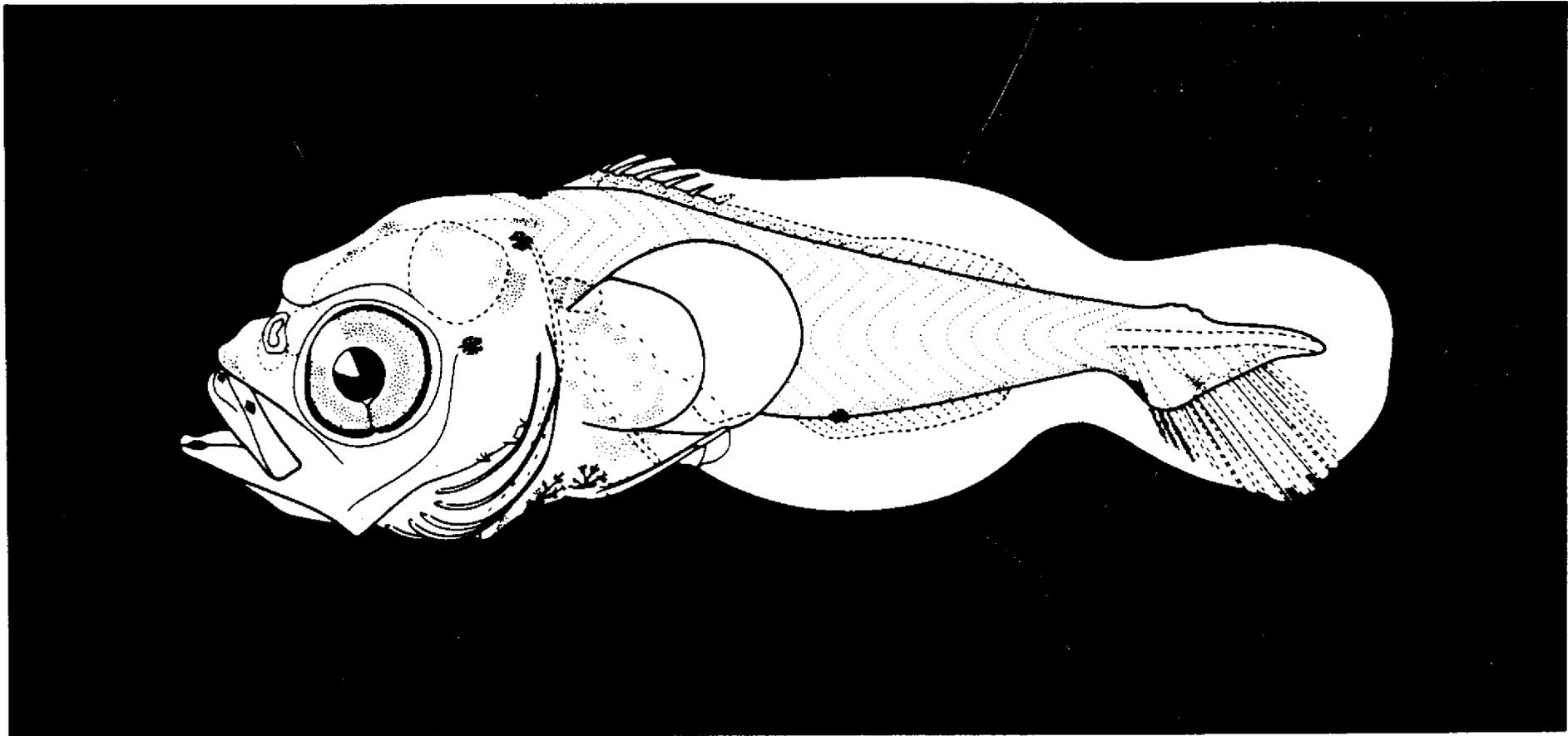


An Atlas of Common Nearshore Marine Fish Larvae of the Hawaiian Islands

John M. Miller, William Watson, and Jeffrey M. Leis



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SEA GRANT MISCELLANEOUS REPORT
UNIHI-SEAGRANT-MR-80-02

November 1979

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Library of Congress Catalog Card No. 79-92062
Manufactured in the United States of America

Book design by Wendy F. Nakano

PREFACE

This atlas is primarily the result of a larval fish investigation conducted at the Hawaii Institute of Marine Biology between 1970 and 1974. During this period a major effort was made to collect and identify nearshore marine fish larvae for the purpose of determining (1) the relative importance of different segments of the nearshore environment around the Hawaiian Islands as nursery grounds for marine fishes and (2) the relative impact of different kinds of shore-line developments on these larval fish resources. Since fewer than 25 percent of the 530 species of Hawaiian fish larvae had been described previously, an atlas containing descriptions of a greater percentage of the species was considered to be a vital precursor to any ecological investigation.

Owing to the termination of the program in 1974, all of the forms that would be encountered in nearshore collections are not included. However, the descriptions contained in this atlas will suffice to identify over three-fourths of the specimens (not species) obtained in such collections and, hence, are sufficient for many ecological purposes. Furthermore, the descriptions of the species included in Part I of this atlas are based on sufficient material to minimize the probability that these described species will be misidentified. However, complete reliance on this atlas for the identification of any larva may result in incorrect "identification" of larvae of the many other (undescribed) species in these waters. This would result in overestimates of abundance of the common forms. Since the rarer forms are generally much less abundant, this bias would be slight. Until additional work on larval taxonomy is resumed, useful taxonomic keys cannot be constructed.

Part II of this atlas is a summary of the winter and summer distribution patterns of the common larvae. In addition, overall larval fish diversity and density maps of three islands—Kauai, Oahu, and Maui—are provided. Although scanty, these distributional data could serve to indicate the more valuable segments of coastline for planning purposes. At least they suggest that the nearshore waters of certain segments of coastline merit more intensive study of larval fishes before they are altered by intensive shoreline development.

Part III of this atlas contains a list of larval fish literature pertinent to Hawaii. This list, although not all-inclusive, was essentially compiled by the authors in 1975. The literature included is widely scattered and much of it is in foreign journals, so a systematic index is provided. Part IV is a list of the specimens in the larval fish collections taken during this study, including the unidentified types of larvae.

It is the sincere hope of the authors that this atlas will stimulate further ecological and taxonomic investigations of the larval fishes of Hawaii.

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ACKNOWLEDGMENTS

During the course of this ichthyoplankton study, many people provided valuable aid in the collecting and processing of samples, and we express our gratitude to them. Space does not permit thanking each of them individually, but several people deserve special recognition, for without them the work would have been much more difficult, if not impossible.

Our sincerest thanks and appreciation go to the following individuals:

- Ed Bilderback, Doug Shepard, and Jim Vansant, captain and crew of the RV *Valiant Maid*
- Takeo Okamura and Lester Zukeran, who operated the RV *Salpa II*
- Barbara Sumida of the National Marine Fisheries Service, La Jolla, California, an invaluable assistant in all aspects of the ichthyoplankton work
- Linda Yamanoha and Candy Stanley, plankton sorters and field assistants
- Elizabeth Corbin, illustrator and assistant in all aspects of data collection and analysis
- Henrietta Rogell, illustrator
- Wendy Nakano, graphic artist
- Doreen Emerson, typist
- Sherry Saito, typesetter
- David Hashimoto, who conducted some of the more successful larval rearing experiments
- William Madden of the Oceanic Institute, Waimanalo, Hawaii and Drs. Thomas A. Clarke and Richard E. Young of the University of Hawaii, who allowed us to examine their samples for specimens
- Dr. Elbert H. Ahlstrom of the National Marine Fisheries Service, La Jolla, California, who identified several of our larval species and made valuable comments on the larval illustrations

This work is the result of research funded by the University of Hawaii Sea Grant College Program under Institutional Grant Nos. 2-35243, 04-3-158-29, and 04-5-158-17 from NOAA Office of Sea Grant, Department of Commerce, and by the National Science Foundation.

TABLE OF CONTENTS

<p>Part I. Larval Fish Descriptions 1</p> <p>INTRODUCTION 3</p> <p>DUSSUMIERIIDAE. 6</p> <p style="padding-left: 20px;">Etrumeus teres (makiawa) 6</p> <p style="padding-left: 20px;">Spratelloides delicatulus (piha) 11</p> <p style="padding-left: 20px;">Identification 16</p> <p style="padding-left: 20px;">Literature 16</p> <p>ENGRAULIDAE. 17</p> <p style="padding-left: 20px;">Stolephorus purpureus (nehu) 17</p> <p style="padding-left: 20px;">Stolephorus buccaneeri 22</p> <p style="padding-left: 20px;">Identification 22</p> <p style="padding-left: 20px;">Literature 22</p> <p>CHANIDAE. 23</p> <p style="padding-left: 20px;">Chanos chanos (awa) 23</p> <p style="padding-left: 20px;">Identification 25</p> <p style="padding-left: 20px;">Literature 25</p> <p>GONOSTOMATIDAE 26</p> <p style="padding-left: 20px;">Cyclothone sp. 26</p> <p style="padding-left: 20px;">Vinciguerria nimbaria 26</p> <p style="padding-left: 20px;">Identification 27</p> <p style="padding-left: 20px;">Literature 27</p> <p>SYNODONTIDAE. 28</p> <p style="padding-left: 20px;">Trachinocephalus myops 28</p> <p style="padding-left: 20px;">Identification 28</p> <p style="padding-left: 20px;">Literature 29</p> <p>CHLOROPHTHALMIDAE 30</p> <p style="padding-left: 20px;">Chlorophthalmus proridens 30</p> <p style="padding-left: 20px;">Identification 30</p> <p style="padding-left: 20px;">Literature 30</p> <p>MYCTOPHIDAE. 31</p> <p style="padding-left: 20px;">Ceratoscopelus warmingi 31</p> <p style="padding-left: 20px;">Diaphus spp. 32</p> <p style="padding-left: 20px;">Hygophym proximum 32</p> <p style="padding-left: 20px;">Lampadena sp. 33</p> <p style="padding-left: 20px;">Lampanyctus nobilis 35</p> <p style="padding-left: 20px;">Identification 36</p> <p style="padding-left: 20px;">Literature 37</p>	<p>EXOCOETIDAE (Malolo). 38</p> <p style="padding-left: 20px;">Cypselurus sp. 1 38</p> <p style="padding-left: 20px;">Cypselurus sp. 2 39</p> <p style="padding-left: 20px;">Identification 39</p> <p style="padding-left: 20px;">Literature 40</p> <p>ATHERINIDAE 40</p> <p style="padding-left: 20px;">Pranesus insularum (iao) 40</p> <p style="padding-left: 20px;">Iso hawaiiensis 42</p> <p style="padding-left: 20px;">Identification 43</p> <p style="padding-left: 20px;">Literature 43</p> <p>KYPHOSIDAE 45</p> <p style="padding-left: 20px;">Kyphosus vaigiensis (nenu) 45</p> <p style="padding-left: 20px;">Identification 46</p> <p style="padding-left: 20px;">Literature 46</p> <p>MULLIDAE. 46</p> <p style="padding-left: 20px;">Mullid sp. 46</p> <p style="padding-left: 20px;">Identification 49</p> <p style="padding-left: 20px;">Literature 49</p> <p>SERRANIDAE. 51</p> <p style="padding-left: 20px;">Serranid Sr-5 (Anthiinae) 51</p> <p style="padding-left: 20px;">Identification 52</p> <p style="padding-left: 20px;">Literature 52</p> <p>APOGONIDAE. 52</p> <p style="padding-left: 20px;">Foa brachygramma (upapulu) 52</p> <p style="padding-left: 20px;">Identification 54</p> <p style="padding-left: 20px;">Literature 54</p> <p>CARANGIDAE. 55</p> <p style="padding-left: 20px;">Caranx (=Atule) mate (omaka) 55</p> <p style="padding-left: 20px;">Gnathanodon speciosus (pa'opa'o) 57</p> <p style="padding-left: 20px;">Seriola sp. (kahala) 59</p> <p style="padding-left: 20px;">Trachurops (=Selar) crumenophthalmus (akule) 60</p> <p style="padding-left: 20px;">Identification 61</p> <p style="padding-left: 20px;">Literature 62</p> <p>CORYPHAENIDAE. 63</p> <p style="padding-left: 20px;">Coryphaena hippurus (mahi mahi) 63</p> <p style="padding-left: 20px;">Identification 65</p> <p style="padding-left: 20px;">Literature 65</p>
---	---

POMACENTRIDAE	65
<i>Abudefduf abdominalis</i> (mao mao)	65
<i>Eupomacentrus fasciolatus</i>	67
Identification	69
Literature	69
LABRIDAE	69
Labrid L-3	69
Identification	70
Literature	70
SCOMBROLABRACIDAE	71
<i>Scombrolabrax heterolepis</i>	71
Identification	71
GEMPYLIDAE	72
<i>Gempylus serpens</i> (Hauliuli - puhi)	72
<i>Nealotus tripes</i>	73
Identification	74
Literature	75
SCOMBRIDAE	75
<i>Auxis</i> spp. (keokeo)	75
<i>Thunnus albacares</i> (ahi)	76
Identification	77
Literature	78
NOMEIDAE	78
<i>Cubiceps pauciradiatus</i>	78
Identification	81
Literature	81
GOBIIDAE	81
<i>Psilogobius mainlandi</i>	81
Identification	83
Literature	84
TRIPTERYGIIDAE	85
<i>Tripterygion atriceps</i>	85
Identification	87
Literature	87
BLENNIIDAE	87
<i>Enchelyurus brunneolus</i>	87
<i>Istiblennius zebra</i> (panoa)	88
Identification	90
Literature	91

vi

SCHINDLERIIDAE	92
<i>Schindleria pietschmanni</i>	92
Identification	93
Literature	93
SCORPAENIDAE	94
Identification	94
Literature	95
CALLIONYMIDAE	96
<i>Callionymus decoratus</i>	96
Identification	97
Literature	97
TETRAODONTIDAE	98
Tetraodontid 1 (keke)	98
Identification	98
Literature	98
MOLIDAE	101
<i>Ranzania laevis</i> (makua)	101
Literature	101
MELANOCETIDAE	102
<i>Melanocetus johnsoni</i>	102
Identification	102
Literature	102
Part II. Larval Fish Distributions	105
INTRODUCTION	107
METHODS	107
SAMPLING LOCATIONS	107
Surveys of Kauai, Oahu, and Maui	107
Kaneohe Bay studies	107
Kahe Point, Oahu	108
Molokini Island	109
Maalaea Bay, Maui	109
Additional sources of larvae	109
DUSSUMIERIIDAE	111
<i>Etrumeus teres</i>	111
<i>Spratelloides delicatulus</i>	111
ENGRAULIDAE	111
<i>Stolephorus purpureus</i>	111
<i>Stolephorus buccaneeri</i>	111

CHANIDAE	111
<i>Chanos chanos</i>	111
GONOSTOMATIDAE	111
<i>Cyclothone</i> sp.	111
<i>Vinciguerria nimbaria</i>	113
SYNODONTIDAE.	113
<i>Trachinocephalus myops</i>	113
CHLOROPHTHALMIDAE	113
<i>Chlorophthalmus proridens</i>	113
MYCTOPHIDAE.	113
<i>Ceratoscopelus warmingi</i>	113
<i>Diaphus</i> spp.	113
<i>Hygophum proximum</i>	117
<i>Lampadena</i> spp.	117
EXOCOETIDAE.	117
<i>Cypselurus</i> spp.	117
ATHERINIDAE	117
<i>Pranesus insularum</i>	117
<i>Iso hawaiiensis</i>	117
KYPHOSIDAE	121
MULLIDAE	121
SERRANIDAE	121
Serranid Sr-5 (<i>Anthiinae</i>)	121
APOGONIDAE.	121
<i>Foa branchygramma</i>	121
CARANGIDAE.	121
<i>Seriola</i> sp.	124
<i>Trachurops crumenophthalmus</i>	124
CORYPHAENIDAE.	124
<i>Coryphaena hippurus</i>	124
POMACENTRIDAE.	126
<i>Abudefduf abdominalis</i>	126
<i>Eupomacentrus fasciolatus</i>	126
LABRIDAE	129
Labrid L-3	129

SCOMBROLABRACIDAE	129
<i>Scombrolabrax heterolepis</i>	129
GEMPYLIDAE	129
SCOMBRIDAE	129
<i>Auxis</i> sp.	129
<i>Thunnus albacares</i>	129
<i>Acanthocybium solandri</i>	132
<i>Scomber australicus</i>	132
<i>Katsuwonus pelamis</i>	132
<i>Euthynnus yaito</i> = <i>E. affinis</i>	132
<i>Euthynnus affinis</i>	132
<i>Thunnus obesus</i>	132
GOBIIDAE	132
<i>Psilogobius mainlandi</i>	132
TRIPTERYGIIDAE.	135
<i>Tripterygion atriceps</i>	135
NOMEIDAE.	135
<i>Cubiceps pauciradiatus</i>	135
BLENNIIDAE	135
<i>Enchelyurus brunneolus</i>	135
<i>Exallias brevis</i>	135
SCHINDLERIIDAE.	139
<i>Schindleriidae pietchmanni</i>	139
SCORPAENIDAE	139
CALLIONYMIDAE	139
TETRAODONTIDAE	139
MOLIDAE.	139
<i>Ranzania laevis</i>	139
MELANOCETIDAE.	142
<i>Melanocetus johnsoni</i>	142
PATTERNS OF DISTRIBUTION.	144
Abundance of larvae	144
Species composition.	148

Part III. Bibliography and Systematic Index 153

INTRODUCTION	155
------------------------	-----

BIBLIOGRAPHY	156
SYSTEMATIC INDEX TO LITERATURE	169

Part IV. Appendix—Larval Fish Collection175

LIST OF FIGURES

viii

Figure 1.	Composite of larval and juvenile morphological characteristics	5
Figure 2.	<i>Etrumeus teres</i> yolk sac larva, day 2, 5.7 mm SL	6
Figure 3.	<i>Etrumeus teres</i> , day 4, 6.6 mm SL	7
Figure 4.	<i>Etrumeus teres</i> , day 4, 6.6 mm SL, dorsal view of head	7
Figure 5.	<i>Etrumeus teres</i> , day 4, 6.6 mm SL, ventral view	8
Figure 6.	<i>Etrumeus teres</i> , day 9, 6.2 mm SL	8
Figure 7.	<i>Etrumeus teres</i> , 12.6 mm SL	9
Figure 8.	<i>Etrumeus teres</i> , 12.6 mm SL, ventral view	9
Figure 9.	<i>Etrumeus teres</i> , 19.0 mm SL, view of head	10
Figure 10.	<i>Etrumeus teres</i> , 19.0 mm SL, ventral view	10
Figure 11.	<i>Etrumeus teres</i> : predorsal myomeres vs. larval length	11
Figure 12.	<i>Spratelloides delicatulus</i> , 6.3 mm SL	12
Figure 13.	<i>Spratelloides delicatulus</i> , 9.4 mm SL, pectoral fin diagrammatic	13
Figure 14.	<i>Spratelloides delicatulus</i> , 9.4 mm SL, ventral view	13
Figure 15.	<i>Spratelloides delicatulus</i> , 9.4 mm SL, dorsal view of head	14
Figure 16.	<i>Spratelloides delicatulus</i> , 15.9 mm SL	15
Figure 17.	<i>Spratelloides delicatulus</i> , 15.9 mm SL, ventral view	15
Figure 18.	<i>Spratelloides delicatulus</i> , 15.9 mm SL, dorsal view of head	16
Figure 19.	<i>Stolephorus purpureus</i> yolk sac larva, day 1, 3.3 mm SL	17
Figure 20.	<i>Stolephorus purpureus</i> , 7.6 mm SL	18
Figure 21.	<i>Stolephorus purpureus</i> , 7.6 mm SL, ventral view	18
Figure 22.	<i>Stolephorus purpureus</i> , 8.9 mm SL	19
Figure 23.	<i>Stolephorus purpureus</i> and <i>S. buccaneeri</i> : preanal myomeres vs. larval length	20
Figure 24.	<i>Stolephorus purpureus</i> and <i>S. buccaneeri</i> : predorsal myomeres vs. larval length	20
Figure 25.	<i>Stolephorus purpureus</i> , 15.7 mm SL	21
Figure 26.	<i>Stolephorus purpureus</i> , 15.7 mm SL, ventral view	21
Figure 27.	<i>Stolephorus buccaneeri</i> , 15.8 mm SL	22
Figure 28.	<i>Stolephorus purpureus</i> and <i>S. buccaneeri</i> : eye diameter vs. standard length	23
Figure 29.	<i>Chanos chanos</i> , yolk sac larva, 4.8 mm SL	24
Figure 30.	<i>Chanos chanos</i> , 10.2 mm SL	24
Figure 31.	<i>Chanos chanos</i> , 10.2 mm SL, ventral view	25
Figure 32.	<i>Chanos chanos</i> , 10.2 mm SL, dorsal view	25
Figure 33.	<i>Cyclothone</i> sp., 4.8 mm SL	26
Figure 34.	<i>Vinciguerria nimbaria</i> , 9.1 mm SL	27
Figure 35.	<i>Trachinocephalus myops</i> , 9.6 mm SL	28

