	3	0+8	0+8	4	nubs	nubs.
10–10.9 mm	4	0+9–0+11	0+9.9	2	0+11	0+11.
11–11.9 mm	3	0+9–0+10	0+9.7	5	0+11–0+13	0+12.
12–12.9 mm	1	0+11	0+11	1	0+12	0+12.
13–13.9 mm	4	0+10–0+12	0+11.2	3	0+13–0+15	0+13.7.
14–14.9 mm	3	0+13–2+13	.7+13	4	0+12–0+15	0+13.8.
15–15.9 mm				2	0+14–0+17	0+15.2.
16–16.9 mm	1	0+13	0+13	2	0+16	0+16.
17–17.9 mm				1	0+16	0+16.

pigmentation developed in late egg stages; in the material examined, *V. nimbaria* has less pigment on late-stage embryos. The size range of eggs identified as *V. nimbaria* is from 0.64 to 0.72 millimeter in diameter.

The pigmentation of larvae of the two species is so similar that we have found no diagnostic differences. All of the pigment areas described for *V. lucetia* also develop on larvae of *V. nimbaria*. Since Jespersen and Tåning (1926) have also described the pigmentation of larvae of *V. sanzoi* (=*nimbaria*), there can be no question about the accuracy of this observation. In both species the caudal spot is near the ventral margin. Both species develop several pigment spots above the anal fin, and also along the base of the caudal fin rays. Morphometric measurements have not shown any clear-cut differences in body proportions. Two characters are useful in separating late-stage larvae: gill rakers and teeth. As noted previously, only the gill rakers on the lower limb of the first branchial arch develop during the larval period; rakers were developed on the upper limb of only one specimen that we have examined. The number of gill rakers on the lower limb in late stage larvae of *V. nimbaria* is 12 or 13, as compared with 15 or 16 on late-stage larvae of *V. lucetia* (table 34). *V.* lucetia usually has two more gill rakers at initial formation during the larval period and three more at the beginning of metamorphosis than *V. nimbaria*.

There are more maxillary and mandibular teeth on larvae of *V. nimbaria* than on larvae of comparable size of *V. lucetia* (tables 8 and 35). Larger larvae of *V. nimbaria* usually have about 2 more maxillary teeth and 1 more mandibular tooth per side than do comparable-sized larvae of *V. lucetia*.

TABLE 35.—*Number of teeth per side in larval* Vinciguerria nimbaria

Standard length	Number of specimens	Maxillary		Mandibular lateral		Premaxillary	
		Range	Average	Range	Average	Range	Average
5–5.9 mm	2	2–3	2.5	0	0	0	0
6–6.9 mm	4	3–6	4.8	0	0	0	0
7–7.9 mm	3	6	6.0	1–3	1.4	0	0
8–8.9 mm	4	7–8	7.5	2–4	3.0	0	0
9–9.9 mm	3	7–9	8.2	3–5	3.8	0	0
10–10.9 mm	4	10–13	11.0	3–5	4.4	0	0
11–11.9 mm	3	11	11.0	5–6	5.2	0	0
12–12.9 mm	1	13	13.0	5–6	5.5	0	0
13–13.9 mm	4	11–13	12.2	4–8	6.0	0–2	1.0
14–14.9 mm	3	12–15	13.3	6–8	6.8	2–4	2.8
16–16.9 mm	1	13	13.0	5–6	5.5	2	2.0

Metamorphosing and older individuals of *V. nimbaria* are readily separable from specimens of *V. lucetia* on the basis of measurements and meristic counts (table 36), and especially of photophore counts (table 37). In addition to differences in number of gill rakers, there are differences in the number of IV and OV photophores. Specimens of *V. nimbaria* have 16 (rarely 17) photophores in the ventral IV group and 13 (rarely 14) in the adjacent OV group. Occasionally, *V. lucetia* may have as many as 16 ventral IV photophores and 13 OV photophores (8 specimens out of 586 studied), but the average numbers in these groups are only 14.34 and 11.34 photophores, respectively. The few specimens of the two species that have identical numbers of IV and OV photophores may be separated by examining the gill rakers (table 30). The full complement of gill rakers in *V. nimbaria* is 5–6+15 in the material examined, while in *V. lucetia* the range is from 8–10+18–23. It will be noted that *V. nimbaria* and *V. lucetia* have identical numbers of lateral VA and ventral VA photophores (table 27). Both species average about one photophore more per side in the VA groups than *V. poweriae*. *V. nimbaria* has a somewhat lower average AC photophore count than *V. lucetia:* 13.35, as compared to 13.86. This difference is even more marked if the comparison is confined to individuals of *V. lucetia* having 15 or more ventral IV photophores per side; the average AC count on these specimens is approximately 14.25 photophores per side.

The number and location of late-forming photophores are identical in *V. nimbaria* and *V. lucetia*. *V. nimbaria* averages nearly 1 vertebra more than *V. lucetia*. Of 16 cleared and stained specimens of *V. nimbaria* that had the vertebral column developed, 12 individuals had 42 vertebrae, 1 had 43, and 3 had 41, for an average of 41.9 vertebrae. The range in vertebral numbers in *V. lucetia* is from 39 to 42, with an average of 40.9 vertebrae.

Differences in body proportions between *V. nimbaria* and *V. lucetia* are too slight to be of use in separating the two species.