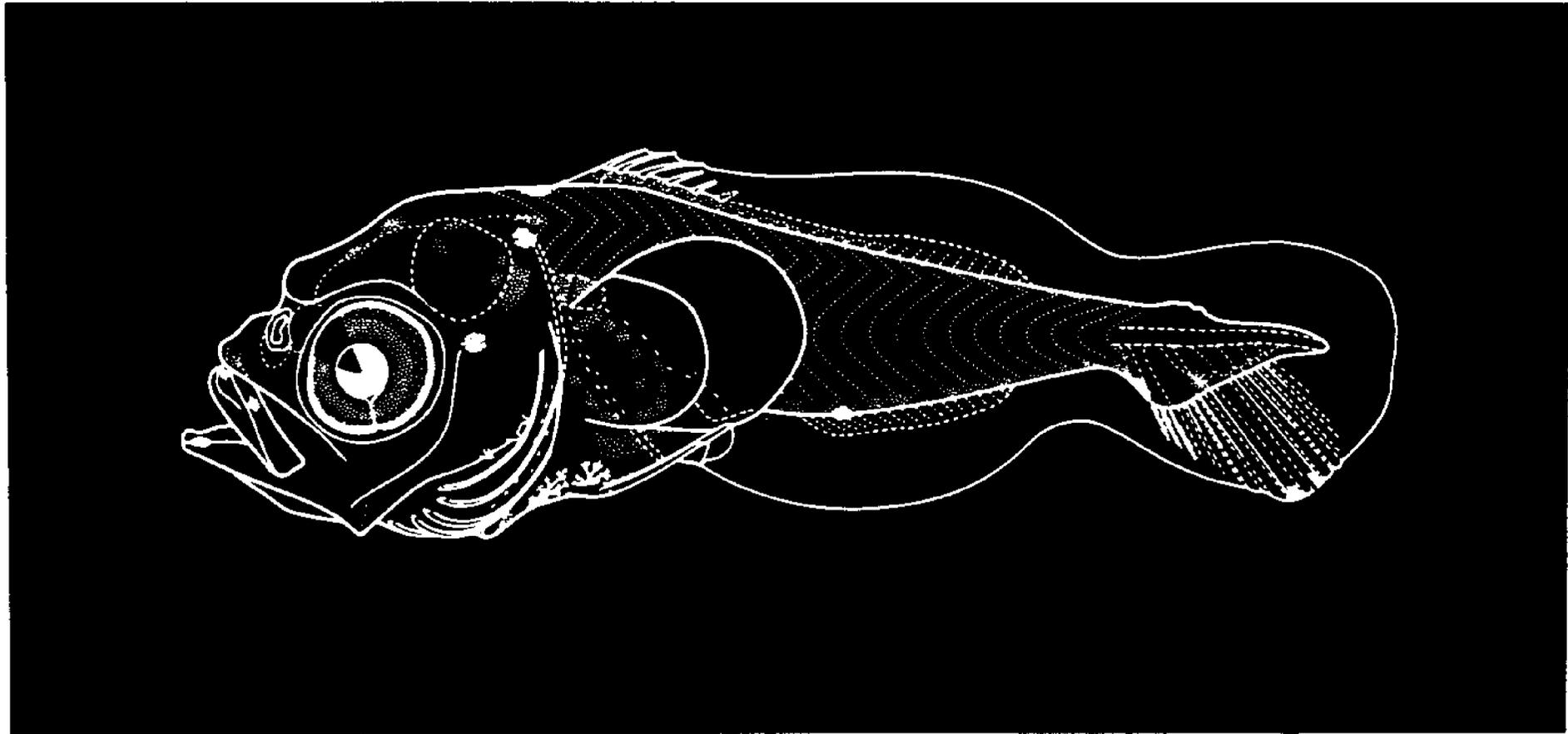
Figure 36.	<i>Chlorophthalmus proridens</i> , 6.4 mm SL	30
Figure 37.	<i>Ceratoscopelus warmingi</i> , 5.2 mm SL	31
Figure 38.	<i>Diaphus</i> sp., 5.0 mm SL	32
Figure 39.	<i>Diaphus</i> sp., 4.6 mm SL, ventral view	33
Figure 40.	<i>Hygophum proximum</i> , 4.5 mm SL	34
Figure 41.	<i>Lampadena luminosa</i> , 4.8 mm SL	34
Figure 42.	<i>Lampadena luminosa</i> , 4.8 mm SL, dorsal view	35
Figure 43.	<i>Lampanyctus nobilis</i> , 3.6 mm SL	36
Figure 44.	<i>Cypselurus</i> sp. 1, 3.6 mm SL	38
Figure 45.	<i>Cypselurus</i> sp. 2, 3.4 mm SL	39
Figure 46.	<i>Pranesus insularum</i> , 5.4 mm SL	41
Figure 47.	<i>Pranesus insularum</i> , 5.4 mm SL, dorsal view of head	42
Figure 48.	<i>Iso hawaiiensis</i> , 6.2 mm SL	43
Figure 49.	<i>Iso hawaiiensis</i> , 6.9 mm SL, dorsal view of head	44
Figure 50.	<i>Kyphosus vaigiensis</i> , 3.0 mm SL	45
Figure 51.	Mullid sp., 5.1 mm SL	47
Figure 52.	Mullid sp., 5.1 mm SL, dorsal view of head	48
Figure 53.	Mullid sp., 8.2 mm SL	49
Figure 54.	Mullid sp., 8.2 mm SL, dorsal view of head	50
Figure 55.	Serranid Sr-5, 2.7 mm SL	51
Figure 56.	<i>Foa brachygramma</i> , day 4, 2.4 mm SL	53
Figure 57.	<i>Foa brachygramma</i> , day 4, 2.4 mm SL, ventral view	53
Figure 58.	<i>Foa brachygramma</i> , day 12, 4.2 mm SL	54
Figure 59.	<i>Caranx</i> (=Atule) <i>mate</i> , day 6, 3.1 mm SL	55
Figure 60.	<i>Caranx</i> (=Atule) <i>mate</i> , day 12, 4.0 mm SL	56
Figure 61.	<i>Caranx</i> (=Atule) <i>mate</i> , day 18, 7.7 mm SL	57
Figure 62.	<i>Gnathanodon speciosus</i> , day 10, 4.0 mm SL	57
Figure 63.	<i>Gnathanodon speciosus</i> , day 38, 14.4 mm SL	58
Figure 64.	<i>Seriola</i> sp., 5.8 mm SL	59
Figure 65.	<i>Trachurops</i> (=Selar) <i>crumenophthalmus</i> , 3.8 mm SL	61
Figure 66.	<i>Trachurops</i> (=Selar) <i>crumenophthalmus</i> , 8.1 mm SL	62
Figure 67.	<i>Coryphaena hippurus</i> , day 7, 4.2 mm SL	64
Figure 68.	<i>Coryphaena hippurus</i> , 7.9 mm SL	64
Figure 69.	<i>Abudefduf abdominalis</i> , day 1, 2.5 mm SL	66
Figure 70.	<i>Abudefduf abdominalis</i> , day 1, 2.5 mm SL, dorsal view	66
Figure 71.	<i>Abudefduf abdominalis</i> , day 13, 4.0 mm SL	67
Figure 72.	<i>Eupomacentrus fasciolatus</i> , day 3, 1.9 mm SL	68
Figure 73.	<i>Eupomacentrus fasciolatus</i> , day 3, 1.9 mm SL, dorsal view	68
Figure 74.	Labrid L-3, 7.2 mm SL	70
Figure 75.	<i>Scombrolabrax heterolepis</i> , 4.2 mm SL	71
Figure 76.	<i>Gempylus serpens</i> , 5.3 mm SL	73
Figure 77.	<i>Nealotus tripes</i> , 4.2 mm SL	74
Figure 78.	<i>Auxis</i> sp., 3.6 mm SL	76
Figure 79.	<i>Thunnus albacares</i> , 5.7 mm SL	77
Figure 80.	<i>Cubiceps pauciradiatus</i> , 4.6 mm SL	79
Figure 81.	<i>Cubiceps pauciradiatus</i> , 5.5 mm SL	80
Figure 82.	<i>Psilogobius mainlandi</i> , 4.1 mm SL	82
Figure 83.	<i>Psilogobius mainlandi</i> , 4.1 mm SL, ventral view	82
Figure 84.	<i>Psilogobius mainlandi</i> , 5.8 mm SL	83
Figure 85.	<i>Tripterygion atriceps</i> , 3.2 mm SL	85
Figure 86.	<i>Tripterygion atriceps</i> , 5.8 mm SL	86

Figure 87.	<i>Tripterygion atriceps</i> , 8.5 mm SL, ventral view	86
Figure 88.	<i>Enchelyurus brunneolus</i> , 3.2 mm SL	88
Figure 89.	<i>Enchelyurus brunneolus</i> , 6.1 mm SL	89
Figure 90.	<i>Istiblennius zebra</i> , day 4, 3.3 mm SL	89
Figure 91.	<i>Istiblennius zebra</i> , 11.0 mm SL	90
Figure 92.	<i>Istiblennius zebra</i> , 11.0 mm SL, view of jaw	91
Figure 93.	<i>Schindleria pietschmanni</i> , 3.5 mm SL	92
Figure 94.	<i>Schindleria pietschmanni</i> , 4.7 mm SL	93
Figure 95.	Scorpaenid S-3, 3.6 mm SL	95
Figure 96.	<i>Callionymus decoratus</i> , 2.5 mm SL	96
Figure 97.	<i>Callionymus decoratus</i> , 2.9 mm SL	97
Figure 98.	Tetraodontid 1, 2.1 mm SL	99
Figure 99.	Tetraodontid 1, 3.6 mm SL	100
Figure 100.	<i>Ranzania laevis</i> , 3.1 mm SL	101
Figure 101.	<i>Melanocetus johnsoni</i> , 2.3 mm SL	103
Figure 102.	Sampling locations 1971-72.	108
Figure 103.	Winter distribution of <i>Cyclothone</i> sp. larvae	112
Figure 104.	Summer distribution of <i>Cyclothone</i> sp. larvae	112
Figure 105.	Winter distribution of <i>Vinciguerria nimbaria</i> larvae	114
Figure 106.	Summer distribution of <i>Vinciguerria nimbaria</i> larvae	114
Figure 107.	Winter distribution of <i>Ceratoscopelus warmingi</i> larvae	115
Figure 108.	Summer distribution of <i>Ceratoscopelus warmingi</i> larvae	115
Figure 109.	Winter distribution of <i>Diaphus</i> spp. larvae	116
Figure 110.	Summer distribution of <i>Diaphus</i> spp. larvae	116
Figure 111.	Winter distribution of <i>Hygophum proximum</i> larvae	118
Figure 112.	Summer distribution of <i>Hygophum proximum</i> larvae	118
Figure 113.	Winter distribution of <i>Lampadena</i> sp. larvae	119
Figure 114.	Summer distribution of <i>Lampadena</i> sp. larvae	119
Figure 115.	Summer distribution of <i>Cypselurus</i> sp. 1 larvae	120
Figure 116.	Summer distribution of <i>Cypselurus</i> sp. 2 larvae	120
Figure 117.	Winter distribution of <i>Kyphosus</i> sp. larvae	122
Figure 118.	Summer distribution of <i>Kyphosus</i> sp. larvae	122
Figure 119.	Winter distribution of Mullidae larvae	123
Figure 120.	Summer distribution of Mullidae larvae	123
Figure 121.	Summer distribution of <i>Foa branchygramma</i> larvae	124
Figure 122.	Winter distribution of <i>Seriola</i> sp. larvae	125
Figure 123.	Summer distribution of <i>Seriola</i> sp. larvae	125
Figure 124.	Summer distribution of <i>Coryphaena hippurus</i> larvae	126
Figure 125.	Winter distribution of <i>Abudefduf abdominalis</i> larvae	127
Figure 126.	Summer distribution of <i>Abudefduf abdominalis</i> larvae	127
Figure 127.	Winter distribution of <i>Eupomacentrus fasciolatus</i> larvae	128
Figure 128.	Summer distribution of <i>Eupomacentrus fasciolatus</i> larvae	128
Figure 129.	Winter distribution of Gempylidae larvae	130
Figure 130.	Summer distribution of Gempylidae larvae	130
Figure 131.	Summer distribution of <i>Auxis</i> sp. larvae	131
Figure 132.	Summer distribution of <i>Thunnus albacares</i> larvae	131
Figure 133.	Winter distribution of Gobiidae larvae	133
Figure 134.	Summer distribution of Gobiidae larvae	133
Figure 135.	Winter distribution of <i>Psilogobius mainlandi</i> larvae	134
Figure 136.	Summer distribution of <i>Psilogobius mainlandi</i> larvae	134
Figure 137.	Winter distribution of <i>Tripterygion atriceps</i> larvae	136
Figure 138.	Summer distribution of <i>Tripterygion atriceps</i> larvae	136
Figure 139.	Winter distribution of <i>Enchelyurus brunneolus</i> larvae	137
Figure 140.	Summer distribution of <i>Enchelyurus brunneolus</i> larvae	137
Figure 141.	Winter distribution of <i>Exallias brevis</i> larvae	138
Figure 142.	Summer distribution of <i>Exallias brevis</i> larvae	138
Figure 143.	Winter distribution of Schindleriidae larvae	140
Figure 144.	Summer distribution of Schindleriidae larvae	140
Figure 145.	Winter distribution of Tetraodontidae larvae	141
Figure 146.	Summer distribution of Tetraodontidae larvae	141
Figure 147.	Winter distribution of <i>Ranzania laevis</i> larvae	142
Figure 148.	Winter distribution of <i>Melanocetus johnsoni</i> larvae	143
Figure 149.	Summer distribution of <i>Melanocetus johnsoni</i> larvae	143
Figure 150.	Winter distribution of total fish larvae	145
Figure 151.	Summer distribution of total fish larvae	145
Figure 152.	Winter distribution of number of species	146
Figure 153.	Summer distribution of number of species	146
Figure 154.	Winter distribution of species diversity H'	147
Figure 155.	Summer distribution of species diversity H'	147
Figure 156.	Sum of ranks of density, species, and diversity of fish larvae in winter	150
Figure 157.	Sum of ranks of density, species, and diversity of fish larvae in summer	150

LIST OF TABLES

Table 1.	Identification Methods for Fish Larvae	3
Table 2.	Meristics of Selected Clupeoid, Gonorhynchoid, and Stomioid Fishes	17
Table 3.	Diagnostic Characteristics of Selected Synodontid Larvae and Prejuveniles	29
Table 4.	Fin Ray Counts of Hawaiian Carangid Species.	63
Table 5.	Fin Ray Counts of Hawaiian Pomacentrid Species	69
Table 6.	Fin Ray Counts of Hawaiian Labrid Genera	70
Table 7.	Meristics of Selected Gempylid, Scombrabracid, and Trichiurid Fishes	75
Table 8.	Selected Meristics of Hawaiian Blennioid Species.	91
Table 9.	<i>Schindleria</i> Meristics	93
Table 10.	Fin Ray Counts of Hawaiian Scorpaenid Genera	94
Table 11.	Fin Ray Counts of Hawaiian Tetraodontid Genera.	98
Table 12.	Sampling Locations, Dates, and Depths, 1971-74.	109
Table 13.	Data From Other Sampling Studies.	110

Part I. Larval Fish Descriptions



INTRODUCTION

The larval stages of tropical marine fishes are, in general, inadequately described. For example, prior to 1971 fewer than 50 larvae of the 530 fish species in Hawaiian waters could be identified. During the following 3 years this number was substantially increased through the efforts of the personnel of this project, so that about 95 percent or more of the larvae obtained in any nearshore plankton tow can now be identified to at least the familial level. In total about 250 kinds are identifiable to some taxonomic level at present (the larval identification methods used are given in Table 1), while another 100 can be recognized but remain unidentified. Numbers were assigned to each of the unidentified larval forms, leading to the possible separation of the different stages of a single species, or to the grouping of more than one similar species under a single number. In practice, when subsequently captured stages have produced revision of the

system, in most cases it has been to synonymize forms. Thus, in Part II, data on number of species, diversity, etc., should be regarded as maximum numbers.

The sparse literature on larvae of fish which frequent Hawaiian waters is widely scattered and not always readily available. For these reasons, illustrations and descriptions of some of the more common larvae typically encountered in nearshore surface plankton tows, even though they have been previously described, are included. Papers dealing with these, and most other families inhabiting Hawaiian waters, are listed in Part III.

Although brief descriptions and literature citations for the eggs of many species are given on the following pages, no effort has been made to provide either complete descriptions or an exhaustive literature search. Hawaiian fish eggs are discussed in greater detail in Watson and Leis (1974).

Complete adult meristics for each species are given whenever possible. Abbreviated tables of meristics, derived from counts made during this study and taken from the literature, are given in some sections. Vertebral counts include all centra plus the urostyle. Fin elements are given in Roman (=spines) and Arabic (=rays) numerals and the types of fins are given as follows: D = dorsal fin; A = anal fin; P = pectoral fin; V = pelvic (ventral) fin; and C = caudal fin. A divided fin is signified by a plus, "+"; separate spines and rays within an undivided fin is signified by a comma, ",". A dash, "-", indicates a range. For example, D: III-V + I, 8-10 means three to five first dorsal spines plus one spine and eight to ten rays in the second, separate, dorsal fin.

The meristic counts are invaluable for the identification of metamorphic stage specimens and are often of use with older larvae, when fin anlagen are present. The approximately 1:1 correspondence between myomere and vertebral numbers makes this particular characteristic a useful identification tool at all larval stages.

Larval descriptions are based primarily on the sizes commonly encountered in daytime surface plankton tows although the clupeoids are considered in somewhat greater detail. Species descriptions are of stages of common larvae encountered in the nearshore waters of Hawaii. All descriptions are based on at least five specimens of each species; for many, they are based on 20 or more specimens. For most species all descriptions are of "average" larvae; a given specimen may differ from the average in numbers of melanophores—rarely in pigment pattern—and in the sizes at which various characteristics are acquired. All lateral views are illustrated as if the larvae were straight, with intact, erect fins. Dorsal and ventral views are unmodified. In certain instances laboratory-reared specimens are described and illustrated; in all cases these were indistinguishable from field

TABLE 1. IDENTIFICATION METHODS FOR FISH LARVAE

Species	Method of Identification	Species	Method of Identification
<i>Etrumeus teres</i>	S, RP, L	<i>Gnathanodon speciosus</i>	RP
<i>Spratelloides delicatulus</i>	S	<i>Seriola</i> sp.	S
<i>Stolephorus purpureus</i>	S, RP, L	<i>Trachurops crumenophthalmus</i>	S
<i>Stolephorus buccaneeri</i>	S	<i>Coryphaena hippurus</i>	RS
<i>Chanos chanos</i>	S, L	<i>Abudefduf abdominalis</i>	RD
<i>Cyclothone</i> sp.	S, L	<i>Pomacentrus jenkensi</i>	RD
<i>Vinciguerria nimbaria</i>	S, L	Labrid L-3	S
<i>Trachinocephalus myops</i>	S, L	<i>Scombrolabrax heterolepis</i>	S
<i>Chlorophthalmus proridens</i>	S	<i>Gempylus serpens</i>	S, L
<i>Ceratoscopelus warmingi</i>	S	<i>Nealotus tripes</i>	S, L
<i>Diaphus</i> sp.	L	<i>Auxis</i> sp.	L
<i>Hygophym proximum</i>	L	<i>Thunnus albacares</i>	L
<i>Lampadena</i> sp.	B.Y. Sumida*	<i>Cubiceps pauciradiatus</i>	S
<i>Lampanyctus nobilis</i>	L, E.H. Ahlstrom*	<i>Psilogobius mainlandi</i>	S, RL
<i>Cypselurus</i> sp. 1	S	<i>Tripterygion atriceps</i>	S
<i>Cypselurus</i> sp. 2	S	<i>Enchelyurus brunneolus</i>	S, RL
<i>Pranestes insularum</i>	S, RA	<i>Istiblennius zebra</i>	S, RD
<i>Iso hawaiiensis</i>	S	<i>Schindleria pietschmanni</i>	S
<i>Kyphosus vaigiensis</i>	RP	Scorpaenid S-3	S
Mullid sp.	S	<i>Callionymus decoratus</i>	S, RP
Serranid Sr-5	S, L	Tetraodontid 1	S
<i>Foa brachygrammus</i>	S, RD	<i>Ranzania laevis</i>	S, RP, L
<i>Caranx mate</i>	RP	<i>Melanocetus johnsoni</i>	S, L

Note: L = literature; RA = reared from attached, unattended eggs; RD = reared from demersal eggs guarded or brooded by an identifiable adult; RL = reared to identifiable size from planktonic larvae; RP = reared to identifiable size from planktonic eggs; RS = reared from eggs spawned in captivity; S = size series of preserved specimens.