TABLE 36.—*Measurements and meristic characters in metamorphosing, juvenile, and adult stages of* Vinciguerria nimbaria *from the eastern Pacific*

Area	Body measurements (in mm.)							Meristic counts							Number of gill rakers	Number of vertebrae
	Standard length	Head length	Eye width	Depth at pectoral	Snout to ventral	Snout to dorsal	Snout to anus	Dorsal	Anal	Pectoral	Ventral	Caudal				
												Principal	Secondary D	Secondary V		
Prometamorphic:																
20°06.5′ N., 153°06′ W	14.2	------	0.65	------	------	------	------	14	13	0	Bud	19	6	4	2+13	42
19°57.5′ N., 144°15′ W	14.8	3.18	.60	1.66	7.7	9.0	11.0	14	14	0	Bud	19	6	4	1+13	42
31°09.5′ N., 148° 24′ W	15.1	3.28	.69	1.37	8.1	9.6	11.3	13	14	0	5	19	7	4	2+13	42
20°03′ N., 150°01.5′ W	15.3	3.28	.66	1.43	8.2	9.8	11.4	14	15	0	6	19	7	4	2+13	42
23°45′ N., 150°00′ W	15.3	3.23	.63	1.44	8.0	9.7	11.3	13	15	0	Bud	19	6	4	2+14	42
28°06.5′ N., 151°25′ W	15.6	3.30	.77	1.77	7.9	9.3	11.5	15	15	0	7	19	8	4	3+14	42
32°02′ N., 140°55′ W	17.5	------	------	------	------	------	------	14	15	1	7	19	8	4	2+14	43
31°08.5′ N., 130°59′ W	19.4	3.66	.74	1.74	9.9	12.2	14.2	14	14	1	7	19	7	4	2+13	42
Midmetamorphic:																
22°34′ N., 154°01′ W	17.3	4.05	1.14	2.36	8.2	9.7	11.4	14	15	10	7	19	8	4	4+15	42
23°45′ N., 150°00′ W	17.6	4.00	1.10	2.48	8.5	10.0	11.6	14	15	10	7	19	8	4	4+14	42
22°53′ N., 134°13′ W	17.9	3.92	1.03	2.28	8.8	10.2	12.4	14	14	7	7	19	7	4	3+14	41
Postmetamorphic:																
22°34′ N., 154°01′ W	17.2	4.41	1.36	2.82	8.2	9.7	11.5	14	15	10	7	19	8	4	5+15	42
23°40′ N., 141°06′ W	18.2	4.55	1.19	2.63	8.5	10.0	12.0	14	15	10	7	19	8	4	5+15	42
Juvenile and adult:																
19°57.5′ N., 144°15′ W	24.1	6.60	2.34	4.90	12.0	14.0	16.5	14	14	10	7	19	8	4	5+15	41
20°03′ N., 150°01.5′ W	24.5	6.50	2.23	5.10	12.0	13.9	15.9	14	14	10	7	19	8	4	5+15	41
21°52′ N., 133°51′ W	30.0	------	------	------	------	------	------	------	------	------	------	------	------	------	5+15	------
Scripps Canyon	48.0	13.25	3.50	8.10	25.0	28.8	33.5	14	15	10	7	------	------	------	6+15	------

TABLE 37.—*Number of photophores in metamorphosing, juvenile, and adult stages of* Vinciguerria nimbaria *from the eastern Pacific*

[Both sides of body given]

Station	North latitude	West longitude	Standard length	Head				Lateral row		Ventral row		Anal-caudal (AC group)	Number of photophores incomplete	Total number of photophores
				Orb and Op	So	Br	Is	OV group	VA group	IV group	VA group			
Prometamorphic:			*Mm.*											
Chinook 14	32°38′	172°21′	14.0	4-4	0	8-8	7-7	13-13	8-8	16-16	10-10	6+5-6+6	6-6	83-84
Norpac 81.5	31°09.5′	148°24′	15.1	4-4	0	8-8	7-7	13-13	8-9	16-16	10-11	5+6-5+6	6-6	83-85
N. Holiday 56	28°06.5′	151°25′	15.6	4-4	0	8-8	7-7	13-13	8-8	16-16	10-10	6+6-7+6	6-6	84-85
N. Holiday 61	32°02′	140°55′	17.5	4-4	0	8-8	7-7	13-13	8-8	16-16	10-11	7+7-6+7	6-7	86-87
Norpac 76D	31°08.5′	130°59′	19.4	4-4	0	8-8	7-7	14-14	7-7	17-17	9-9	6+7-7+6	6-6	85-85
Midmetamorphic:														
Norpac 131.5	22°34′	150°01′	17.3	5-5	0	8-8	7-7	13-13	8-8	16-16	10-10	6+6-7+5	5-5	84-84
Norpac 131D	23°45′	150°00′	17.6	4-4	0	8-8	7-7	13-13	8-8	16-16	10-10	6+6-6+6	6-6	84-84
N. Holiday 64	32°53′	134°13′	17.9	4-4	0	8-8	7-7	13-13	8-8	16-16	10-10	6+6-6+6	6-6	84-84
Postmetamorphic:														
Norpac 131.5	22°34′	150°01′	17.2	5-5	1-1	8-8	7-7	13-13	9-9	16-16	10-10	6+6-6+7	3-3	84-85
Norpac 128D	23°40′	141°06′	18.2	5-5	0	8-8	7-7	13-13	9-8	16-16	10-10	6+6-6+7	4-5	84-85
Juvenile and adult:														
Norpac 155D	19°57.5′	144°15′	24.1	5-5	1-1	8-8	7-7	13-13	11-11	16-16	10-10	13-13	----------	84-84
Norpac 157D	20°03′	150°01.5′	24.5	5-5	1-1	8-8	7-7	13-13	10-11	16-16	9-10	14-13	----------	83-84
Norpac 141D	21°52′	133°51′	30.0	5-5	1-1	8-8	7-7	13-13	11-11	16-16	10-10	13-13	----------	84-84
Scripps Canyon	32°53′	117°17′	48.0	5-5	1-1	8-8	7-7	13-13	10-11	16-16	9-10	14-12	----------	83-83

SUMMARY

The development of *Vinciguerria lucetia*, family Gonostomatidae, is described from the embryonic to the adult stages. *V. lucetia* is one of the most abundant pelagic forage fishes in the eastern north Pacific.