*Personal communication.

specimens of similar size. Larval ages, i.e., day 1 (=first 24 hours after hatching), day 2 (=second 24 hours), etc., are of larvae reared at ambient temperature (ca. 24 to 26 degrees C).

All specimens were preserved in 5 percent neutral formalin for at least 6 months prior to use. This is sufficient time for all shrinkage to have taken place, so that given sizes are stable but smaller (as much as ca. 20 percent) than life size (Miller and Sumida, 1974). Since all pigments other than melanin were lost during preservation, the descriptions of pigmentation refer to melanophores only (except where noted, when comments on color were added from observations of live specimens).

Descriptions include, in part, myomere counts (ignoring the triangular segment between the otic capsule and the first myoseptum), myomere formulae (preanal + postanal myomeres), pigment patterns, body shape, spination, gut length and configuration, gas bladder position, and, where applicable, meristics. These characteristics—especially myomere counts, shape, and pigmentation—are most useful in the identification of fish larvae.

4 The descriptive terminology follows that of Mansueti and Hardy (1967), except that their "auditory vesicle" is called an "otic capsule" and "anlage" is used only with reference to fin primordia. The term "prejuvenile" is restricted as defined by Hubbs (1958); "metamorphic stage" is used instead of the "prejuvenile stage" as defined by Mansueti and Hardy. Several additional morphological terms are used in this text; see Figure 1.

The phylogenetic arrangement of larvae in this atlas follows the work of Gosline (1971). Nomenclature is based primarily on Gosline and Brock (1960), with some changes as noted.

The following larval fish descriptions, and accompanying illustrations are included to represent the more common types encountered in nearshore surface plankton tows in Hawaii.

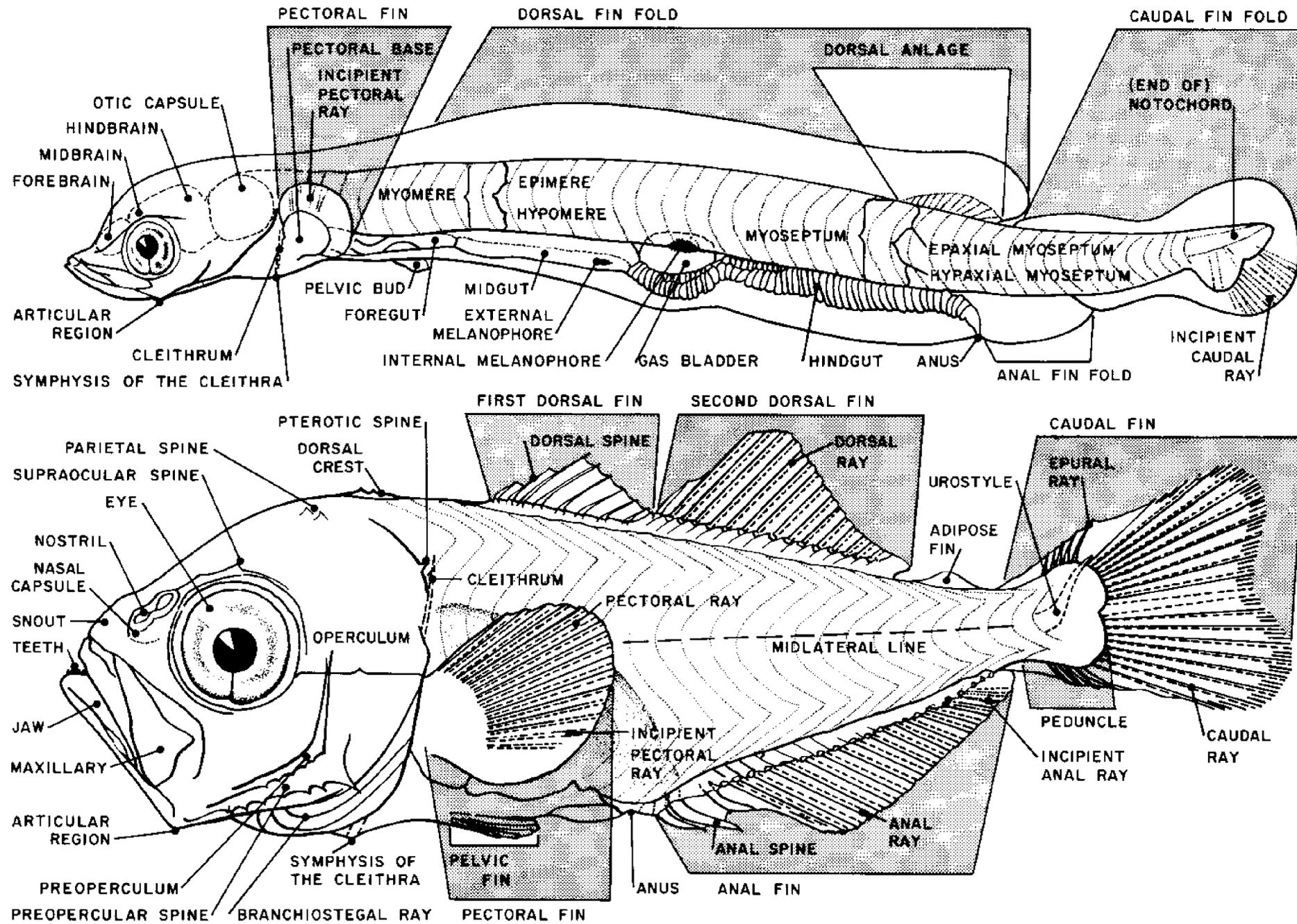


Figure 1. Composite of larval and juvenile morphological characteristics

DUSSUMIERIIDAE

Etrumeus teres (makiawa)

Adult meristics

D: 20–21; A: 10–11; P: 16; V: 8–9; C: 19; vertebrae: 54–56

Eggs

The transparent planktonic eggs are spherical, 1.45 to 1.53 mm in diameter, with a weakly segmented yolk and no oil droplet. In Watson and Leis (1974), the *E. teres* egg is illustrated as *E. micropus*, and diel and seasonal abundances are described.

Yolk sac larvae

Etrumeus teres are larger at hatching (ca. 6 mm SL) than most of the other Hawaiian clupeoid fishes. The yolk sac larvae are elongate, with a simple tubular gut. Melanophores are restricted to three areas: an internal group over the forebrain region; a group over the gut and ventral finfold, centered approximately two-thirds of the way posteriorly along the gut; and single melanophores on the hindgut above the anus and on the ventral midline near the terminus of the

notochord. The eyes of reared larvae remain unpigmented through day 2 (Figure 2). Day 3 larvae retain some yolk, have functional jaws, and begin developing pigmented eyes. The myomere formula during this stage is 42 + 12–13. Fin anlagen are absent.

Larvae

By day 4, the yolk is gone, the eyes and jaws are functional, the hindgut has become convoluted, and the caudal fin anlage is present (Figure 3). The forebrain pigment has condensed to form a single anterior pair of melanophores (Figure 4). A pair of melanophores occurs alongside the anterior foregut, others are paired along each side of the posterior midgut, and the group over the hindgut is still present. A single melanophore lies at the symphysis of the cleithra (Figure 5). One or two melanophores occur on the caudal fin anlage.

As development proceeds the jaws become elongate, the teeth lengthen, and the eyes become noticeably ovoid (Figure 6). The gas bladder is indistinct in larvae smaller than ca. 8 mm SL. At 8 mm SL the dorsal and anal fin anlagen become apparent, the notochord begins to flex, and nineteen caudal fin rays may be discerned. Concurrent pigment changes include the extension of the midgut melanophores cephalad, the movement of the hindgut pigment out of the finfold, and the development of a single row of melanophores along the ventral midline of the gut.

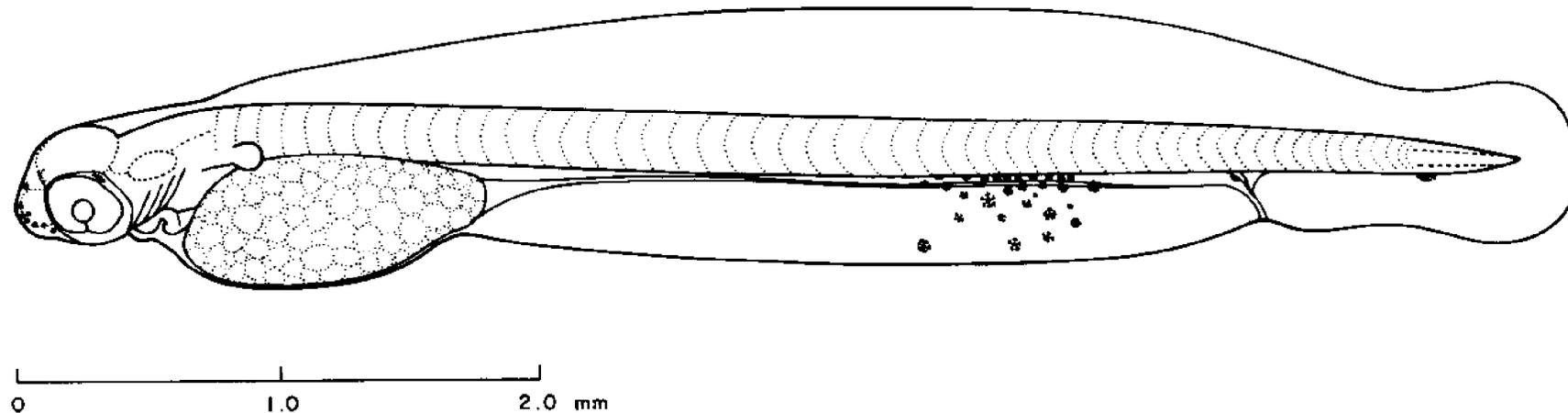


Figure 2. *Etrumeus teres* yolk sac larva, day 2, 5.7 mm SL

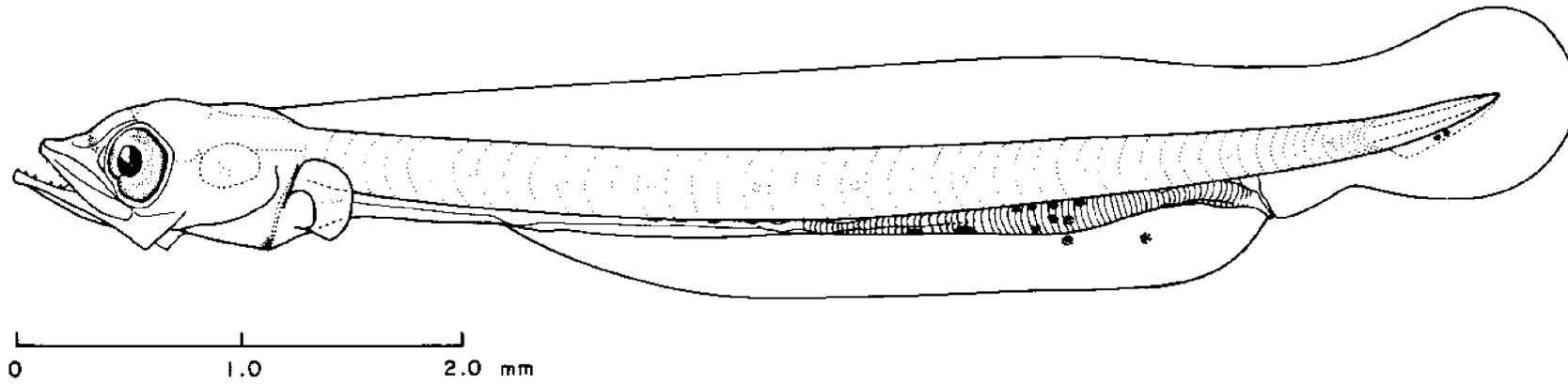


Figure 3. *Etrumeus teres*, day 4, 6.6 mm SL

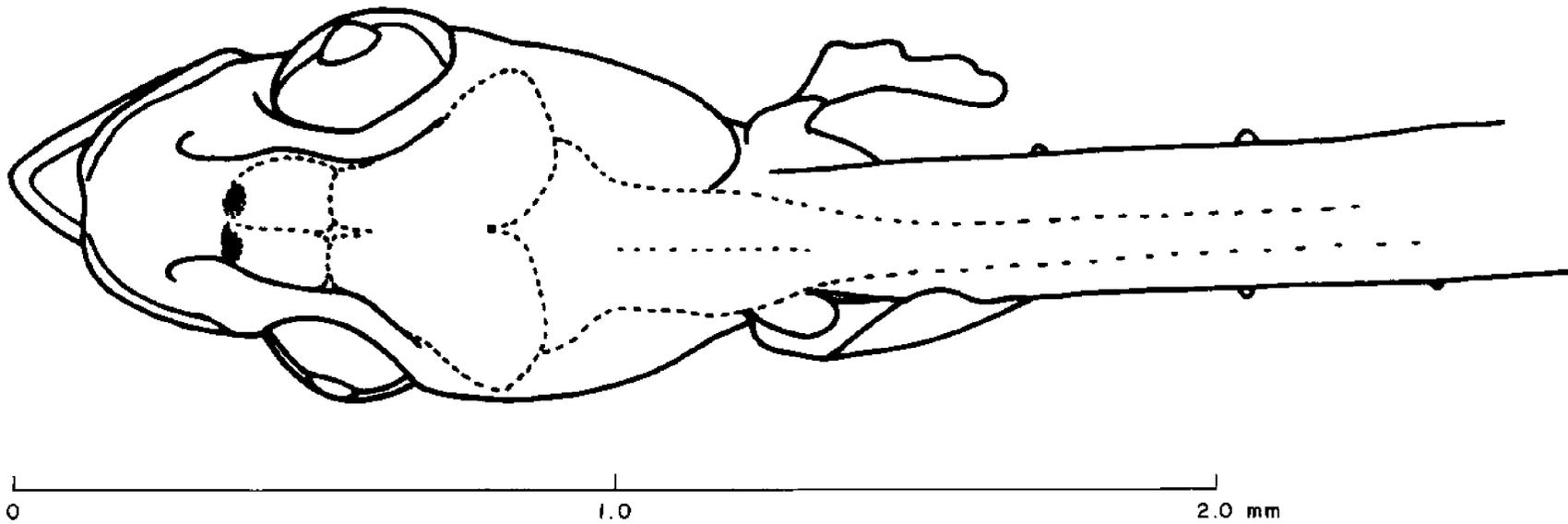


Figure 4. *Etrumeus teres*, day 4, 6.6 mm SL, dorsal view of head

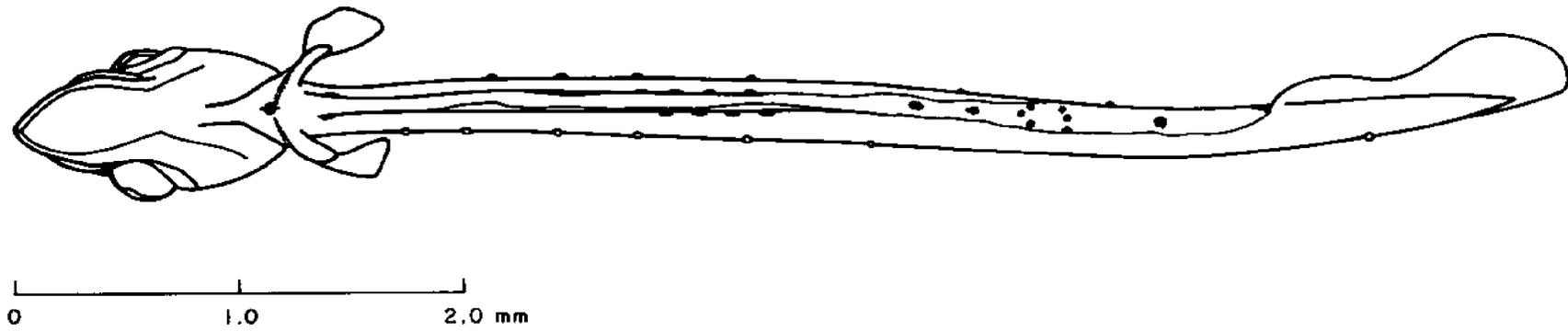


Figure 5. *Etrumeus teres*, day 4, 6.6 mm SL, ventral view

8

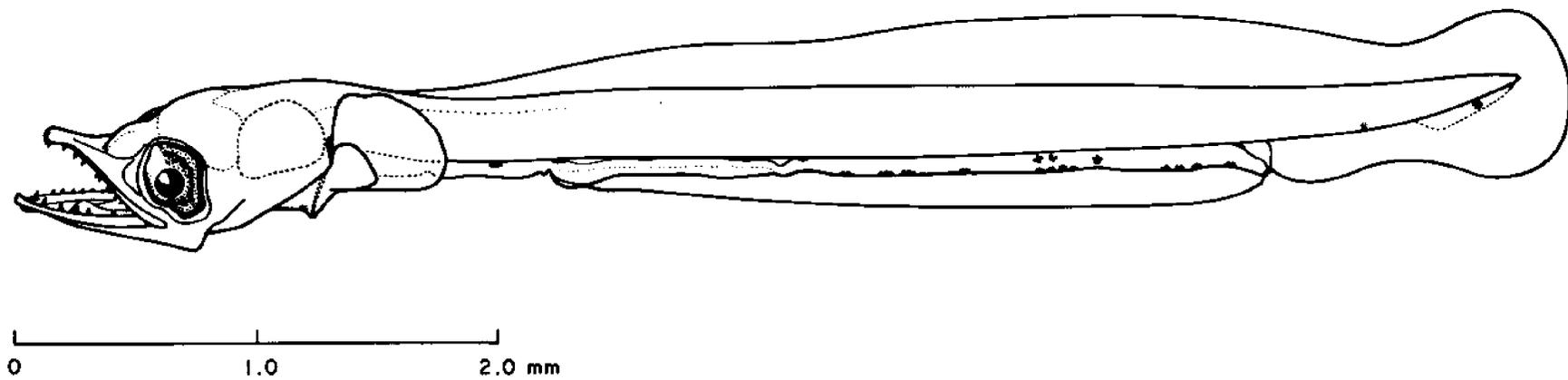


Figure 6. *Etrumeus teres*, day 9, 6.2 mm SL. (Specimen shrank prior to preservation.)

The notochord is fully flexed, the dorsal and anal fins are partly ossified, the eye is round, and the myomere formula remains $42 + 12-13$ by ca. 12 mm SL (Figure 7). In addition, the paired ventrolateral melanophores extend nearly the length of the midgut, and a single row extends along the midventral side of the gut from the level of the gas bladder to the anus (Figure 8). A row of three or four melanophores lies along the isthmus, and another—usually of three or four

melanophores—extends caudad along the midventral line beginning immediately behind the anal fin (Figure 8). A diagonal row of melanophores extends along the lower caudal fin rays (Figure 7).

Between ca. 12 mm SL and metamorphosis, the number of melanophores along the ventral side and cleithrum increases (Figures 9 and 10).