The pelagic egg is moderately small (0.58–0.74 mm.), spherical, lacks an oil globule, has segmented yolk and a double shell membrane. There is an apparent cline in egg size with latitude.

Postembryonic development has been divided into six stages: larval, prometamorphic, midmetamorphic, postmetamorphic, juvenile, and adult. In dealing with changes in body form, each stage has been treated separately. Six dimensions have been studied in addition to standard length: head length, body depth, eye width, distance from snout to insertion of ventral fins, distance from snout to dorsal origin, and distance from snout to anus. Rectilinear regressions of size on size have been derived for each body dimension.

The threadlike, nearly colorless larvae are similar in appearance to larvae of the sardine and anchovy. The range in standard length of larvae studied was 2.2 to 18.2 mm.

Marked changes take place in body proportions and body structures during metamorphosis with little or no increase in standard length. The head length increases about 20 percent between the larval stage and postmetamorphic, the eye diameter and also body depth increase approximately 80 percent. On the other hand, there is approximately a 10-percent decrease in distance from snout to insertion of ventral fins and from snout to dorsal origin, and a somewhat greater decrease in the distance from snout to anus.

Specimens of *V. lucetia* metamorphose at a smaller size in the area south of 25° N. latitude than in the northern part of the range.

Ossification of the vertebral column occurs immediately before metamorphosis. The centra of vertebrae ossify before the neural or haemal spines. The range in number of vertebrae is from 39 to 42. The total number of vertebrae shows a definite latitudinal variation.

Gill rakers form on the lower limb during the larval period, but do not appear on the upper limb until metamorphosis. Gill-raker formation is completed by the end of metamorphosis.

Tooth development is traced from the larval period through to the adult. Maxillary, premaxillary, and mandibular teeth first form in the larval stage, but palatine and vomerine teeth do not appear until postmetamorphosis.

The caudal, dorsal, and anal fins form during the larval period, but procurrent caudal-ray formation is not completed until metamorphosis. Rays do not form in either the pectoral or ventral fins until metamorphosis.

Photophores develop during metamorphosis, at first as white photophores (prometamorphic stage) then as pigmented functional organs. Six or seven pairs of photophores form late; two pairs are usually added during the midmetamorphic stage, the remainder during the postmetamorphic stage. Photophore formation is completed and all photophores are pigmented by the end of metamorphosis. Marked differences were found in the average total number of photophores per side in different parts of the range between 35° N. and 14° S. in the eastern Pacific. Specimens from 30° to 35° N. averaged nearly 83 photophores per side, while specimens obtained between 5° and 15° N. averaged less than 80.5 photophores per side.

Abundance and distribution of larvae within the California Cooperative Oceanic Fisheries Investigations survey area are estimated and illustrated for 1951 and 1952. Based on more extensive collections, *V. lucetia* has been obtained between 35° N. and 14° S. latitude and 78° and 134° W. longitude.

Two other species of *Vinciguerria* have been found to occur in the eastern Pacific: *V. nimbaria* and *V. poweriae*. Both occur on the fringes of the area routinely surveyed on CCOFI cruises, but both were well represented in the extensive coverage obtained on "Norpac." Characters used to separate the three species at different stages of development are given.

V. poweriae is readily separated in the adolescent and adult stages by the absence of the symphyseal pair of photophores, which is developed in *lucetia* and *nimbaria*. The simplest character for separating late-larval, and early-metamorphic stages of *V. poweriae* from the two other species is pigmentation, especially the mediolateral position of the caudal pigment spot. Measurements and meristic counts are given for larvae and metamorphosing stages of *V. poweriae* and for all stages in the development of *V. nimbaria*.

V. nimbaria can be rather easily separated from *V. lucetia* after photophore formation, but the eggs and younger larval stages of the two species are practically identical. Two characters are useful in separating late-stage larvae: gill rakers and teeth. There are more maxillary and mandibular teeth and fewer gill rakers on larvae of *V. nimbaria* than on larvae of *V. lucetia* of comparable size.

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APPENDIX

Measurements of individual specimens of *Vinciguerria lucetia* are given in the following five tables. The different stages of development are presented in separate tables with the exception of juvenile and adult stages, which are combined in one table.

APPENDIX TABLE 1.—*Measurements (in mm.) of larvae of* Vinciguerria lucetia *from the eastern North Pacific*