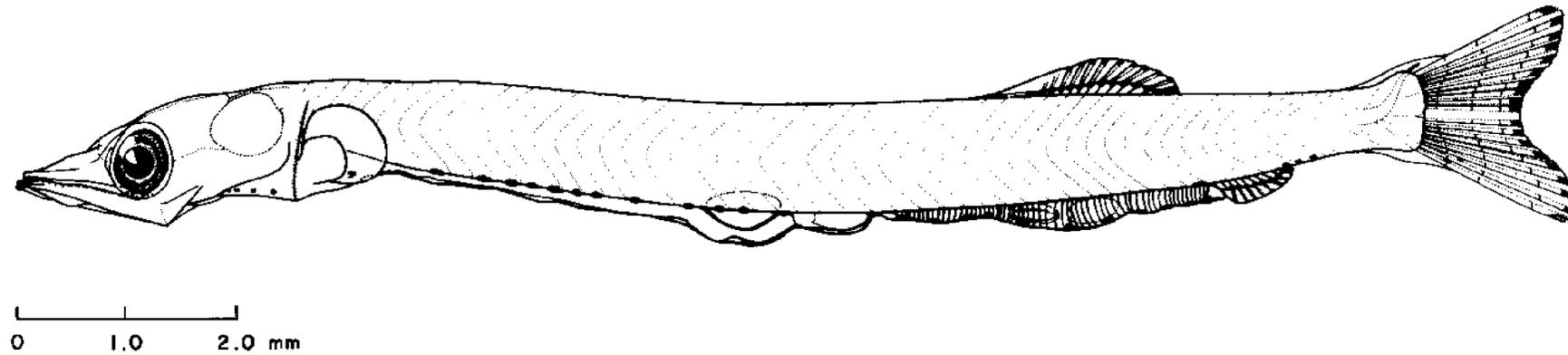


Figure 7. *Etrumeus teres*, 12.6 mm SL

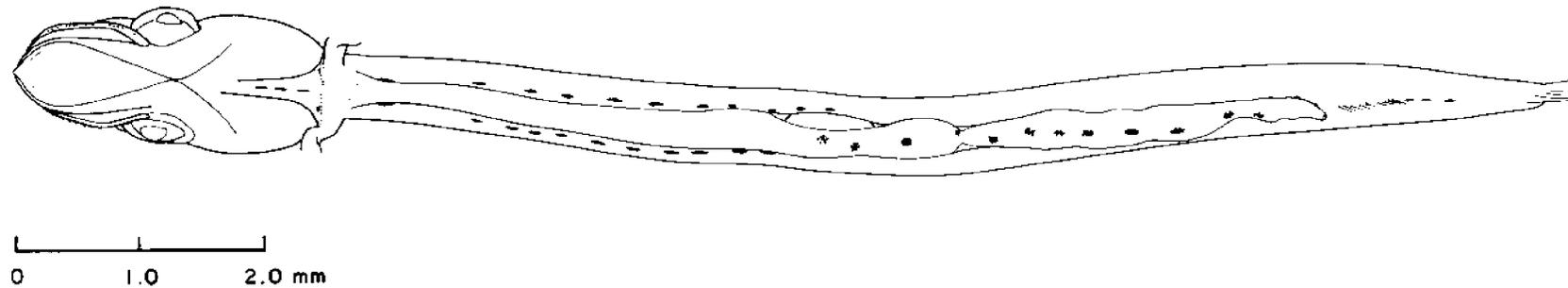


Figure 8. *Etrumeus teres*, 12.6 mm SL, ventral view

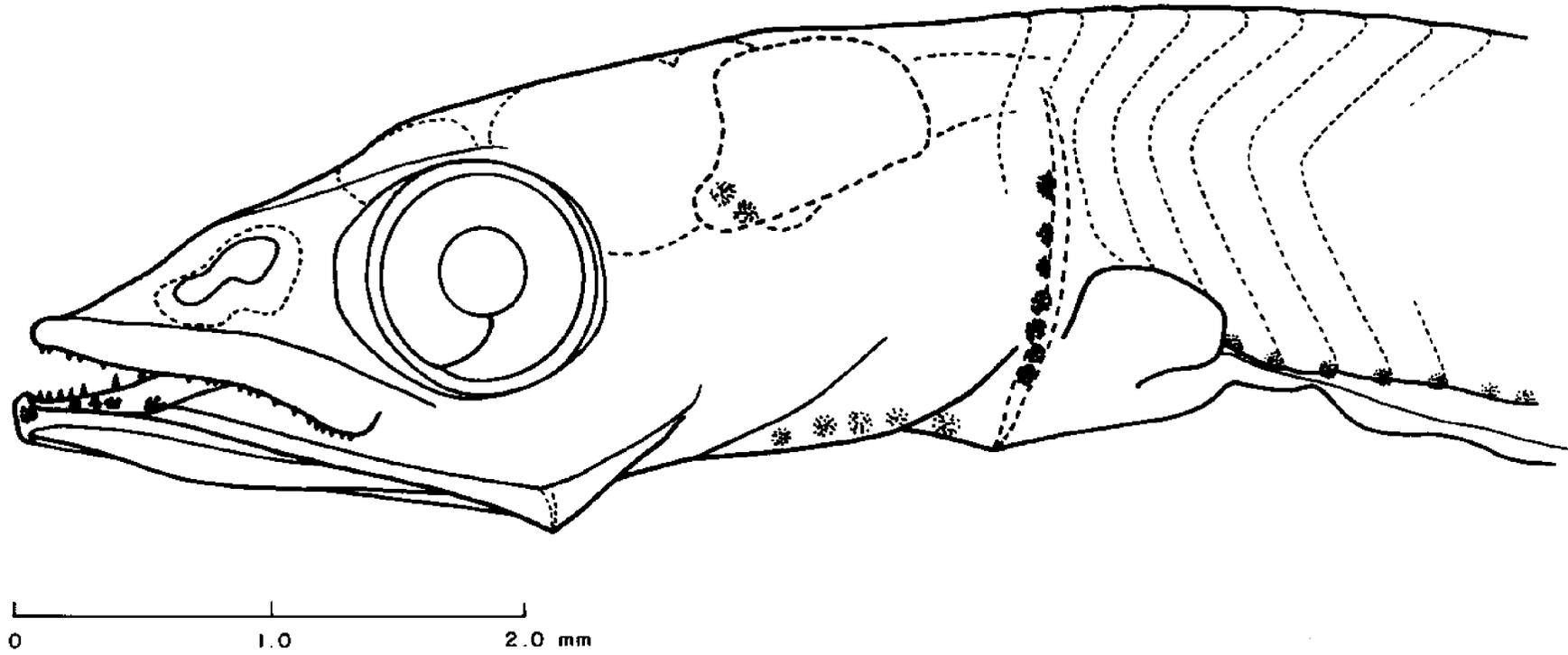


Figure 9. *Etrumeus teres*, 19.0 mm SL, view of head

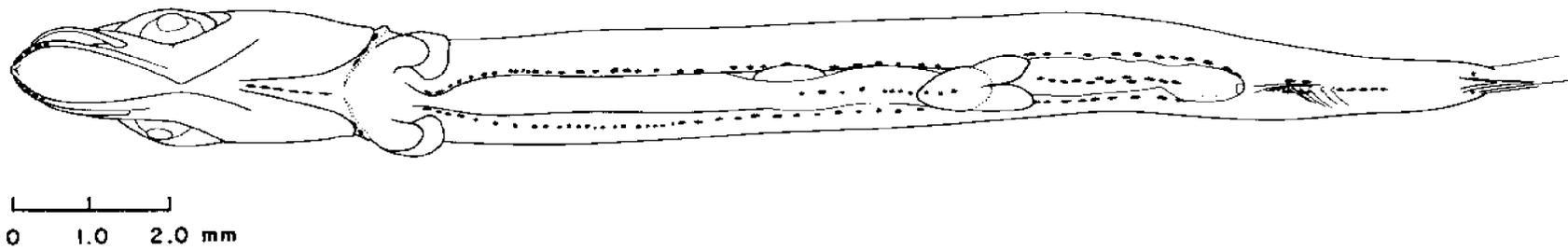


Figure 10. *Etrumeus teres*, 19.0 mm SL, ventral view

Pelvic fins are ossified in ca. 19 mm SL larvae (Figure 10); only the pectoral fins remain unossified. The dorsal fin migrates cephalad as development proceeds: at ca. 35 mm SL (Figure 11).

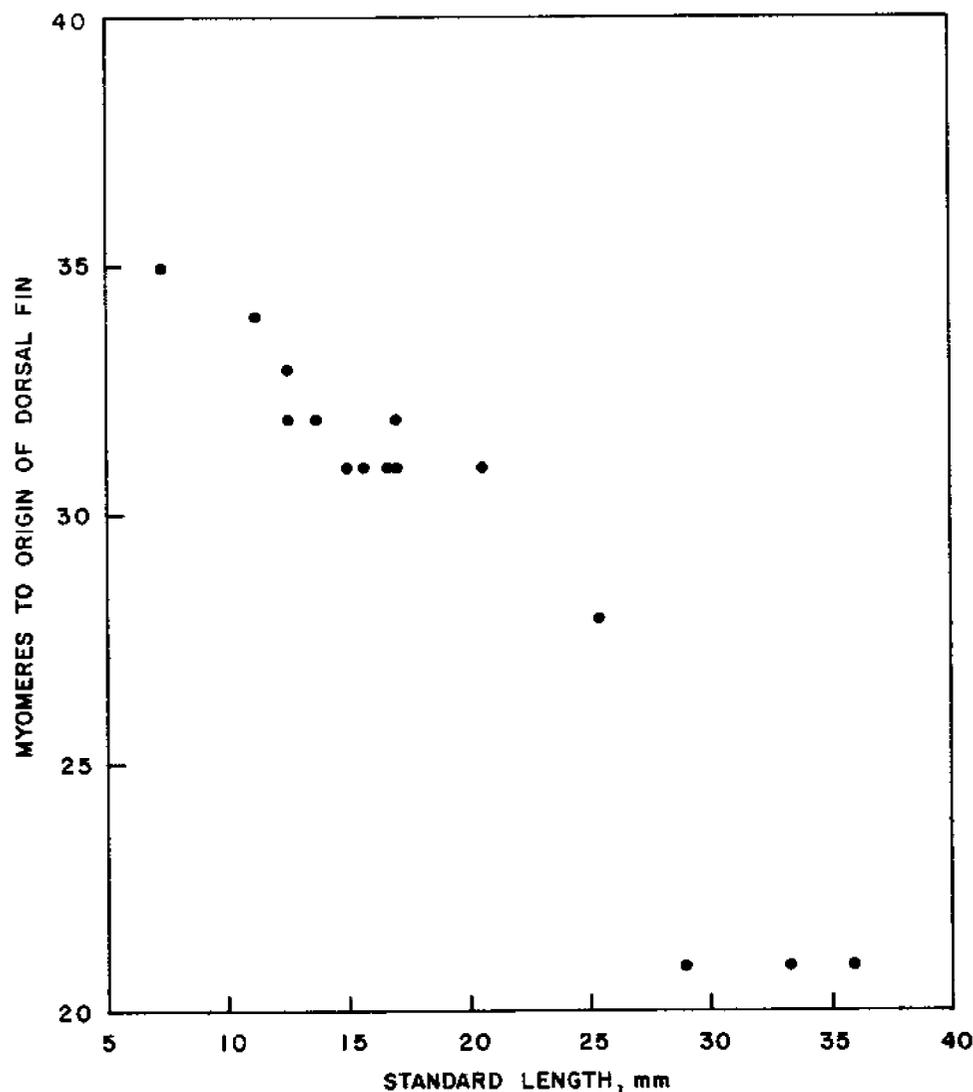


Figure 11. *Etrumeus teres*: predorsal myomeres vs. larval length

Spratelloides delicatulus (piha)

Adult meristics

D: 10–12; A: 9–10; P: 11–13; V: 8; C: 19; vertebrae: 44–45

Eggs

S. delicatulus eggs have not been described in the literature. Uchida et al. (1958) characterized *Spratelloides japonicus* eggs as being adhesive and demersal.

Larvae

Specimens of ca. 6 mm SL lack yolk, but have oval pigmented eyes, functional jaws, a typical convoluted hindgut, a conspicuous gas bladder, and dorsal, anal, and caudal fin anlagen. Also, the notochord is straight and incipient fin rays are not apparent (Figure 12). A single melanophore lies near the upper end on each side of the cleithrum, pairs of melanophores are present alongside the fore- and midgut, single rows lie along the dorsal and ventral midlines of the hindgut, and one or two pairs occur on the dorsolateral surface of the gas bladder. Three melanophores lie on the ventral midline between the anal and caudal fin anlagen, with one or two others on the dorsal midline (Figure 12).

Changes through final caudal flexure (ca. 9 mm SL) are few; the eyes become rounded and the dorsal fin anlage lengthens. Eighteen caudal fin rays may be discerned, but incipient dorsal and anal fin rays are not apparent (Figure 13). The melanophores in the gut region become more numerous, an internal pair appears on the anterior foregut just ahead of the cleithra, and an external pair develops at the base of the anal fin anlage. Internal melanophores are present around the urostyle and at the lower edge of the peduncle. Others lie on the caudal fin membrane near the base of most of the rays (Figures 13 and 14). An internal melanophore develops on the posterior center of each midbrain hemisphere, and an external pair overlies the hindbrain (Figure 15).

The dorsal fin migrates cephalad from an origin at myomere 28 (ca. 9 mm SL) to myomere 16 (ca. 15 mm SL). The gut shortens slightly (the myomere formula is 34 + 11 at ca. 9 mm SL and 32 + 13 at ca. 15 mm SL), and pelvic fins develop. By ca. 15 mm SL all fins are completely developed except the pectoral fin, which has only the uppermost three to five rays ossified (Figure 16).

The row of melanophores along the midventral side of the hindgut disappears by ca. 15 mm SL, while the ventrolateral melanophore pairs extend caudad to lie along the entire gut (Figure 17). The middorsal hindgut series,

12

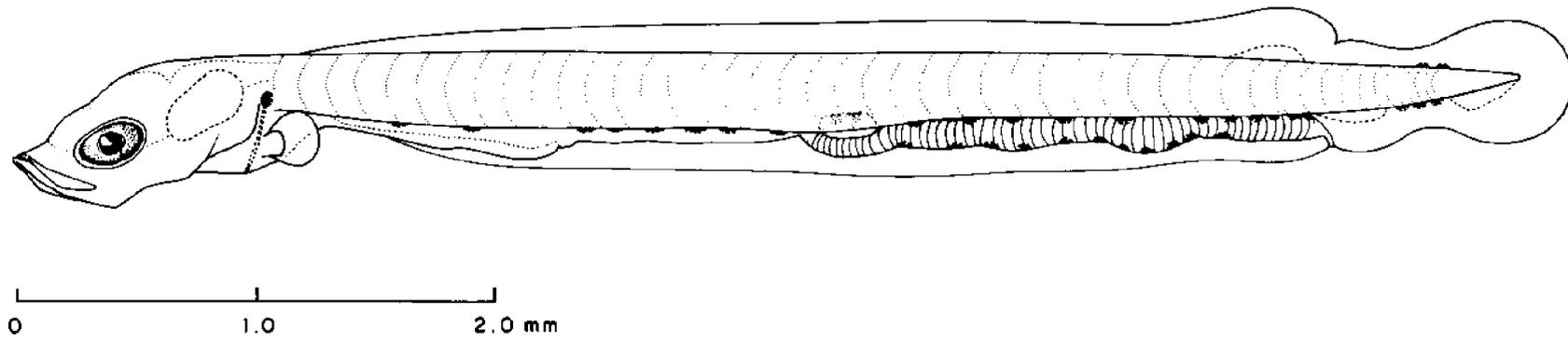


Figure 12. *Spratelloides delicatulus*, 6.3 mm SL. (Semidiagrammatic reconstruction of damaged specimen.)