Station	North latitude	West longitude	Standard length	Head length	Eye width	Depth at pectoral	Snout to ventral	Snout to dorsal	Snout to anus
5106-107.40	30°23′	116°46′	2.24	0.38	0.10	0.14			1.35
5106-120.110	25°38′	119°44′	2.37	.43	.12	.16			1.66
5106-120.110	25°38′	119°44′	2.42	.43	.12	.18			1.65
5106-127.40	26°40′	114°31′	2.45	.38	.12	.18			1.66
5106-120.110	25°38′	119°44′	2.47	.43		.18			1.80
5106-120.110	25°38′	119°44′	2.47	.43		.18			1.69
5106-127.40	26°40′	114°31′	2.60	.50	.10	.21			1.60
5106-127.40	26°40′	114°31′	2.60	.50	.12	.14			1.69
5106-107.40	30°23′	116°46′	2.62	.49	.14	.18			1.70
5106-127.40	26°40′	114°31′	2.75	.49	.10	.16			1.80
5105-137.60	24°21′	114°40′	3.00	.61		.19			2.05
5106-107.40	30°23′	116°46′	3.00	.61	.14	.18			2.05
5106-107.40	30°23′	116°46′	3.05	.63	.14	.21			2.08
5105-137.60	24°21′	114°40′	3.50	.70		.23			2.55
5106-120.110	25°38′	119°44′	3.50	.70	.16	.21			2.47
5106-107.35	30°31′	116°25′	3.51	.61	.14	.18			2.47
5106-120.110	25°38′	119°44′	3.70	.79	.18	.26			2.75
5106-127.40	26°40′	114°31′	3.75	.79	.14	.23			2.70
5106-120.110	25°38′	119°44′	4.00	.70	.16	.26			2.54
5106-107.35	30°31′	116°25′	4.05	.70	.14	.18			2.90
5106-107.40	30°23′	116°46′	4.10	.88	.18	.33			2.95
5106-130.90	24°27′	117°18′	4.25	.79	.18	.26			3.15
5106-107.40	30°23′	116°46′	4.25	.89	.18	.26			3.20
5103-120.110	25°33′	119°44′	4.60	.88	.18				3.30
5106-127.40	26°40′	114°31′	4.75	.91	.19	.39			3.55
5106-127.40	26°40′	114°31′	4.75	.92	.18	.35			3.50
5106-130.90	24°27′	117°18′	4.75	.95	.18	.35			3.65
5106-130.90	24°27′	117°18′	4.90	1.00	.18	.35			3.60
5103-120.110	25°33′	119°44′	5.00	1.00					3.75
5106-127.40	26°40′	114°31′	5.00	.95	.18	.34			3.75
5106-130.90	24°27′	117°18′	5.15	1.15	.21	.35			4.05
5106-130.90	24°27′	117°18′	5.25	1.14	.21	.40			3.85
5106-130.90	24°27′	117°18′	5.35	1.20	.23	.35			4.10
5106-127.40	26°40′	114°31′	5.45	1.15		.31			4.00
5009-70.145	33°06′	128°20′	5.80	1.40		.40			4.35
5105-137.60	24°21′	114°40′	5.80	1.22	.21	.43			4.35
5009-70.160	32°40′	129°24′	5.85	1.36		.39			4.45
5106-127.40	26°40′	114°31′	5.95	1.28	.23	.39			4.35
5106-130.90	24°27′	117°18′	6.00	1.45	.28	.49			5.25
5105-137.60	24°21′	114°40′	6.25	1.30	.24	.46			4.65
5106-130.90	24°27′	117°18′	6.25	1.35	.23	.47			4.60
5106-107.35	30°31′	116°25′	6.50	1.30	.26	.43			4.90
5106-120.110	25°38′	119°44′	6.65	1.50	.26	.47		4.50	5.00
5106-130.90	24°27′	117°18′	6.85	1.50	.28	.52		4.50	5.20
5106-130.90	24°27′	117°18′	7.25	1.50	.28	.52		5.00	5.60
5106-123.40	27°18′	114°52′	7.30	1.53	.28	.52			5.55
5106-130.90	24°27′	117°18′	7.40	1.60	.26	.50		5.00	5.60
5009-70.145	33°06′	128°20′	7.45	1.70	.32	.54		5.00	5.55
5106-107.40	30°23′	116°46′	7.50	1.60	.30	.52		5.00	5.50
5105-137.60	24°21′	114°40′	7.60	1.55	.30	.63		5.00	5.90
5106-93.90	30°50′	121°34′	7.70	1.60	.30	.52		5.00	5.60
5106-107.35	30°31′	116°25′	7.75	1.65	.30	.52		5.00	5.85
5009-70.160	32°40′	129°24′	8.10	1.80		.55		5.25	6.50
5009-70.160	32°40′	129°24′	8.25	1.95	.30	.65		5.45	6.20
5009-70.145	33°06′	128°20′	8.30	2.00	.35	.70		5.75	6.25
5106-130.90	24°27′	117°18′	8.45	1.85	.32	.70		5.75	6.35
5106-93.90	30°50′	121°34′	8.45	1.95	.35	.74		5.30	6.50
5106-93.90	30°50′	121°34′	8.50	1.85	.35	.66		5.50	6.35
5106-107.40	30°23′	116°46′	8.75	2.02	.30	.70		5.50	6.30
5106-93.90	30°50′	121°34′	8.80	1.95	.37	.68		5.60	6.35
5106-107.40	30°23′	116°46′	8.90	2.00	.32	.70		5.75	6.55
5009-70.145	33°06′	128°20′	9.15	2.15	.38	.78		6.30	7.00
5106-93.90	30°50′	121°34′	9.30	2.20	.37	.79		5.80	6.75
5106-93.90	30°50′	121°34′	9.50	2.05	.35	.80		6.25	7.25
5103-120.110	25°33′	119°44′	9.60	1.87	.35	.79		6.25	7.15
5106-93.90	30°50′	121°34′	9.65	2.20	.40	.79		6.25	7.05
5009-70.145	33°06′	128°20′	10.15	2.40	.40	.85		6.55	7.70
5105-93.80	31°10′	120°54′	10.35	2.25	.35	.88		6.50	7.50
5009-70.145	33°06′	128°20′	10.50	2.50	.40	1.00		6.75	7.95
5011-133.60	24°53′	115°10′	10.65	2.40	.47	1.05	5.50	6.60	8.00
5106-93.90	30°50′	121°34′	11.25	2.40	.50	.96		6.95	8.35
5009-70.160	32°40′	129°24′	11.30	2.55	.47	.91		7.75	8.50
5009-70.160	32°40′	129°24′	11.35	2.60	.50	1.00		7.25	8.40
5106-93.90	30°50′	121°34′	11.35	2.60	.50	1.05		7.00	8.60
5106-93.90	30°50′	121°34′	11.35	2.35	.52	.89		7.30	8.25

APPENDIX TABLE 1.—*Measurements (in mm.) of larvae of* Vinciguerria lucetia *from the eastern North Pacific*—Continued