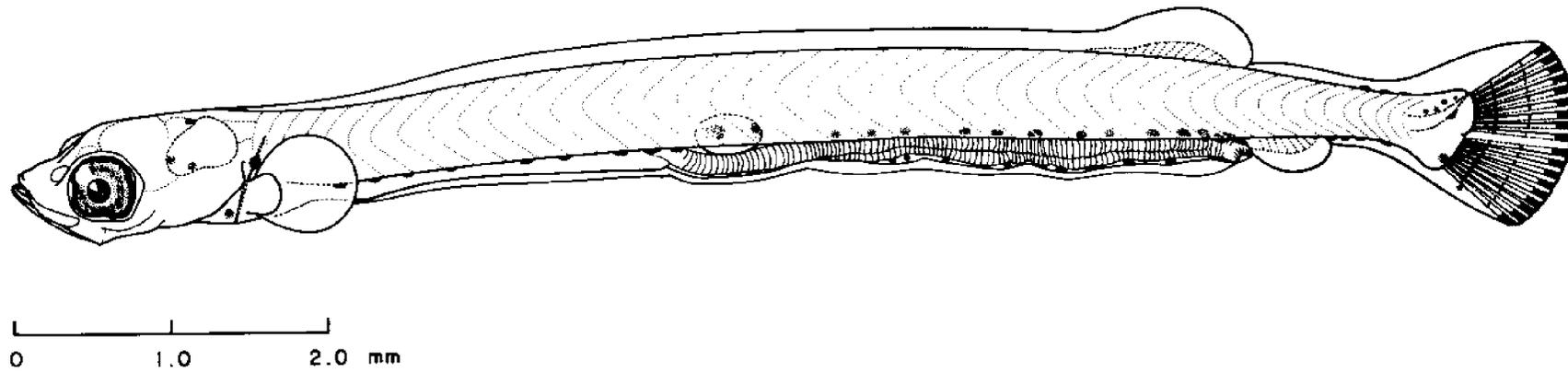


Figure 13. *Spratelloides delicatulus*, 9.4 mm SL, pectoral fin diagrammatic

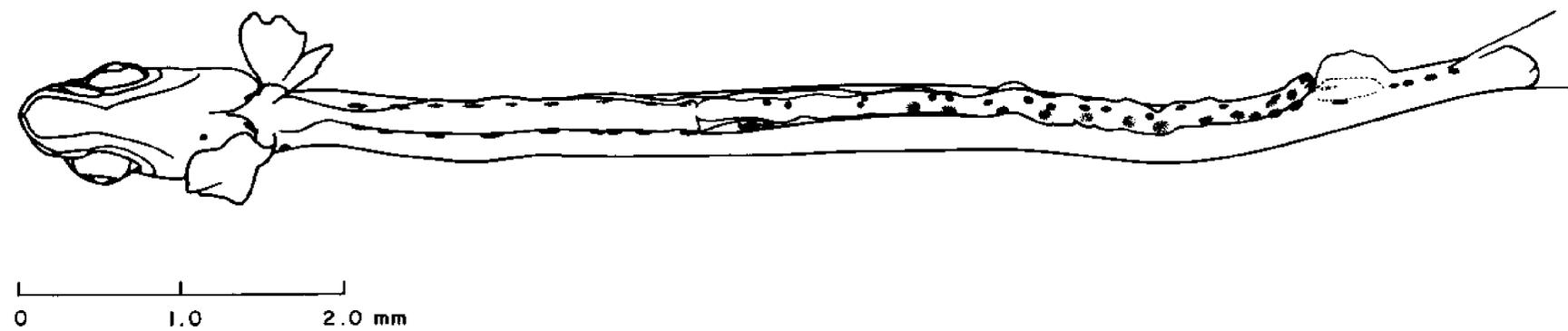


Figure 14. *Spratelloides delicatulus*, 9.4 mm SL, ventral view

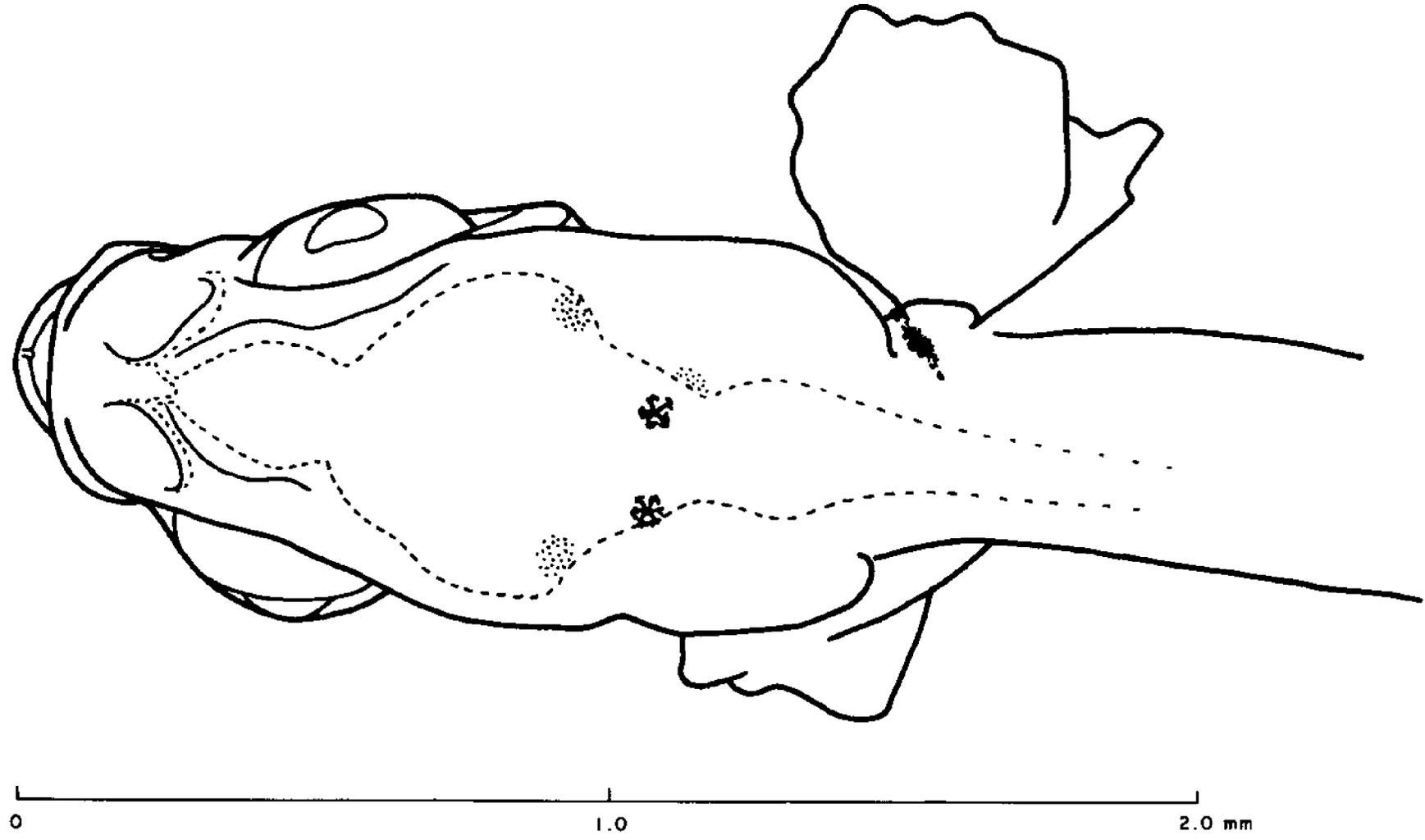


Figure 15. *Spratelloides delicatulus*, 9.4 mm SL, dorsal view of head

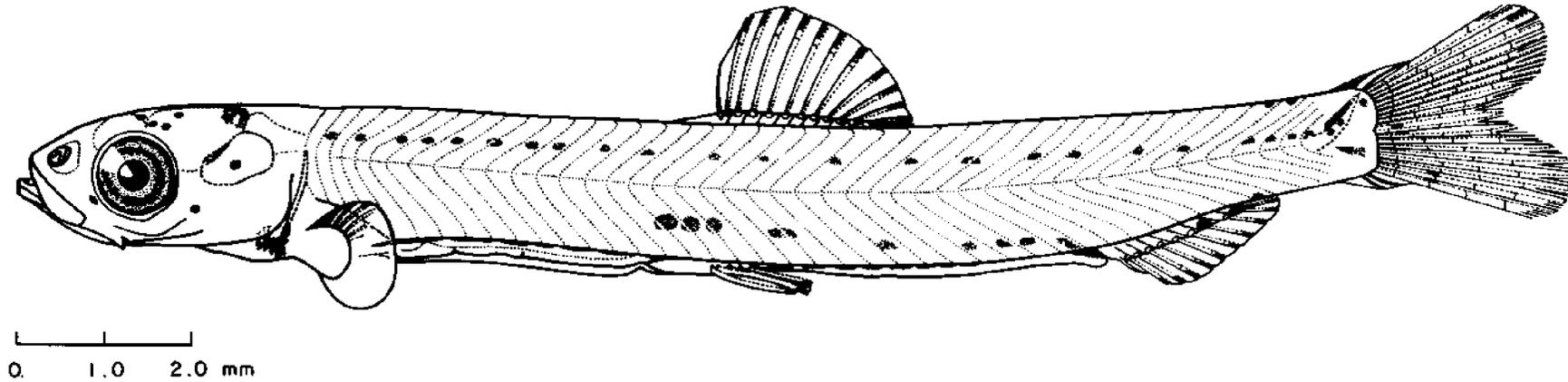


Figure 16. *Spratelloides delicatulus*, 15.9 mm SL

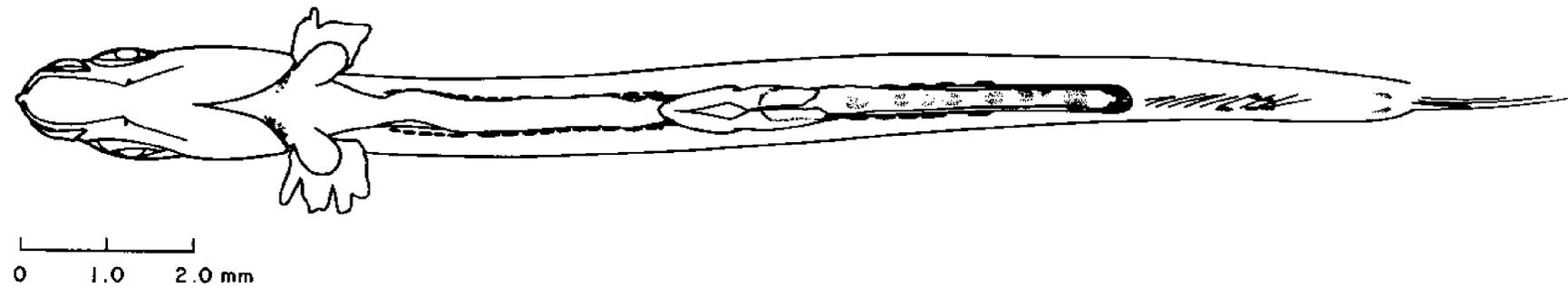


Figure 17. *Spratelloides delicatulus*, 15.9 mm SL, ventral view

extending from the gas bladder to above the anus, remains. Two or three pairs of melanophores lie on the dorsolateral surface of the gas bladder and a pair lies at the base of each of the last three or four anal fin rays. In addition, the internal peduncle pigment, together with the external melanophores on the caudal fin, forms a characteristic triangular or pentagonal pattern (Figure 16) which remains until metamorphosis.

The posterior middorsal and midventral melanophores are usually present throughout the larval stages. Internal melanophores overlie the notochord from

ca. 13 mm SL. The head becomes more heavily pigmented as development proceeds, but the external pair of melanophores above the hindbrain remains visible throughout the larval period (Figure 18). By ca. 15 mm SL the lower parts of the cleithra are heavily pigmented.

Melanophores may develop midlaterally on the postanal myomeres (one per myomere) in larvae larger than ca. 15 mm SL, but these are quite variable in number.

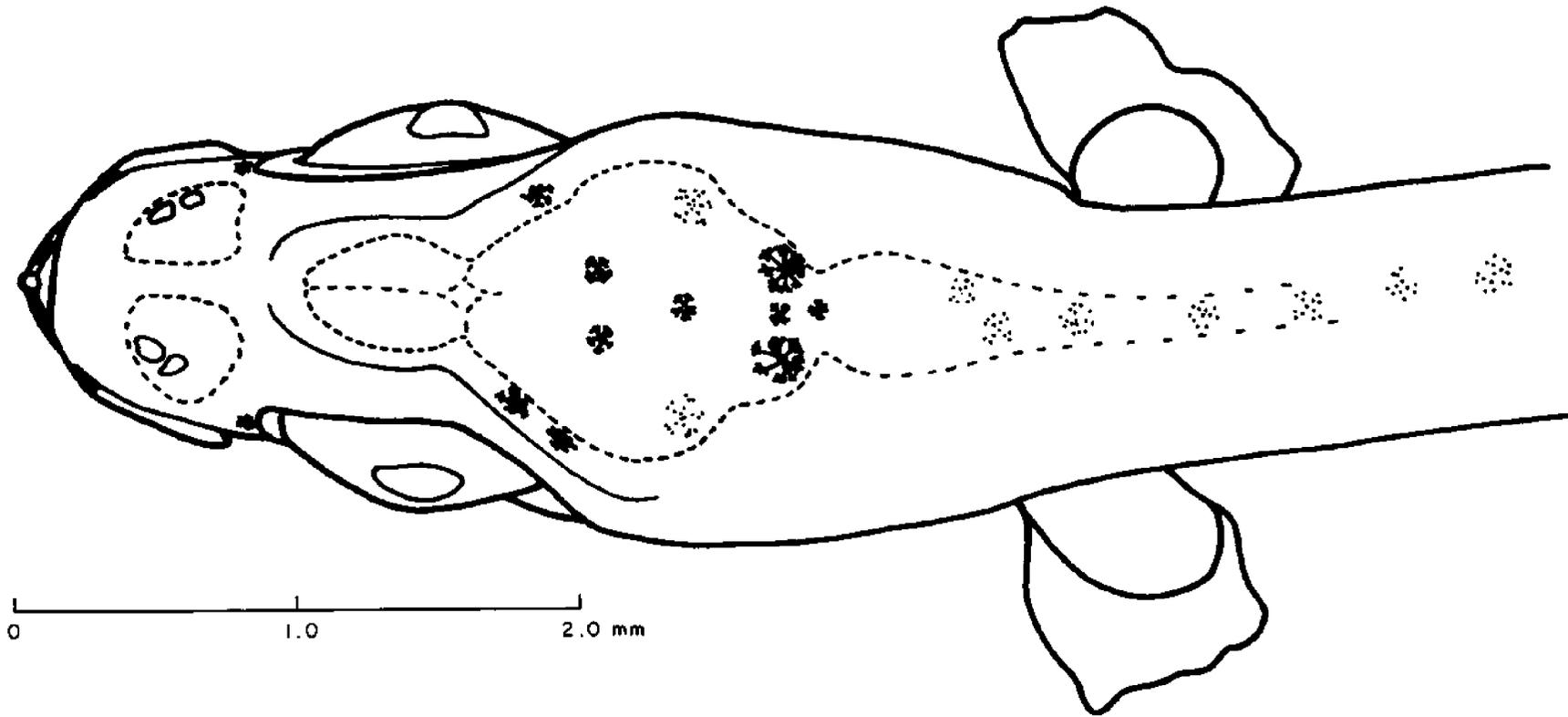


Figure 18. *Spratelloides delicatulus*, 15.9 mm SL, dorsal view of head

Identification

Dussumieriid larvae are recognized by shape and pigment pattern. *S. delicatulus*, which may be confused with *Chanos chanos* in the ca. 10 to 15 mm SL size range, may be distinguished from the latter by the different ventral and caudal pigment patterns. Also, the longitudinal muscle fibers of *C. chanos* are readily distinguishable from the "cross-hatched" muscle fibers typical of *S. delicatulus*. Larger individuals can be differentiated by fin ray counts (Table 2).

Etrumeus teres may be confused with the gonostomatid, *Vinciguerria nimbaria*, and the engraulids, *Stolephorus purpureus* and *S. buccaneeri*. This is especially true for larvae smaller than ca. 12 to 14 mm SL. Myomere counts can be used to distinguish between the smaller larvae and fin ray counts to distinguish between larger specimens (Table 2). Additional distinguishing characteristics

include the convoluted hindgut and ventral pigment which *V. nimbaria* lacks but the others have, the narrow eye of *V. nimbaria*, and differences in the ventral pigment patterns between the *Stolephorus* species and *E. teres*.

Larvae of the Marquesan sardine, *Sardinella marquesensis*, resemble the dussumieriid larvae. These are distinguishable by myomere and fin ray counts (Table 2). *Gonorhynchus gonorhynchus* (not identifiable from project material) can be similarly identified (Table 2).

Literature

Delsman (1925), Houde and Fore (1973), Mito (1961a), Uchida et al. (1958), Watson and Leis (1974)

TABLE 2. MERISTICS OF SELECTED CLUPEOID, GONORHYNCHOID, AND STOMIATOID FISHES

Species	Reference*	Vertebrae	D	A	P	V
<i>Chanos chanos</i>	1	44-46	14-16	8-11	17	10-12
<i>Gonorhynchus gonorrhynchus</i>	1, 2	55	11-13	9-10	11	8-9
<i>Etrumeus teres</i>	1	54-56	20-21	10-11	16	8-9
<i>Spratelloides delicatulus</i>	1	44-45	10-12	9-10	11-13	8
<i>Sardinella marquesensis</i>	3	41-43	16-17	18-20	13-15	8
<i>Stolephorus buccaneeri</i>	1, 4	42-43	13-14	14-16	14-15	7
<i>Stolephorus purpureus</i>	1, 4, 5	41-44	12-14	15-17	13-15	7
<i>Cyclothone</i> spp.	6	29-33	13-15	16-19	13	7
<i>Vinciguerria nimbaria</i>	1, 7	41-42	13-15	13-15	10	7

*1 = counts made by project personnel; 2 = Furukawa (1951); 3 = Berry and Whitehead (1968); 4 = Strasburg (1960a); 5 = Tester and Hiatt (1952); 6 = Grey (1964); 7 = Ahlstrom and Counts (1958)

ENGRAULIDAE

Stolephorus purpureus (nehu)

Adult meristics

D: 12-14; A: 15-17; P: 13-15; V: 7; C: 19; vertebrae: 41-44

Eggs

The transparent planktonic eggs are ellipsoidal, 1.75 mm x 0.65 mm, with no oil droplet or segmented yolk. Egg development is illustrated in Nakamura (1970); diel and seasonal distributions are discussed in Watson and Leis (1974).

Yolk sac larvae

Newly hatched *S. purpureus* larvae are small—ca. 3 mm SL (Figure 19). They are elongate with a large yolk sac and a simple tubular gut. They lack pigment. The myomere formula is 30 + 13-14.

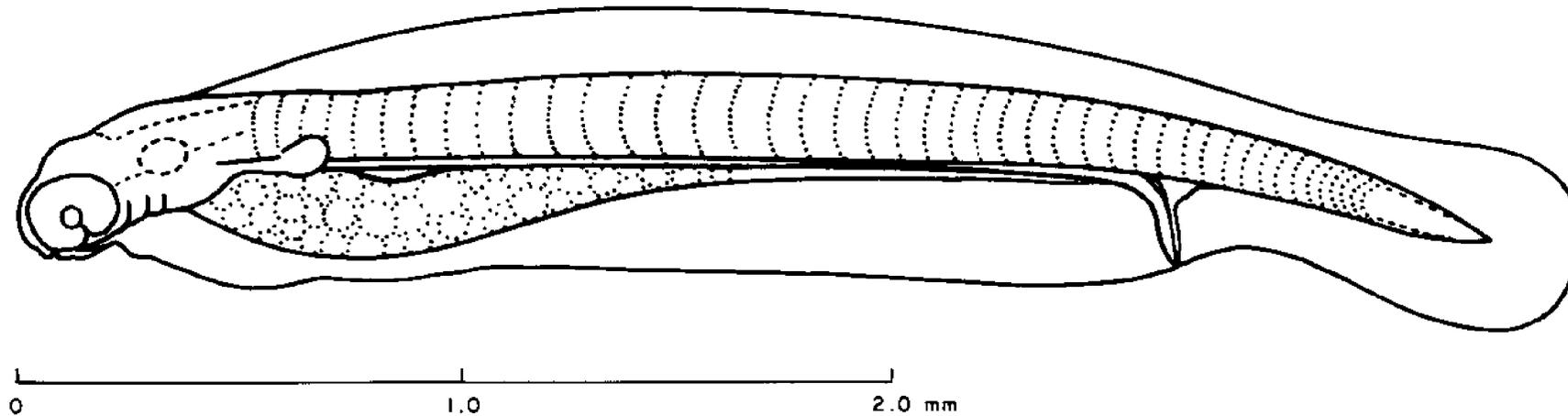


Figure 19. *Stolephorus purpureus* yolk sac larva, day 1, 3.3 mm SL

Larvae

By ca. 4 mm SL the eyes are pigmented and the jaws functional. Melanophores paired along the sides of the midgut develop concurrently with the eye pigment. The head is rounded at this stage, but by ca. 6 mm SL, the jaws are more elongate, appearing somewhat pointed.

Dorsal, anal, and caudal fin anlagen are present and the notochord is just beginning to flex by ca. 7.5 mm SL (Figures 20 and 21). Ten caudal rays may be discerned, but incipient dorsal and anal fin rays are not yet apparent. The gas bladder is conspicuous, and the typical convoluted hindgut is present (Figure 20). The myomere formula is 29 + 14–15.

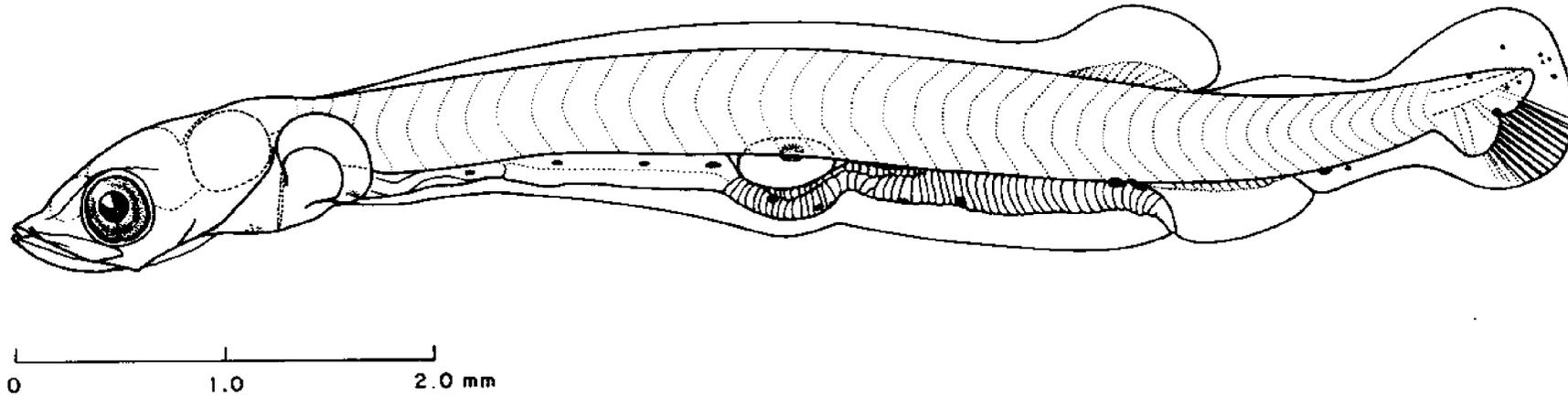


Figure 20. *Stolephorus purpureus*, 7.6 mm SL

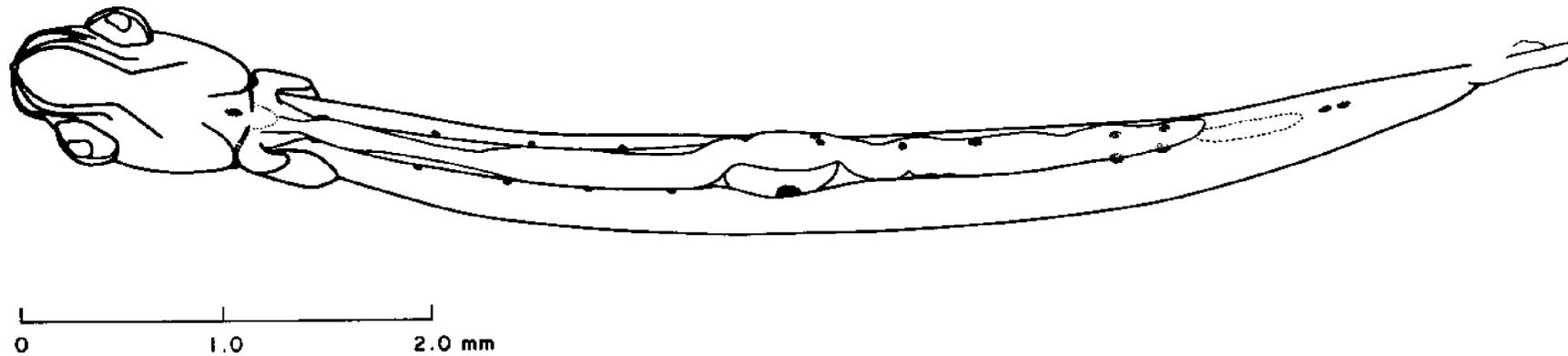


Figure 21. *Stolephorus purpureus*, 7.6 mm SL, ventral view

Pigmentation includes a single melanophore at the isthmus, paired melanophores along the midgut (which are present throughout the larval stage), a pair (sometimes absent) centered on the dorsolateral surface of the gas bladder, a few on the ventral midline of the anterior one-half to two-thirds of the hindgut, one to three pairs dorsally on the posterior hindgut, and two on the ventral midline just behind the anal fin anlage (Figures 20 and 21). Melanophores are also found along the sides of some of the caudal fin rays (one or two per ray). Others are scattered over the upper peduncle and caudal finfold. One melanophore lies at the distal end of the peduncle between the superior and inferior hypural elements (Figure 20).

Few changes occur by ca. 9 mm SL (Figure 22). At this size the notochord is flexed, the anal and principal caudal fin rays are ossified, and the dorsal fin rays are becoming ossified. A pair of melanophores is present on the cleithra just above the symphysis, the number of pairs on the gas bladder increases to four, and the midventral pigment on the hindgut disappears. A row of melanophores on the

mid-dorsal surface of the hindgut extends from just behind the gas bladder to above the anus. The number of melanophores on the ventral midline posterior to the anal fin increases to three or four. Melanophores lying along the caudal fin rays are found only on the proximal half of the fin (Figure 22).

The head remains "pointed" through ca. 12 mm SL, and the myomere formula remains 28 + 15–16.

Pelvic fin buds appear at ca. 13 mm SL. The head begins to become rounded and the dorsal, anal, and caudal fins are complete at ca. 14 mm SL. Pelvic fin rays begin to ossify at ca. 15 mm SL; pectoral fin rays do not develop until metamorphosis (ca. 20 mm SL). The gut continues to shorten as development proceeds: at ca. 15 mm SL the myomere formula is 26 + 17–18; at ca. 19 mm SL it is 23–24 + 19–20 (Figure 23). The dorsal fin likewise migrates cephalad: the dorsal fin origin lies at myomere 26 at ca. 15 mm SL and no further caudad than myomere 23 by ca. 15.5 mm SL (Figure 24).

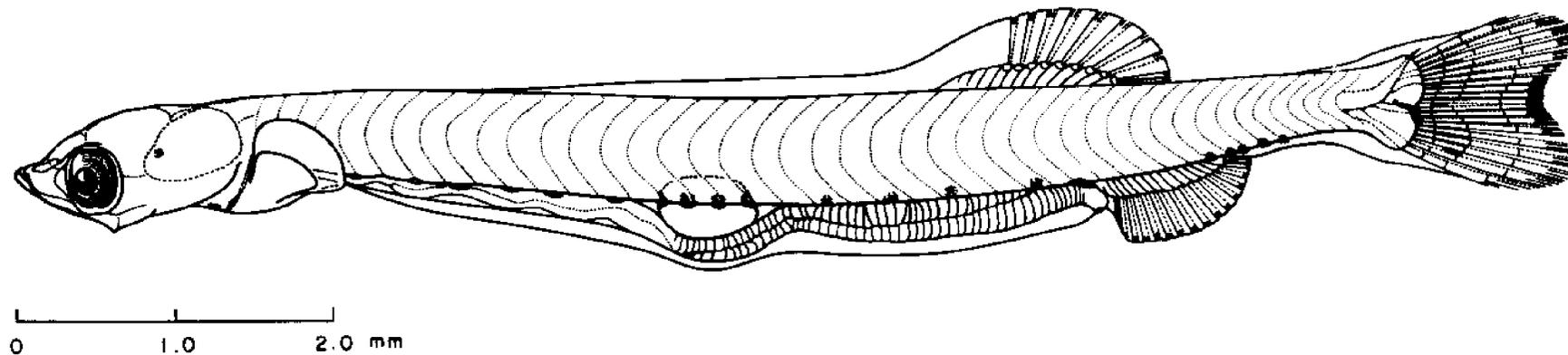


Figure 22. *Stolephorus purpureus*, 8.9 mm SL

20

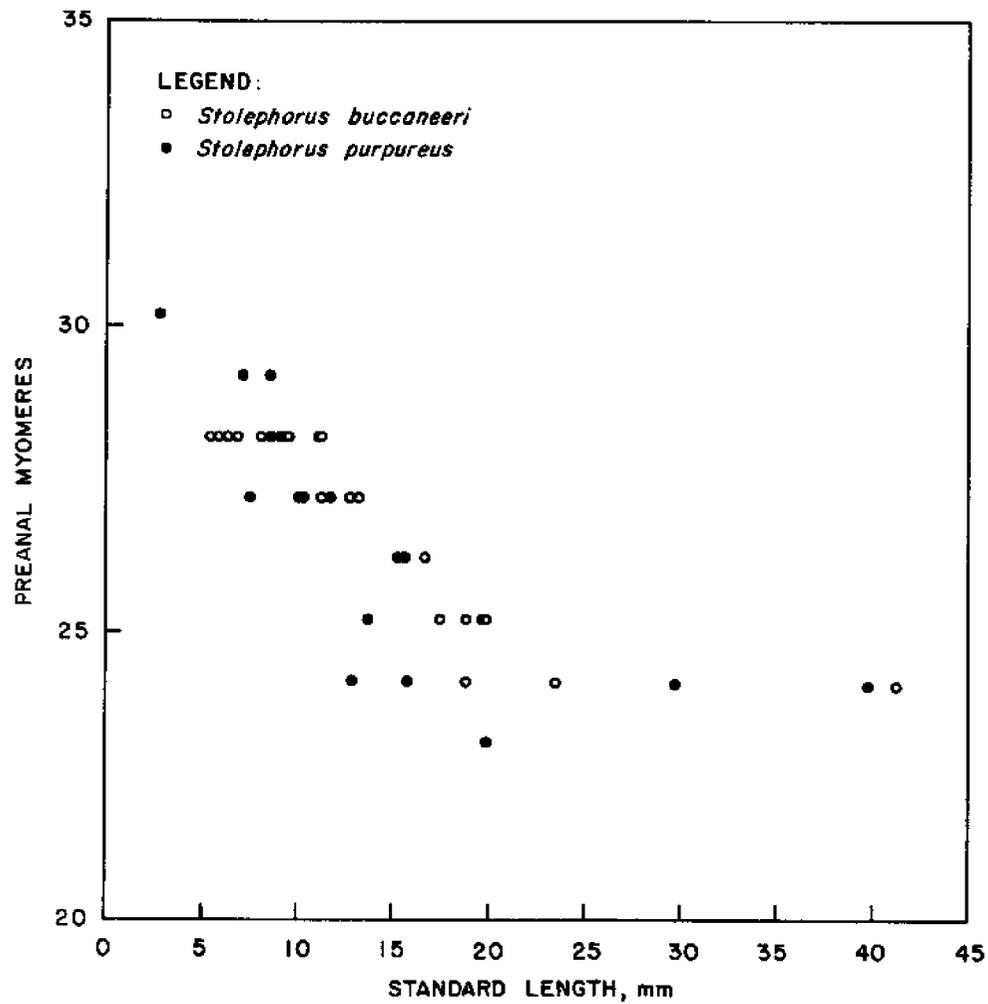


Figure 23. *Stolephorus purpureus* and *S. buccaneeri*: preanal myomeres vs. larval length

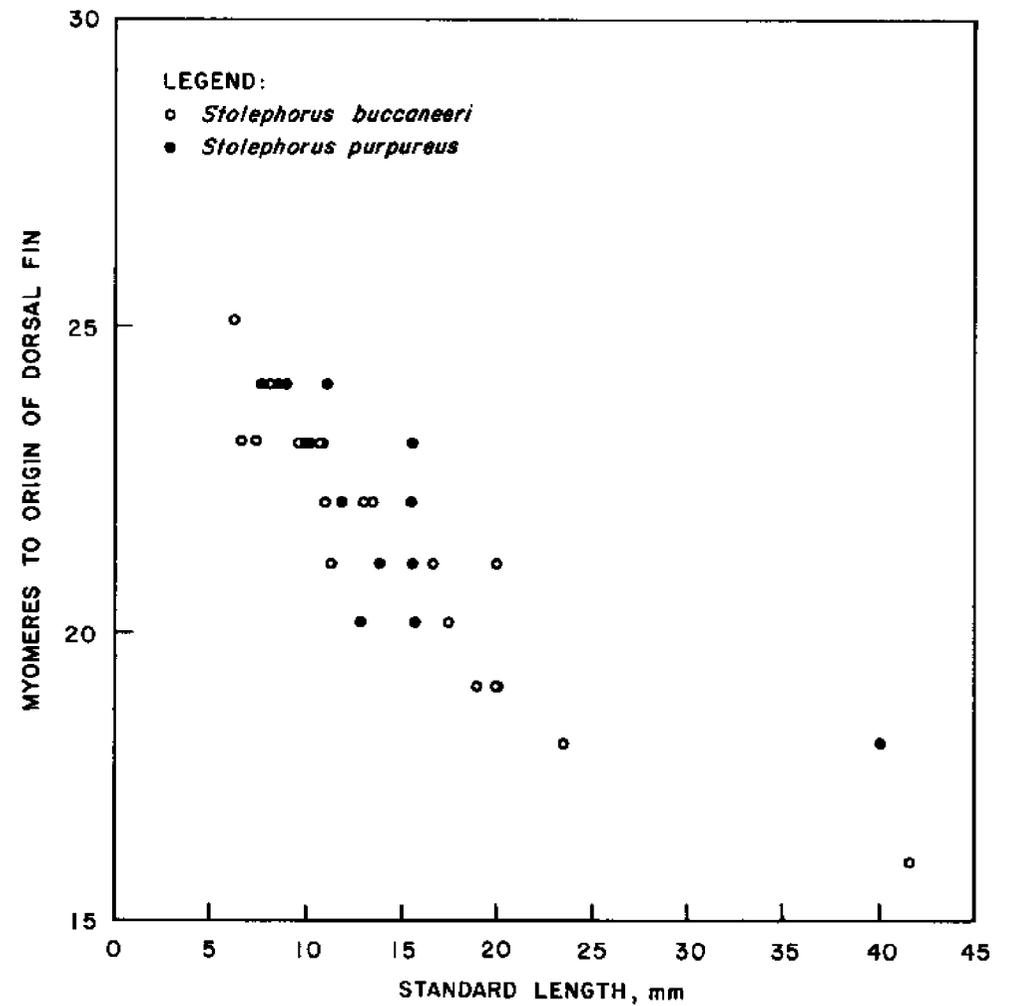


Figure 24. *Stolephorus purpureus* and *S. buccaneeri*: predorsal myomeres vs. larval length

There is little pigment change between ca. 9 and 15 mm SL. The number of melanophores along the isthmus and on the posterior ventral midline increases, and one or two pairs develop along the base of the anal fin (Figures 25 and 26).

The caudal pigment is found only within a diagonal band along the lower caudal fin rays (Figure 25). Dorsal or lateral pigments do not develop until metamorphosis.

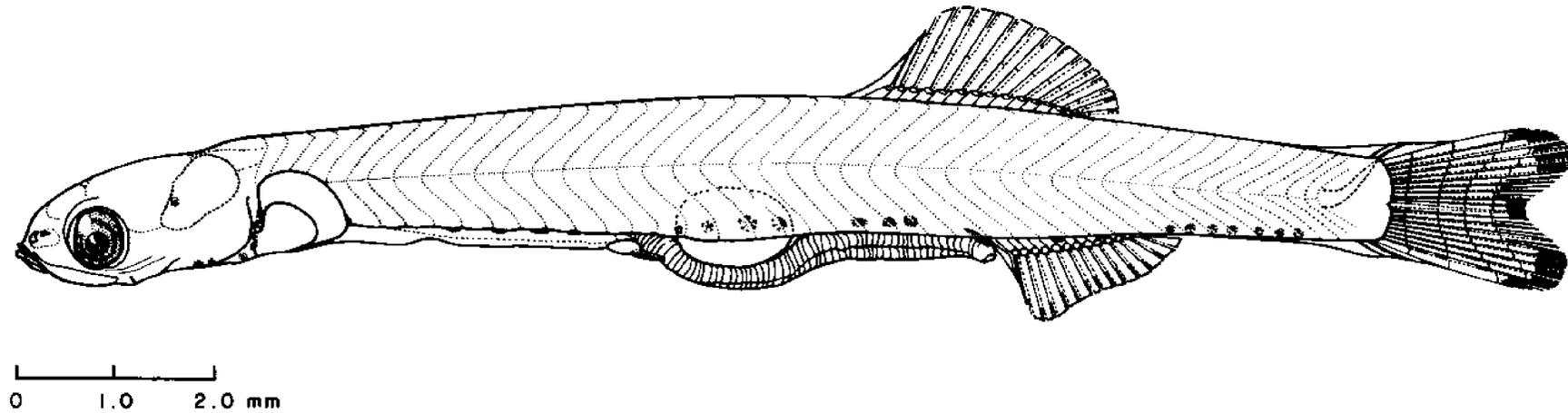


Figure 25. *Stolephorus purpureus*, 15.7 mm SL

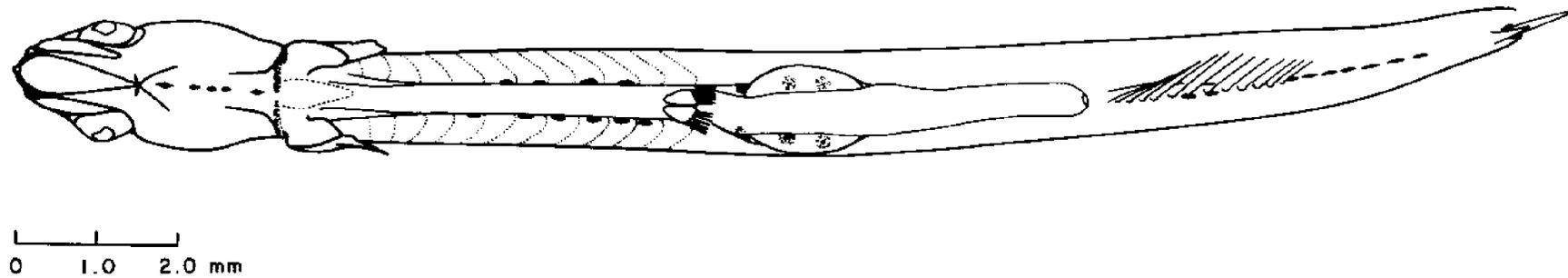


Figure 26. *Stolephorus purpureus*, 15.7 mm SL, ventral view

Stolephorus buccaneeri

Adult meristics

D: 13–14; A: 14–16; P: 14–15; V: 7; C: 19; vertebrae: 42–43

Eggs

In Delsman (1931), *Stolephorus zollingeri* is described as a planktonic, ellipsoidal egg without an oil droplet. Ozawa and Tsukahara (1973) cited this as the egg of *S. buccaneeri*. Strasburg (1960a) described ovarian eggs as oval, with no oil droplet.

Larvae

S. buccaneeri larvae develop in much the same way as *S. purpureus*, except the former develops somewhat faster (cf. Figures 25 and 27). The gut shortens and the fins migrate as in *S. purpureus* (Figures 23 and 24). The larval development of *S. buccaneeri* larvae is discussed and illustrated in detail in Ozawa and Tsukahara (1973).

Identification

Stolephorus larvae may be confused with *Etrumeus teres* larvae at sizes between ca. 6 and 14 mm SL. Their distinctions are discussed in the "Dussumieriidae" section.

Sardinella marquesensis and *Gonorhynchus gonorhynchus* resemble the *Stolephorus* species; the latter can be distinguished by myomere counts and the former two are separated by numbers of dorsal and anal fin rays (Table 2).

S. purpureus may be confused with *S. buccaneeri* at all sizes. Larvae are usually distinguishable by eye diameter: *S. buccaneeri* has a larger eye (Figure 28). It is easiest to identify larvae between ca. 8 and 20 mm SL. *S. buccaneeri* is usually more heavily pigmented than *S. purpureus* and is usually found in open coastal waters rather than in harbors and bays as is *S. purpureus*. Unfortunately these two species overlap to some extent in all characteristics. The differences between these species are discussed in greater detail in Ozawa and Tsukahara (1973).

Literature

Delsman (1931), Nakamura (1970), Ozawa and Tsukahara (1973), Strasburg (1960a), Tester and Hiatt (1952), Watson and Leis (1974), Yamashita (1951)

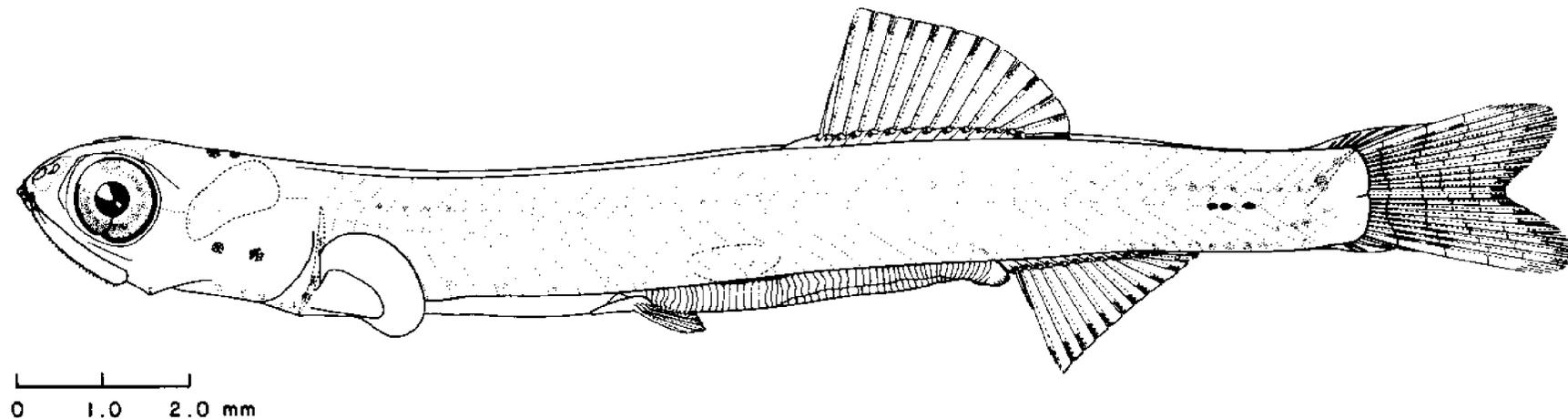


Figure 27. *Stolephorus buccaneeri*, 15.8 mm SL

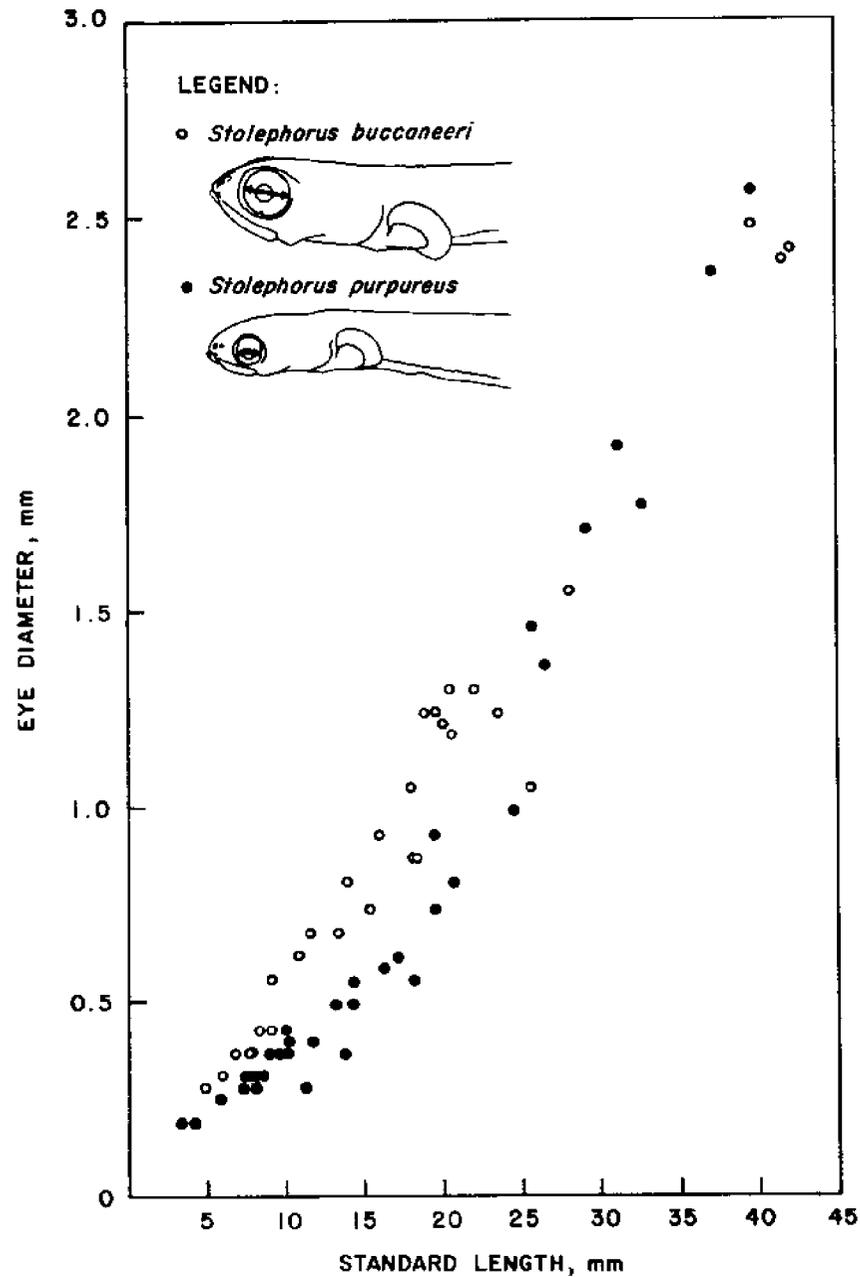


Figure 28. *Stolephorus purpureus* and *S. buccaneeri*: eye diameter vs. standard length

CHANIDAE

Chanos chanos (awa)

Adult meristics

D: 14–16; A: 8–11; P: 17; V: 10–12; C: 19; vertebrae: 44–46

Eggs

Delsman (1926c, 1929) described *C. chanos* as pelagic, spherical, 1.2 mm in diameter, lacking oil droplets, and having a weakly segmented yolk.

Yolk sac larvae

Larvae of 4.8 mm SL (Figure 29) retain some yolk and have unpigmented eyes, incompletely developed jaws, and a simple tubular gut. The myomere formula is 34 + 10. The longitudinal muscle fibers are visible. Melanophores are scattered throughout the dorsal and anal finfolds, others lie dorsally along the trunk, a few lie along the gut, some are widely scattered laterally on the trunk and yolk sac, and others are scattered on the head, mostly in the forebrain region.

Larvae

Specimens of *C. chanos* between ca. 5 and 8.5 mm SL and those larger than ca. 13.5 mm SL were not taken during this study.