Station	North latitude	West longitude	Standard length	Head length	Eye width	Depth at pectoral	Snout to ventral	Snout to dorsal	Snout to anus
5106-107.40	30°23′	116°46′	11.55	2.30	0.42	.80		6.75	7.85
5009-70.145	33°06′	128°20′	11.60	2.50	.50	.95		7.25	8.55
5106-107.35	30°31′	116°25′	11.60	2.35	.42	.91		7.25	8.35
5106-107.35	30°31′	116°25′	11.70	2.39	.40	.80		7.50	8.60
5009-70.160	32°40′	129°24′	11.75	2.70	.50	1.00		7.35	8.65
5009-70.160	32°40′	129°24′	11.90	2.70	.57	1.05		7.40	9.00
5009-70.145	33°06′	128°20′	12.05	2.75	.50	1.15	6.25	7.75	9.00
5106-107.35	30°31′	116°25′	12.20	2.60	.49	.96	6.00	7.25	9.00
5106-107.80	28°54′	119°18′	12.80	2.70	.49	.96	6.50	8.00	9.40
5011-130.110	23°57′	118°33′	13.20	2.89	.65	1.30		8.05	9.20
5011-133.60	24°53′	115°10′	13.30	2.90	.51	1.17		8.20	9.65
5009-70.145	33°06′	128°20′	13.40	2.75	.50	1.20	6.75	8.40	10.00
5106-93.90	30°50′	121°34′	13.50	2.75	.52	1.14	7.00	8.40	10.00
4909-81.107	32°22′	124°13′	13.60	2.86	.52	1.10		8.30	9.80
5009-70.145	33°06′	128°20′	13.75	3.00	.60	1.35	6.90	8.50	10.05
5011-133.60	24°53′	115°10′	14.35	3.10	.55	1.30	7.35	9.00	10.70
4909-102.74	29°53′	119°29′	14.70	3.20	.65	1.40		9.00	10.60
4909-71.85	34°54′	124°06′	14.80	3.07	.63	1.54		8.90	10.50
4909-81.107	32°22′	124°13′	14.80	2.88	.61	1.40		9.30	10.80
4909-81.107	32°22′	124°13′	14.80	2.94	.60	1.28		9.10	11.00
5011-133.60	24°53′	115°10′	15.20	3.20	.56	1.30	7.80	9.00	11.10
4909-70.95	34°42′	124°48′	15.50	3.10	.60	1.50	7.60	9.50	11.20
4909-102.74	29°53′	119°29′	16.20	3.43	.66	1.60		10.20	11.65
4909-80.147	31°10′	127°08′	17.20	3.30	.60	1.60		10.40	12.50
4909-70.115	34°19′	126°18′	18.20	3.60	.65	1.60	9.00	11.25	13.10

APPENDIX TABLE 2.—*Measurements (in mm.) of prometamorphic-stage specimens of* Vinciguerria lucetia *from the eastern North Pacific*

Station	North latitude	West longitude	Standard length	Head length	Eye width	Depth at pectoral	Snout to ventral	Snout to dorsal	Snout to anus
5103-157.30	21°53′	110°35′	13.2	2.75	0.56	1.28	6.1	8.0	9.4
5103-140.60	23°50′	114°14′	13.8	3.00	.60	1.66	7.1	8.4	10.0
5103-157.30	21°53′	110°35′	14.2	2.97	.58	1.42	8.1	8.8	10.3
5103-150.60	22°04′	113°18′	15.2	3.25	.58	1.69	8.0	9.7	11.2
5103-157.10	22°33′	109°23′	15.5	3.15	.55	1.50	7.5	9.5	11.0
Shellback 13	18°06′	124°14′	16.0	3.50	.70	1.40	7.5	9.8	11.2
5011-133.60	24°53′	115°10′	16.0	3.25	.75	1.50	8.1	9.8	11.2
5011-133.60	24°53′	115°10′	16.1	3.30	.58	1.25	8.1	10.0	11.7
5011-130.110	23°57′	118°33′	16.5	3.76	.79	1.95	8.4	10.1	11.8
5205-110.90	28°01′	119°36′	17.0	3.60	.65	1.40	8.0	10.0	11.8
4909-102.74	29°53′	119°29′	17.0	3.68	.68	1.70	8.4	10.6	12.2
4909-71.85	34°54′	124°06′	17.2	3.82	.70	1.87	8.8	10.7	12.4
4909-81.107	32°22′	124°13′	17.3	3.80	.79	1.75	8.8	10.6	12.4
5009-70.190	31°35′	131°29′	17.6	3.65	.75	1.70	8.4	10.5	12.2
4909-71.85	34°54′	124°06′	17.8	3.68	.74	1.80	9.3	10.9	12.8
4909-71.85	34°54′	124°06′	18.0	3.90	.84	1.95	9.2	11.0	12.9
4909-80.147	31°10′	127°08′	18.1	3.75	.75	2.00	9.1	11.4	13.2
4909-80.147	31°10′	127°08′	18.2	3.80	.72	1.80	9.0	11.2	13.1
4909-70.95	34°42′	124°48′	18.3	3.60	.70	1.80	9.0	11.5	13.2
4909-102.94	29°10′	120°48′	18.9	3.76	.80	1.84	9.0	11.2	13.0
4909-81.107	32°22′	124°13′	18.9	3.90	.75	1.76	9.5	11.4	13.4
N. Holiday 66	32°39′	129°41′	19.2	3.55	.80	1.70	9.3	11.5	13.2

APPENDIX TABLE 3.—*Measurements (in mm.) of midmetamorphic-stage specimens of* Vinciguerria lucetia *from the eastern North Pacific*

Station	North latitude	West longitude	Standard length	Head length	Eye width	Depth at pectoral	Snout to ventral	Snout to dorsal	Snout to anus
Shellback 13	18°06′	124°14′	13.5	3.15	0.56	1.60	6.6	8.2	9.6
Do	18°06′	124°14′	13.8	3.25	.66	1.77	6.5	8.1	9.1
Do	18°06′	124°14′	13.8	3.35	.66	1.67	6.8	8.4	9.5
5011-153.50	21°47′	112°14′	14.1	3.34	.72	1.33	6.8	8.5	9.5
5011-140.60	23°46′	114°18′	14.2	3.46	.75	2.02	6.7	8.2	9.4
5106-157.10	22°33′	109°23′	14.3	3.41	.77	2.10	6.8	8.2	9.5
5401-143.30	24°13′	112°04′	14.3	3.51	.72	2.11	6.8	8.4	9.4
5106-157.40	21°32′	111°14′	14.6	3.30	.61	1.61	7.0	8.6	9.9
5011-153.50	21°47′	112°14′	14.8	3.35	.60	1.77	7.2	8.8	10.0
5106-157.10	22°33′	109°23′	15.0	3.40	.72	1.72	7.0	8.8	10.0
5011-140.70	23°25′	114°55′	15.0	3.23	.64	1.75	7.0	8.8	10.0
5401-143.30	24°13′	112°04′	15.1	3.36	.66	1.85	7.0	8.8	10.0
5106-157.10	22°33′	109°23′	15.2	3.41	.70	1.85	7.0	8.9	10.0
5106-157.50	21°12′	111°52′	15.3	3.55	.70	2.13	7.2	8.7	10.0
5011-137.50	24°39′	114°02′	15.4	3.51	.68	2.05	7.5	9.1	10.5
5112-120.60	27°13′	116°32′	15.5	3.33	.65	1.82	7.4	9.2	10.5
5106-157.50	21°12′	111°52′	15.6	3.64	.70	2.05	7.2	9.0	10.2
5106-157.40	21°32′	111°14′	15.7	3.36	.58	1.80	7.2	9.4	10.4
Shellback 13	18°06′	124°14′	15.8	3.55	.78	1.95	7.5	9.2	10.4
5106-157.40	21°32′	111°14′	16.0	3.38	.61	1.82	7.5	9.5	10.7
5202-140.40	24°26′	113°02′	16.4	3.46	.61	1.82	7.9	9.9	11.2
5112-120.60	27°13′	116°32′	16.5	3.64	.74	2.10	8.0	10.0	10.9

APPENDIX TABLE 3.—*Measurements (in mm.) of midmetamorphic-stage specimens of* Vinciguerria lucetia *from the eastern North Pacific*—Continued

Station	North latitude	West longitude	Standard length	Head length	Eye width	Depth at pectoral	Snout to ventral	Snout to dorsal	Snout to anus
5011-133.60	24°53′	115°10′	16.6	3.75	0.80	1.95	7.9	9.8	10.9
5106-157.40	21°32′	111°14′	16.7	3.55	.61	1.82	8.2	10.0	11.9
5104-100.100	29°20′	121°28′	16.9	4.00	.91	2.36	7.8	9.5	10.9
5202-120.60	27°13′	116°32′	17.2	3.55	.99	1.87	8.0	10.4	10.7
5009-90.145	29°32′	125°40′	17.2	3.64	.70	1.82	8.0	9.9	11.6
4911-92.137	29°34′	124°52′	17.3	3.90	.79	1.80	8.2	10.1	11.5
4911-80.147	31°11′	127°03′	17.4	4.00	.88	2.16	8.4	10.1	----
4911-123.63	26°40′	116°28′	17.5	4.29	1.00	2.24	8.2	9.9	11.5
4910-70.115	34°07′	126°17′	17.6	3.80	.84	2.08	8.4	10.0	11.8
5108-100.60	30°41′	118°48′	17.7	4.00	.77	2.39	8.6	10.5	12.0
4911-80.137	31°29′	126°20′	17.7	4.00	.89	2.26	8.6	10.1	11.8
4909-80.147	31°10′	127°08′	17.8	4.00	.88	2.20	8.5	10.5	11.7
5011-133.70	24°35′	115°40′	17.9	3.85	.70	1.95	8.0	10.6	12.2
4911-80.137	31°29′	126°20′	17.9	4.02	.96	2.34	8.5	10.0	11.8
4911-102.74	29°56′	119°29′	17.9	3.95	.82	1.85	8.2	10.8	12.2
Shellback 13	18°06′	124°14′	17.9	4.00	.86	1.95	8.6	10.4	12.0
4909-80.147	31°10′	127°08′	18.0	3.90	.88	2.30	8.8	10.6	12.2
5009-70.190	31°35′	131°29′	18.0	3.80	.85	2.30	8.4	10.5	12.0
4908-123.75	26°16′	117°03′	18.2	4.00	.68	2.08	8.9	11.0	12.3
4909-80.147	31°10′	127°08′	18.2	3.75	.88	2.26	8.8	10.4	12.1
5110-107.40	30°08′	116°48′	18.4	4.10	.77	2.13	9.0	11.0	12.5
4911-80.137	31°29′	126°20′	18.4	4.03	.79	2.26	8.9	10.8	12.3
4909-80.147	31°10′	127°08′	18.6	3.90	.80	2.18	9.1	11.1	12.8
4909-80.147	31°10′	127°08′	18.7	4.00	.86	2.30	9.0	11.1	12.8
4909-80.147	31°10′	127°08′	18.7	3.90	.80	2.10	9.1	11.5	13.0
4909-80.147	31°10′	127°08′	19.0	3.90	.82	2.20	9.3	11.5	13.1
5110-107.40	30°08′	116°48′	19.2	4.10	.77	2.21	9.2	11.4	13.0

APPENDIX TABLE 4.—*Measurements (in mm.) of postmetamorphic-stage specimens of* Vinciguerria lucetia *from the eastern Pacific*