By ca. 8.5 mm SL, the larvae have dorsal, anal, and caudal fins, conspicuous gas bladders, and somewhat shortened guts. Pelvic fins and pectoral fin rays are absent before ca. 13.5 mm SL (Figure 30). Between ca. 8.5 and 13.5 mm SL the gut shortens slightly: at ca. 8.5 mm SL the myomere formula is 32 + 12–13; at ca. 10.5 mm SL it is 31 + 13–14 (Figure 30).

The pigment pattern changes considerably between 4.8 and 8.5 mm SL, but very little between ca. 8.5 and 13.5 mm SL. In the latter size range, a single row of melanophores occurs in the ventral finfold from the foregut to about halfway caudad on the hindgut (Figure 31). Two or three pairs of melanophores lie on the dorsolateral surface of the gas bladder, and another two or three pairs on the dorsal surface of the gut immediately anterior to the anus.

Additional melanophores may or may not occur on the dorsal midline of the hindgut (19 of the 26 fish examined had some pigment). When present, these

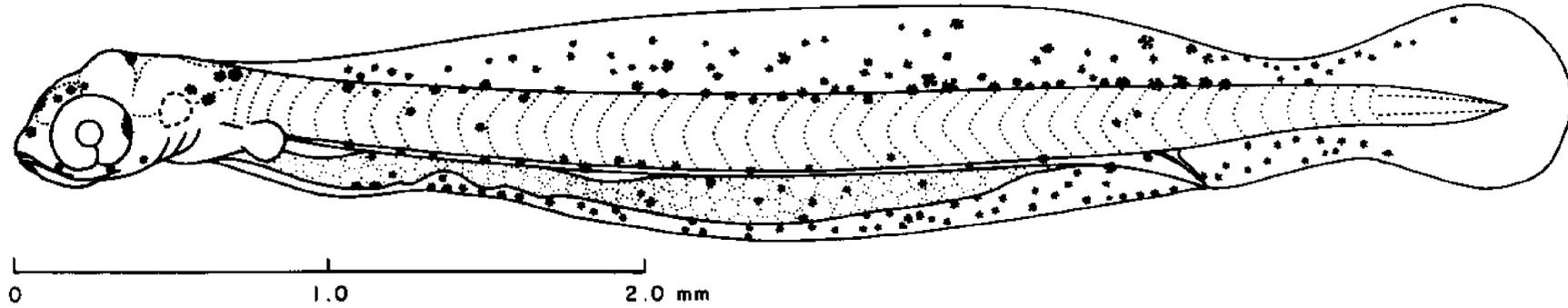


Figure 29. *Chanos chanos* yolk sac larva, 4.8 mm SL

24

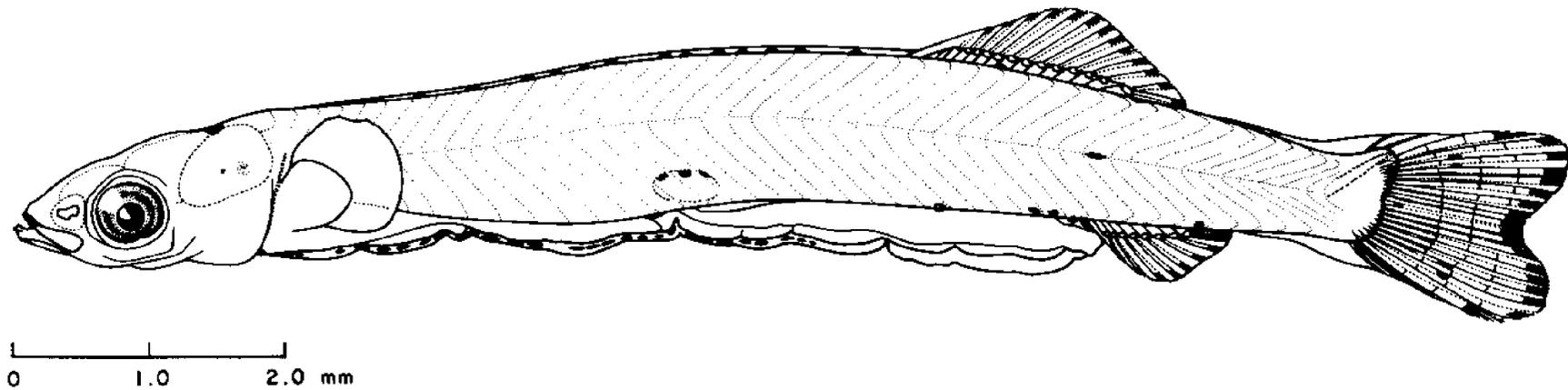


Figure 30. *Chanos chanos*, 10.2 mm SL

usually number between one and four and are evenly spaced between about the midpoint of the hindgut and the paired melanophores near the anus.

Melanophores also occur on the ventral midline immediately posterior to the anal fin. These vary from one to five, usually numbering between two and four (Figure 31). Others lie along the caudal fin rays in the form of a "V" (Figure 30). Midlateral melanophores may be present, although more often they are not

(8 of the 26 fish examined had some midlateral pigment). These number one per myomere at most and are usually found on the posterior half of the body.

The occurrence of dorsal body pigment varies from none to a single row along the midline between the first myomere and the caudal fin plus one or two pairs along the dorsal fin (Figure 32). Some dorsal body pigment was present in 21 of the 26 fish examined. Of the 26 fish examined, 22 had one melanophore and 4 had two melanophores present on the head overlying the hindbrain.

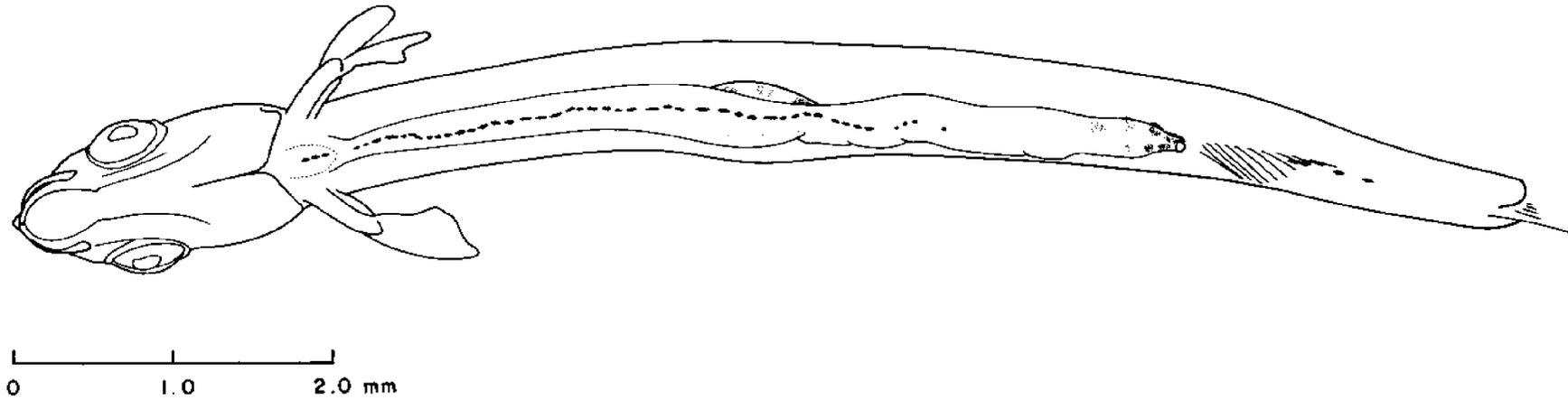


Figure 31. *Chanos chanos*, 10.2 mm SL, ventral view

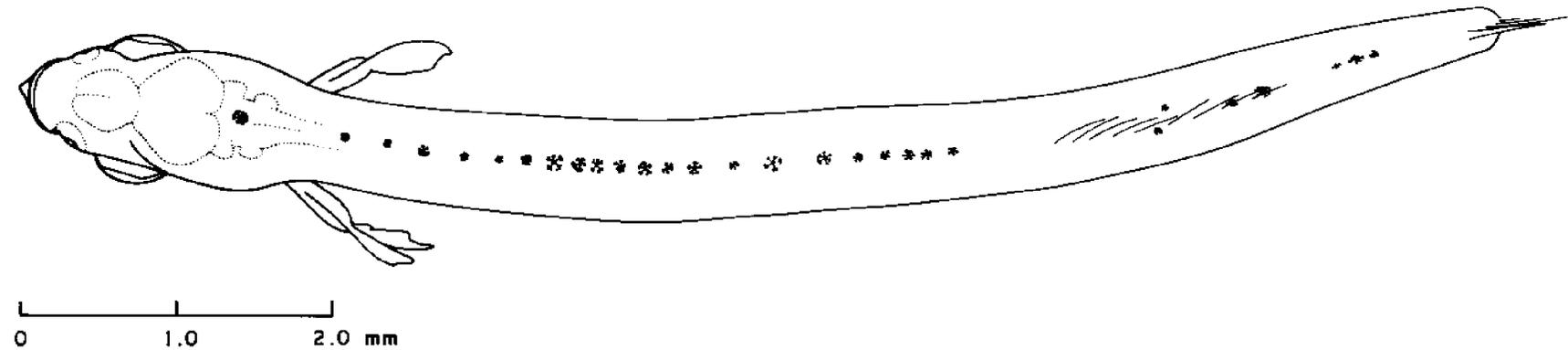


Figure 32. *Chanos chanos*, 10.2 mm SL, dorsal view

Larval development is described and illustrated further in Delsman (1926c, 1929).

resembles *Sardinella marquesensis* and *Gonorhynchus gonorrhynchus*; these can be distinguished meristically (Table 2).

Identification

Literature

C. chanos larvae may be confused with larvae of *Spratelloides delicatulus*; their differences are discussed in the "Dussumieriidae" section. *C. chanos* also

Blanco and Villadolid (1951), Delsman (1926c, 1929)

GONOSTOMATIDAE

Cyclothone sp.

Meristics

D: 13–15; A: 18–19; P: 13; V: 7; C: 19; vertebrae: 32

Eggs

Cyclothone sp. eggs have not been identified in the literature. Pelagic eggs have been described for some other gonostomatids, e.g., *Vinciguerria lucetia* (Ahlstrom and Counts, 1958) and *Maurolicus pennanti* (Sanzo, 1931d).

Larvae

Larvae of 4.8 mm SL (Figure 33) are long and slender, with dorsal, anal, and caudal fin anlagen and four to six incipient caudal fin rays. The notochord is just beginning to flex at this size. The dorsal and anal fin origins are nearly opposite one another, as is typical of *Cyclothone* sp. The gut extends about one-half the length of the body, giving a myomere formula of 15 + 17. The gas bladder is spherical and quite prominent. Numerous small teeth are present on the maxillary.

Three pairs of melanophores lie laterally along the gut: one at the foregut, another at about the midpoint, and the third at the hindgut, above the anus. A pair of melanophores lies on the dorsal surface of the gas bladder. A row of 7 to 12 internal melanophores is present along the ventral midline posterior to the

anus, and an internal diagonal band extends through the lower peduncle. External melanophores are scattered near the terminus of the notochord. A single melanophore lies at the distal edge of the caudal fin anlage between the superior and inferior hypural elements (Figure 33).

By ca. 6.5 mm SL, the notochord is flexed and melanophores embedded over the notochord begin to appear posteriorly, increasing in number cephalad with increasing larval size. Additionally, a melanophore is present at the symphysis of the cleithra. Others develop along the anterior hypaxial myosepta, increasing in number caudad with increasing larval size, and paired melanophores develop at the base of most or all anal fin rays.

The dorsal, anal, and caudal fin rays are ossified by ca. 8.5 mm SL. Pelvic buds and incipient pectoral rays appear at ca. 8.5 mm SL. The myomere formula remains 15 + 17. The pigment pattern typical of smaller *Cyclothone* sp. larvae is retained at this size.

Vinciguerria nimbaria

Adult meristics

D: 13–15; A: 13–15; F: 9–10; V: 7; C: 19; vertebrae: 41–42

Eggs

Ahlstrom and Counts (1958) attributed planktonic, spherical eggs 0.64 to 0.72 mm in diameter, without oil droplets, to *V. nimbaria*.

26

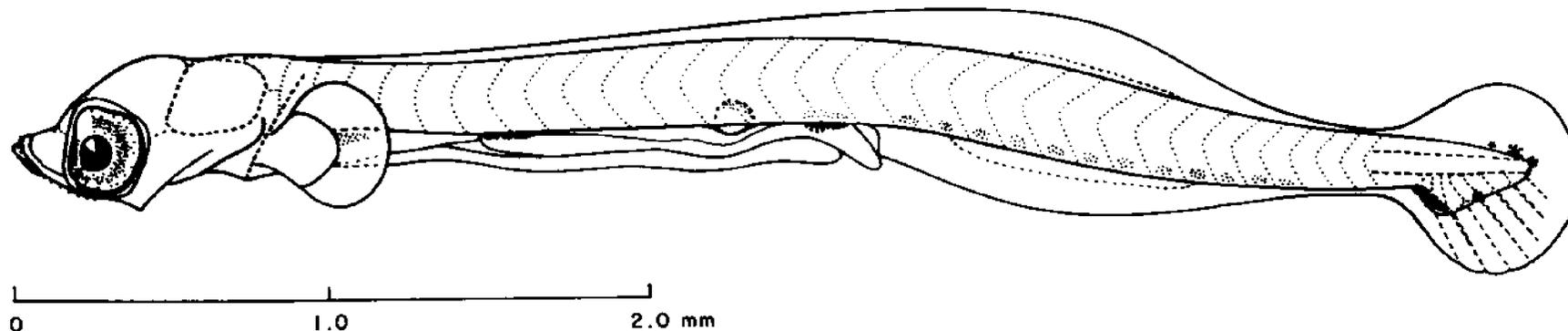


Figure 33. *Cyclothone* sp., 4.8 mm SL

Larvae

Larvae of 5.2 mm SL are elongate, with narrow eyes on very short stalks and dorsal and caudal fin anlagen present. The notochord is straight, but the anal fin anlage is not apparent yet. The pigmentation usually consists of a single melanophore at the anterior end of the caudal fin anlage. Silas and George (1969) described a midlateral melanophore at the level of the pectoral fin and another on the ninth postanal myomere in small *V. nimbaria* larvae from the Indian Ocean.

The anal fin anlage develops by ca. 7 mm SL, and the notochord is flexed at ca. 8 mm SL. By ca. 12 mm SL the adult complement of dorsal and anal fin rays is nearly formed and the adipose fin is becoming visible. The terminus of the dorsal fin lies two or three myomeres behind the origin of the anal fin, as is typical of *V. nimbaria* (Figure 34). The gut extends beyond the midpoint of the body, giving a myomere formula of 26 + 16. Prominent teeth are present along the upper jaw. The pelvic buds appear at ca. 12 mm SL. The eyes remain narrow and the pectoral fin undifferentiated until metamorphosis, which begins at ca. 14 mm SL.

The pigment pattern changes little between ca 5.2 and ca. 12 mm SL: the caudal melanophore remains on the side of the lower peduncle, and a somewhat V-shaped band of melanophores—separated between the superior and inferior caudal rays—lies along the proximal end of the caudal fin (Figure 34). Silas and George (1969) reported the development of melanophores along the anal fin base by ca. 8.5 mm SL and the loss of the midlateral melanophores in larvae larger than ca. 9 mm SL.

The larval development of *V. nimbaria* is described and illustrated in greater detail in Silas and George (1969) and Ozawa (1973).

Identification

Cyclothone sp. may be distinguished from most other elongate fish larvae by myomere number (Table 2), the relative positions of dorsal and anal fins, the position of the anus near the midpoint of the body, and the ventral and caudal pigment patterns.

Gonostoma atlanticum resembles *Cyclothone* sp. They may be distinguished by myomere counts (37 to 40 in *G. atlanticum*), gas bladder shape and position (usually spherical and projecting up into the hypomeres in *Cyclothone* sp. vs. usually oval-shaped and lying below the hypomeres in *G. atlanticum*), and caudal pigment (present in *Cyclothone* sp., but absent in small *G. atlanticum*).

V. nimbaria larvae superficially resemble *Etrumeus teres*. These are easily distinguished by myomere count (Table 2), eye shape, and ventral pigment as described in the "Dussumieriidae" section.

At least three species of *Vinciguerria* are present in Hawaiian waters, including *V. nimbaria* and *V. poweriae*. The differences between these larvae are discussed in Ahlstrom and Counts (1958).

Literature

Ahlstrom (1974), Ahlstrom and Counts (1958), Ahlstrom and Moser (1969), Grey (1964), Jespersen and Taning (1919), Ozawa (1973), Sanzo (1931d), Silas and George (1969)

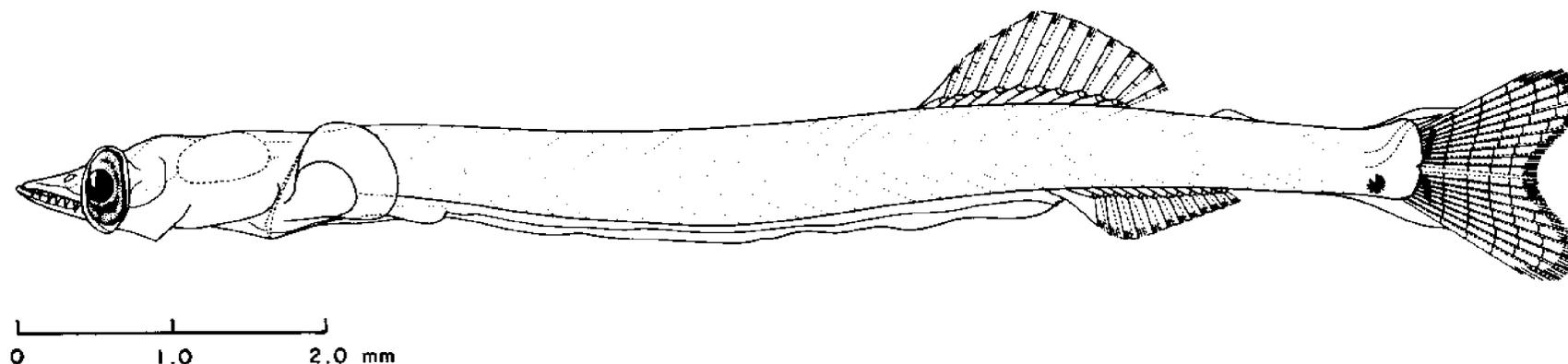


Figure 34. *Vinciguerria nimbaria*, 9.1 mm SL

SYNODONTIDAE

Trachinocephalus myops

Adult meristics

D: 11–14; A: 14–16; P: 11–13; V: 8; C: 19; vertebrae: 54–56

Eggs

None of the eggs sampled during this study was attributed to *T. myops*. However, one synodontid egg not yet identified beyond the familial level is a common component of the nearshore Hawaiian ichthyoplankton. This egg is spherical, 1.25 mm in diameter, without oil droplets, and with the typical synodontid mesh of hexagonal facets on the chorion (Watson and Leis, 1974).

Mito (1961a) tentatively attributed a similar, but smaller (1.13 mm diameter), egg to *Trachinocephalus myops*.

Larvae

Larvae of ca. 9.5 mm SL (Figure 35)—the smallest size of this species normally taken in nearshore plankton tows—are elongate, with a very short snout which gives the head a rounded appearance. Only the caudal fin anlage is present. The gut is long, yielding a myomere formula of 38 + 17–18. The hindgut is convoluted.

The single most distinctive feature of synodontid larvae is the series of large, paired, pigment patches lying along the gut. In the case of *T. myops*, six pairs are present: (1) below the pectoral fin; (2) at myomeres 5–7; (3) at myomeres 13–15; (4) at myomeres 20–22; (5) at myomeres 27–29; and (6) at myomeres 36–38 (Figure 35). These are present until metamorphosis. A large melanophore lying on the ventral midline, about halfway between the anus and the posterior end of the notochord, likewise is present until metamorphosis. Numerous small melanophores are scattered over the peduncle area in ca. 9.5-mm SL larvae. Caudal fin rays begin to develop at ca. 10 mm SL. The notochord begins to flex and the anal fin anlage first appears at ca. 12 mm SL. By ca. 14 mm SL the notochord is fully flexed. Anal fin rays begin to develop at ca. 17 mm SL. When the anal fin is fully developed, the posterior midventral melanophore lies at its terminus. The only pigment changes that occur between ca. 9.5 and 17 mm SL are the presence of the terminal melanophores on only the upper half of the peduncle and the development of melanophores along all but the lower three or four caudal fin rays.

Identification

Synodontid larvae and prejuveniles are immediately recognized by their elongate shape and the large, paired, pigment patches lying along the gut. Prejuveniles typically attain a large size—often 30 mm SL or more. Some argentinids and bathylagid smelts superficially resemble synodontid larvae; these can be differentiated by eye shape (narrow and sometimes stalked in bathylagids, always round in synodontids) and by the usually heavier pigmentation of argentinids (including head and lateral pigment).