Station	Latitude	Longitude	Standard length	Head length	Eye width	Depth at pectoral	Snout to ventral	Snout to dorsal	Snout to anus
5103-157.10	22°33′N.	109°23′W.	13.2	3.50	0.90	1.92	6.3	7.8	8.9
5110-127.50	26°24′N.	115°08′W.	13.2	3.46	.90	2.05	6.3	7.6	8.8
5011-150.100	20°41′N.	115°40′W.	13.7	3.55	.97	2.20	6.5	7.7	8.9
5011-140.70	23°25′N.	114°55′W.	14.0	3.90	1.15	2.35	6.8	7.8	9.0
5201-137.50	24°41′N.	114°02′W.	14.3	3.90	1.06	2.21	6.7	8.1	9.2
5011-157.30	21°52′N.	110°38′W.	14.5	3.80	1.07	2.21	6.7	8.2	9.2
Shellback trawl 16	12°07′N.	106°03′W.	14.7	4.05	1.17	2.65	7.1	8.5	9.2
5011-153.50	21°47′N.	112°14′W.	14.7	3.79	1.18	2.31	7.0	8.5	9.6
5106-153.20	22°48′N.	110°22′W.	14.8	3.87	1.00	2.13	7.0	8.2	9.6
5011-140.70	23°25′N.	114°55′W.	15.2	4.00	.95	2.15	7.0	8.4	9.9
5011-150.110	20°21′N.	116°17′W.	15.2	4.15	1.30	2.45	7.3	8.6	9.8
Shellback trawl 16	12°07′N.	106°03′W.	15.3	4.35	1.40	2.60	7.4	8.8	9.9
5011-137.40	25°00′N.	113°23′W.	15.3	3.95	1.08	2.30	7.1	8.6	9.8
5106-153.20	22°48′N.	110°22′W.	15.8	3.97	1.00	2.18	7.4	9.0	10.2
5401-147.30	23°38′N.	111°47′W.	15.9	3.97	1.13	2.60	7.4	8.9	10.2
5011-157.20	22°13′N.	110°00′W.	16.0	4.08	1.04	2.39	7.2	9.0	10.3
5011-Sp	24°18′N.	112°30′W.	16.0	4.18	1.10	2.64	7.4	8.8	10.3
Shellback 88	04°12′S.	96°07′W.	16.0	4.05	1.11	2.50	7.5	9.0	10.3
5011-153.50	21°47′N.	112°14′W.	16.2	4.05	1.18	2.54	7.5	9.1	10.2
5011-150.25	23°12′N.	115°40′W.	16.3	4.25	1.28	2.56	7.7	9.4	10.4
5011-137.40	25°00′N.	113°23′W.	16.3	4.20	1.23	2.55	7.7	9.2	10.4
5011-157.20	22°13′N.	110°00′W.	16.4	4.20	1.07	2.60	7.7	9.4	10.6
5010-70.130	33°33′N.	127°16′W.	16.4	4.41	1.21	2.64	8.0	9.4	10.8
4910-124.83	25°51′N.	117°37′W.	16.6	4.40	1.43	3.10	8.0	9.2	10.6
5011-Sp	24°18′N.	112°30′W.	16.8	4.25	1.15	2.59	7.7	9.2	10.8
5501-117.35	28°39′N.	115°17′W.	16.8	4.38	1.21	2.54	8.0	9.4	10.9
Shellback 13	18°06′N.	124°14′W.	17.0	4.35	1.35	2.70	8.0	9.5	11.0
4910-82.87	32°57′N.	122°47′W.	17.0	4.35	1.10	2.36	8.0	9.5	10.8
Shellback 83	00°53′N.	97°12′W.	17.0	4.35	1.29	2.70	7.8	9.5	10.9
5401-130.35	26°19′N.	113°48′W.	17.2	4.45	1.31	2.55	8.0	9.6	11.1
4910-102.84	29°35′N.	120°08′W.	17.2	4.45	1.22	2.90	8.0	9.5	11.1
5009-70.235	30°02′N.	134°23′W.	17.2	4.23	1.03	2.51	8.2	9.8	11.1
5002-110.80	28°16′N.	118°58′W.	17.4	4.75	1.20	2.69	8.1	9.6	11.0
5401-130.35	26°19′N.	113°48′W.	17.7	4.90	1.46	2.95	8.4	9.8	11.2
5401-137.40	21°40′N.	119°41′W.	17.7	4.60	1.44	2.90	8.3	9.9	11.5
Shellback trawl 11	08°09′N.	84°58′W.	17.8	4.95	----	3.10	8.4	10.0	11.3
5109-110.60	28°56′N.	117°39′W.	17.9	4.85	1.33	2.80	8.2	9.9	11.2
4911-92.137	29°34′N.	124°52′W.	17.9	----	1.08	2.44	8.4	10.1	11.5
Shellback 13	18°06′N.	124°14′W.	18.0	4.75	1.38	3.00	8.4	10.0	11.5
5401-130.35	26°19′N.	113°48′W.	18.2	4.80	1.46	3.00	8.3	10.1	11.6
5401-110.50	29°14′N.	117°01′W.	18.3	4.90	.91	3.05	8.7	10.0	11.8
5106-153.20	22°48′N.	110°22′W.	18.3	4.90	1.36	3.00	8.6	10.0	11.8
5401-130.35	26°19′N.	113°48′W.	18.7	5.05	1.55	2.95	8.7	10.4	11.8
4902-92.117	30°11′N.	123°37′W.	19.3	5.05	1.46	3.05	8.9	10.8	12.1
5404-123.50	26°58′N.	115°30′W.	19.5	5.10	1.49	3.15	9.1	10.9	12.5
4911-113.127	26°14′N.	121°44′W.	20.2	5.25	1.66	3.50	9.5	11.0	12.8

APPENDIX TABLE 5.—*Measurements (in mm.) of juvenile and adult specimens of* Vinciguerria lucetia *from the eastern Pacific*

Station	North latitude	West longitude	Standard length	Head length	Eye width	Depth at pectoral	Snout to ventral	Snout to dorsal	Snout to anus
5201-137.50	24°41′	114°02′	19.2	5.15	1.70	3.20	8.8	10.5	12.0
5011-143.60	23°10′	113°56′	19.5	5.00	1.60	3.65	9.5	10.8	12.8
Shellback 63	12°20′	102°38′	20.0	5.10	2.15	4.00	9.5	11.8	13.0
5401-130.35	26°19′	113°48′	20.0	5.15	1.55	3.05	9.2	10.8	12.5
5103-157.10	22°33′	109°23′	20.2	5.50	1.75	3.80	9.8	11.5	13.6
5009-90.160	29°07′	126°30′	20.2	5.25	1.80	3.75	9.0	10.8	12.2
5203-137.50	24°40′	114°02′	21.2	5.70	1.65	4.10	10.2	12.0	14.2
5112-110.50	29°17′	117°02′	22.0	5.90	1.85	3.85	10.4	11.9	13.9
5401-140.50	24°08′	113°41′	22.0	5.90	2.00	3.90	10.2	11.5	13.5
5009-90.160	29°07′	126°30′	22.1	5.65	1.90	4.55	10.2	12.1	14.0
5011-133.70	24°35′	115°40′	22.2	5.80	1.95	3.75	10.5	12.0	14.0
5201-110.80	28°18′	118°54′	23.0	6.35	2.10	4.25	11.2	12.8	15.0
5110-127.50	26°24′	115°08′	23.5	6.25	2.00	4.10	11.0	13.1	15.0
5103-120.45	27°41′	115°33′	23.5	6.20	2.00	4.15	11.2	13.1	15.0
5003-120.60	27°14′	116°32′	24.3	6.60	2.50	5.00	11.8	13.5	16.5
5009-90.160	29°07′	126°30′	24.4	6.50	2.20	4.80	11.9	13.8	16.0
4911-112.88	27°48′	119°14′	24.5	6.50	2.30	4.75	11.5	14.0	15.8
5202-110.60	28°56′	117°40′	24.5	6.50	2.15	4.35	11.5	13.8	16.0
4911-112.88	27°48′	119°14′	25.2	6.50	2.35	4.90	11.9	14.4	16.2
5202-123.50	27°01′	115°32′	26.0	6.50	2.45	5.25	12.5	14.6	17.0
5105-90.120	30°26′	124°01′	26.0	7.00	2.30	4.50	12.0	14.2	16.0
4911-112.88	27°48′	119°14′	26.6	6.95	2.40	5.15	12.8	15.0	17.2
5302-120.50	27°34′	115°52′	28.0	7.50	2.50	5.10	13.2	15.2	17.8
4903-111.58	28°47′	117°21′	28.2	7.75	2.65	4.90	13.8	15.8	17.8
5205-110.90	28°01′	119°36′	28.5	8.00	2.70	5.50	14.0	15.8	18.5
4802-Sp	26°30′	113°52′	29.1	8.35	2.90	5.60	14.0	17.5	19.5
5003-110.50	29°15′	116°59′	30.5	8.50	2.95	5.40	15.1	17.5	20.0
4911-103.111	28°31′	121°52′	31.0	8.50	2.60	5.50	15.0	17.5	20.2
5203-117.60	27°49′	116°51′	31.0	8.40	2.85	5.90	14.8	17.8	21.0
5510-120.90	26°15′	118°28′	32.5	9.00	3.05	6.00	15.4	17.8	20.5
5011-Sp	24°18′	112°30′	33.0	9.00	2.75	5.75	15.5	18.5	21.0
4908-112.98	27°36′	119°52′	33.5	9.25	3.10	6.00	16.2	18.5	21.5
5302-110.60	28°56′	117°39′	34.0	9.00	3.05	6.15	16.3	18.5	21.8
5205-110.90	28°01′	119°36′	34.0	9.50	3.05	6.35	16.2	19.0	21.8
5004-90.90	31°25′	121°59′	36.0	10.00	3.20	6.40	18.0	20.5	23.6
5005-120.60	27°20′	116°33′	36.5	10.00	3.10	6.40	18.0	20.0	23.6
4904-112.98	27°21′	119°52′	37.6	10.15	3.35	7.00	18.8	21.0	24.8
5007-100.70	30°21′	119°32′	39.5	10.50	3.45	6.70	19.2	23.1	26.0
Off Guadalupe Is	29°15′	118°20′	41.2	11.00	3.55	7.50	20.0	23.5	28.0
Do	29°15′	118°20′	42.0	11.50	3.75	8.00	20.0	24.0	29.0
Do	29°15′	118°20′	42.8	12.00	3.70	8.00	22.0	24.0	29.0
Do	29°15′	118°20′	43.0	11.40	3.50	8.00	21.8	24.3	29.0
Do	29°15′	118°20′	43.0	11.75	4.05	8.25	22.0	25.0	29.5
Do	29°15′	118°20′	43.0	11.60	3.85	8.00	22.0	24.2	29.5
Do	29°15′	118°20′	45.0	12.05	3.90	8.25	22.5	25.8	31.0
5205-110.90	28°01′	119°36′	45.5	12.20	3.90	7.90	22.5	25.5	29.8
SIO-51-91	25°52′	114°40′	47.2	13.00	3.65	7.50	23.2	27.7	32.0
SIO-54-214	29°15′	118°20′	49.8	12.85	3.75	9.00	24.8	28.5	33.3
SIO-51-91	25°52′	114°40′	51.5	13.35	3.60	8.90	25.3	30.2	35.0
SIO-54-214	29°15′	118°20′	52.2	13.00	3.90	9.30	26.0	29.9	35.6
SIO-54-214	29°15′	118°20′	56.0	14.00	4.10	10.10	28.0	32.5	38.2