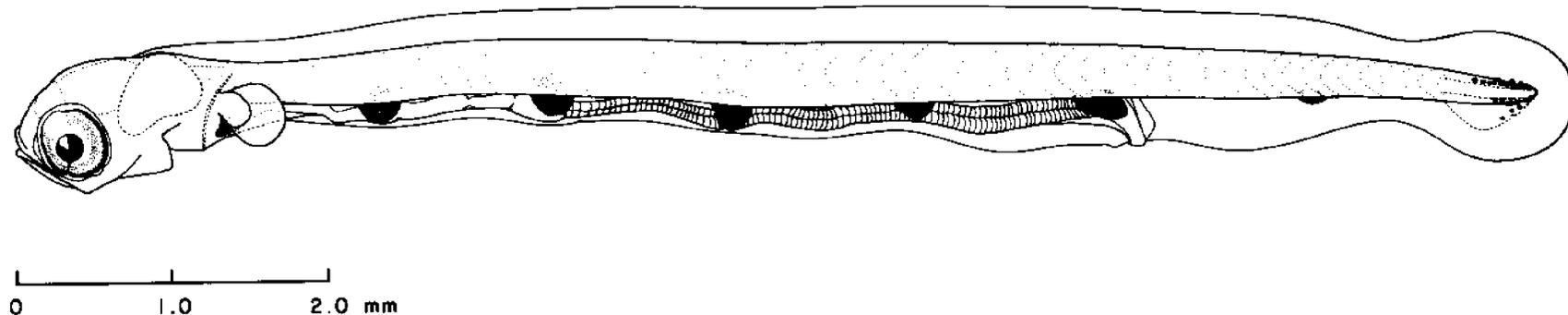


Figure 35. *Trachinocephalus myops*, 9.6 mm SL

Within the synodontids, five of the six Hawaiian species are at least tentatively identifiable by myomere and pigment patch counts (Table 3). The pigment patch counts are not applicable to small larvae—ca. 5 mm SL or less—since these have not yet acquired a full complement of patches (e.g., Okiyama, 1974a).

TABLE 3. DIAGNOSTIC CHARACTERISTICS OF SELECTED SYNODONTID LARVAE AND PREJUVENILES

Species	Myomeres	Paired Pigment Patches
<i>Saurida gracilis</i>	47	7
<i>Synodus binotatus</i>	54–56	11
<i>S. dermatogenys</i> ?	64–66	12
<i>S. variegatus</i> ?	60–64	12
<i>Trachinocephalus myops</i>	54–56	6

T. myops is described above; very brief descriptions of four other synodontid larvae follow. Although the descriptions are based on only one to four specimens and therefore may not be truly representative of each species, they are included here as a source for future reference.

Saurida gracilis (1 specimen: 11.6 mm SL). The myomere formula is 31 + 16. Adult meristics are D: 10; A: 9–10; P: 12; V: 8. Seven paired pigment patches are evenly spaced along the gut, the first lying at the level of the pectoral base and the last at the anus. Two large melanophores are present on the ventral midline posterior to the anus. Scattered melanophores are present along the caudal fin rays and on the lower half of the peduncle. Anal and caudal fins are formed and the dorsal fin anlage is present.

Synodus binotatus (3 specimens: 27.0 to 32.3 mm SL). This species has a total of 54 to 56 myomeres. Adult meristics are D: 11–13; A: 8–10; P: 12; V: 8. Eleven paired pigment patches are evenly spaced along the gut, the first lying just anterior to the pectoral fin base and the last at the level of the anus. One large melanophore is present on the ventral midline at the terminus of the anal fin; paired melanophores are present at the base of the last two or three anal fin rays. Some melanophores are present at the center of the distal edge of the peduncle; others are scattered along the lower caudal fin rays.

Synodus dermatogenys (4 specimens: 12.3 to 30.3 mm SL). The myomere formula is 49–50 + 15–16. There are 8 to 9 anal fin rays in larvae larger than ca. 25 mm SL. The dorsal fin remains as anlage and pelvic fin as buds to at least 30.3 mm SL. There are 13 to 14 dorsal fin rays in adults. Twelve pairs of pigment patches are evenly spaced along the gut, the first lying just anterior to the pectoral base and the last at the level of the anus. One large melanophore is present on the ventral midline at the terminus of the anal fin. One internal melanophore is present on the central lower half of the peduncle at its distal edge. Melanophores are scattered along the lower caudal fin rays and externally on the upper peduncle of the largest specimen.

Synodus variegatus (1 specimen: 37.5 mm SL). This specimen has a total of 63 myomeres. Adult meristics are D: 12; A: 9; P: 12; V: 7. Twelve paired pigment patches are evenly spaced along the gut, the first lying just anterior to the pectoral base and the last at the level of the anus. One elongate melanophore is present on the ventral midline at the terminus of the anal fin; paired melanophores are present at the base of anal fin rays 3 through 9. Small melanophores are scattered over the upper half of the peduncle along the lower caudal fin rays. One internal melanophore is present at the posterior center of each midbrain hemisphere; external melanophores overlie the midbrain region.

Literature

Gibbs (1959), Mito (1961a), Okiyama (1974a), Watson and Leis (1974)

CHLOROPHTHALMIDAE

Chlorophthalmus proridens

Adult meristics

D: 11; A: 9–10; P: 15; V: 8–9; C: 19; vertebrae: 49

Eggs

Chlorophthalmus proridens eggs have not been described in the literature.

Larvae

C. proridens larvae of ca. 6 to 10 mm SL are the most commonly encountered sizes. These are elongate with short guts: the myomere formula is 11 + 38. At ca. 6 mm SL (Figure 36) the caudal fin anlage is present, but the notochord remains straight. Dorsal and anal finanlagen are not visible. The notochord is flexed by ca. 8 mm SL.

Ca. 6 mm SL larvae are lightly pigmented: two or three melanophores lie on the dorsal and ventral midlines just anterior to the caudal fin anlage (Figure 36). Aside from the addition of a single melanin patch overlying the gut near the level of the pectoral fin base at ca. 7 mm, the pigment pattern does not change before ca. 8 mm SL. In larger larvae, the middorsal and midventral melanophores coalesce into a single midlateral melanophore on the peduncle; no other pigment changes occur before at least ca. 30 mm SL.

Identification

Chlorophthalmids are easily distinguished by their short gut and characteristic pigmentation as described above.

Literature

Ahlstrom (1971), Taning (1918)

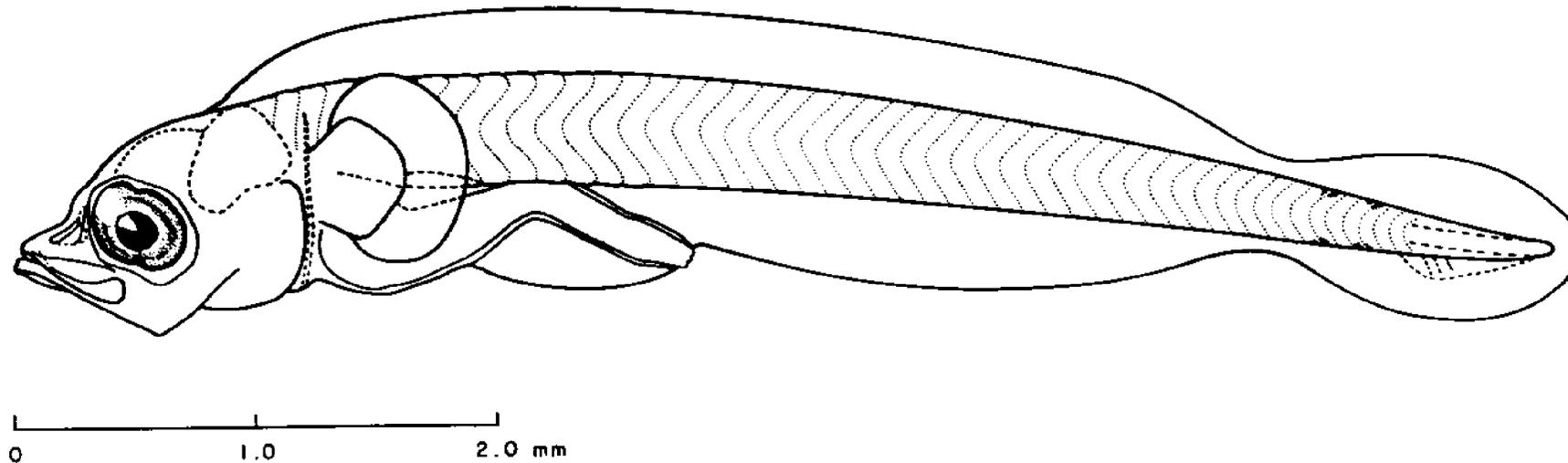


Figure 36. *Chlorophthalmus proridens*, 6.4 mm SL

MYCTOPHIDAE

Myctophids are a very diverse group in Hawaiian waters and are represented by approximately 18 genera and at least 47 species (Clarke, 1973). Their larvae can be recognized by a few common characteristics: myomeres usually number in the mid- to upper thirties; the gut is convoluted and typically not more than one-half the body length; the larvae are usually not especially elongate; in some genera the smaller larvae may have narrow eyes; and the smaller larvae often have melanophores along the ventral midline of the tail.

The following five common species were selected to illustrate the body forms and pigment patterns of larvae of the species most often encountered.

Ceratoscopelus warmingi

Larvae

The *C. warmingi* larvae most commonly encountered are between ca. 3 and 9 mm SL. These have oval eyes, are moderately elongate, have a gut one-half the

length of the body or less, and have pigment restricted to a pair of melanophores on the hindgut and one or more (the number decreases with increasing larval size) on the ventral midline posterior to the anus.

Larvae smaller than ca. 3.5 mm SL lack fin anlagen and have seven melanophores along the ventral midline. In other respects they resemble ca. 5.0 mm SL larvae (Figure 37), which have caudal fin anlagen and prominent gas bladders. The number of midventral melanophores is reduced to five or six in ca. 5.0 mm SL larvae.

By ca. 6.5 mm SL, the notochord is flexed and 19 caudal fin rays are present. Dorsal and anal fin rays are partially ossified (D: 9; A: 8), as are the pectoral fin rays. Pelvic fin buds first appear at about this size and the paired melanophores above the anus are still present. However, the midventral series is reduced to a single melanophore near the midpoint between the anus and the peduncle.

At ca. 9 mm SL the dorsal and anal fins are completely formed (D: 14; A: 14–15), the pectoral fin is nearly developed, and the pelvic fin rays are beginning to ossify. The pigment pattern remains the same, however.

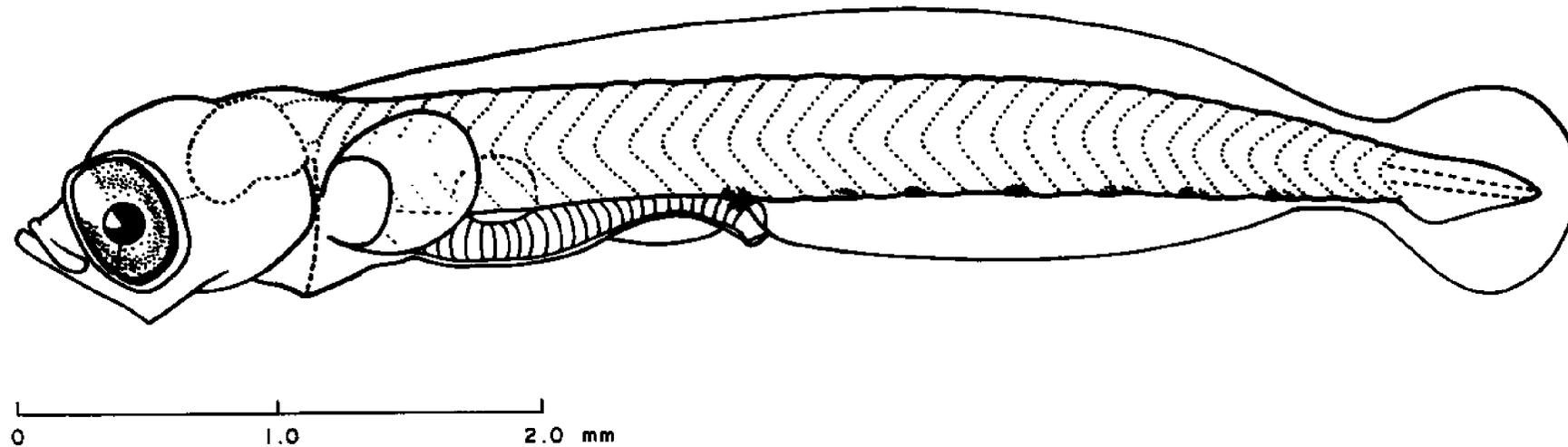


Figure 37. *Ceratoscopelus warmingi*, 5.2 mm SL

Diaphus spp.

The typical myomere formula is 16 + 16–21.

Diaphus spp. larvae in samples taken during this study generally were ca. 2 to 5 mm SL. It was found that they have oval eyes, are moderately slender, and have a gut approximately one-half the body length. In addition, they have melanophores just posterior to the cleithra, along the sides of the gut, and on the ventral midline of the tail.

Larvae smaller than ca. 4 mm SL have no fin anlagen or obvious gas bladder. Their pigment pattern consists of one to three pairs of melanophores lying laterally along the gut, a pair on the hindgut above the anus, and a series along the ventral midline of the tail.

The caudal fin anlage usually begins forming and the notochord begins to flex at ca. 4.5 mm SL; the caudal fin is usually fully formed with 19 rays by ca. 5 mm SL. Dorsal and anal fin anlagen appear as the notochord becomes fully flexed (Figure 38). Probably as a result of more than one species being included, the sizes at which anlagen appear are variable: some 4.6 mm SL specimens already

have dorsal and anal anlagen plus the caudal fin, while 4.7 mm SL specimens have only the caudal anlage with a straight notochord.

The larval pigment pattern, beginning from ca. 4.5 mm SL (Figures 38 and 39), consist of a V-shaped melanophore on the gut just posterior to the cleithra, one to four pairs lying laterally along the gut, and a pair on the hindgut just above the anus. A series of 14 to 18 melanophores lies along the ventral midline posterior to the anus.

Hygophum proximum

The myomere formula is 15 + 19–20.

H. proximum larvae in samples taken during this study are predominantly in the ca. 3 to 5 mm SL size range. They are moderately slender and elongate, with a narrow eye subtended by a semielliptical mass of choroid tissue, a gut extending approximately one-half the length of the body, a sac-like finfold, and pigment near the symphysis of the cleithra, along the gut, and on the hypaxial myosepta posterior to the anus.

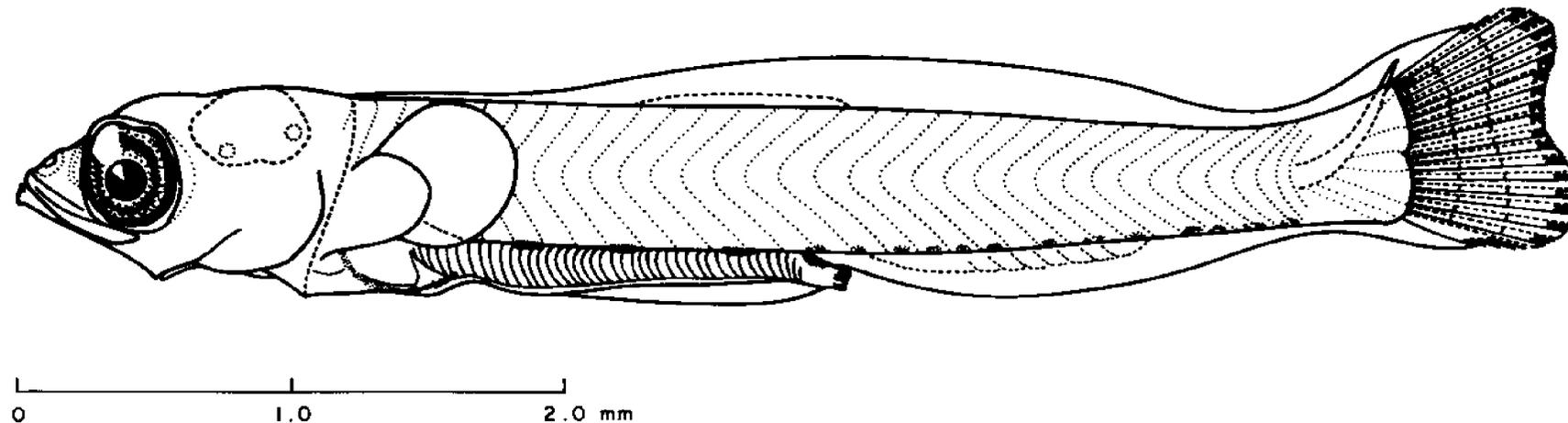


Figure 38. *Diaphus* sp., 5.0 mm SL

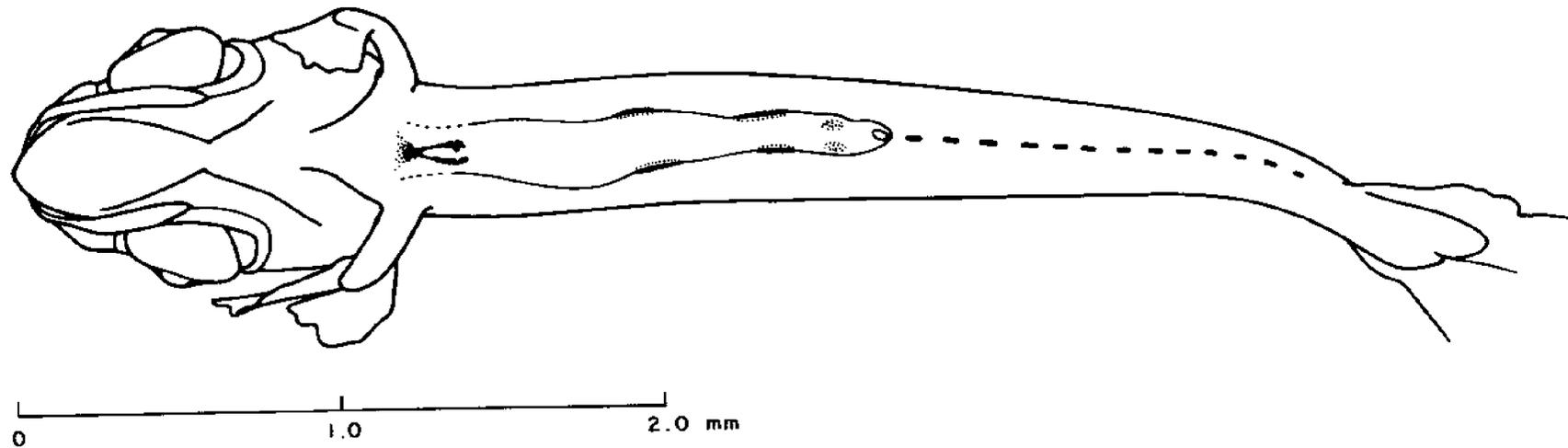


Figure 39. *Diaphus* sp., 4.6 mm SL, ventral view

Larvae of ca. 3 mm SL have very narrow eyes and no fin anlagen. Pigmentation is restricted to large, V-shaped melanophores originating just anterior to the cleithra, a pair of melanophores on the hindgut just above the anus, and two melanophores on the hypaxial myosepta. The latter two are separated by one myomere and usually lie between myomeres 19 and 24. Lateral pigment along the gut is lacking.

The caudal fin anlage develops at ca. 4 mm SL, and by ca. 5 mm SL four incipient caudal fin rays may be discerned, although the notochord remains straight. Dorsal and anal fin anlagen are absent. The eye widens as development proceeds, so that by ca. 4 mm SL it is only moderately narrow (Figure 40). Between ca. 4 and 5 mm SL the pigment pattern consists of the cleithral "V" opening caudad along the gut from an origin on the isthmus just anterior to the cleithra, one or two pairs of melanophores lying laterally along the gut (more often one pair), a pair on the hindgut, just above the anus, and one to five melanophores on the hypaxial myosepta in the region between myomeres 19 and 25. The latter group outlines adjacent myosepta when more than one melanophore is present (Figure 40).

Dorsal and anal fins begin developing and the notochord begins to flex by ca. 6 mm SL. Myoseptal and gut pigments decrease as larval development proceeds.

Lampadena sp.

The myomere formula is 15 + 22 for ca. 5 mm SL larvae, 17 + 20 for ca. 5.5 mm SL larvae, and 19 + 18 for ca. 6 mm SL larvae.

Most of the *Lampadena* sp. larvae sampled during this study were between ca. 4.5 and 6.5 mm SL (Figures 41 and 42). It was found that they have round eyes, are somewhat deeper-bodied than the preceding genera, have a gut extending approximately one-half or a little less than one-half the length of the body (shorter in smaller larvae), have double rows of melanophores along the dorsal and ventral midlines, and have pigment on only the posterior half of the gut.

The smallest larvae have a caudal fin anlage, but the notochord is straight and the dorsal and anal fin anlagen are lacking. Caudal fin rays are not visible

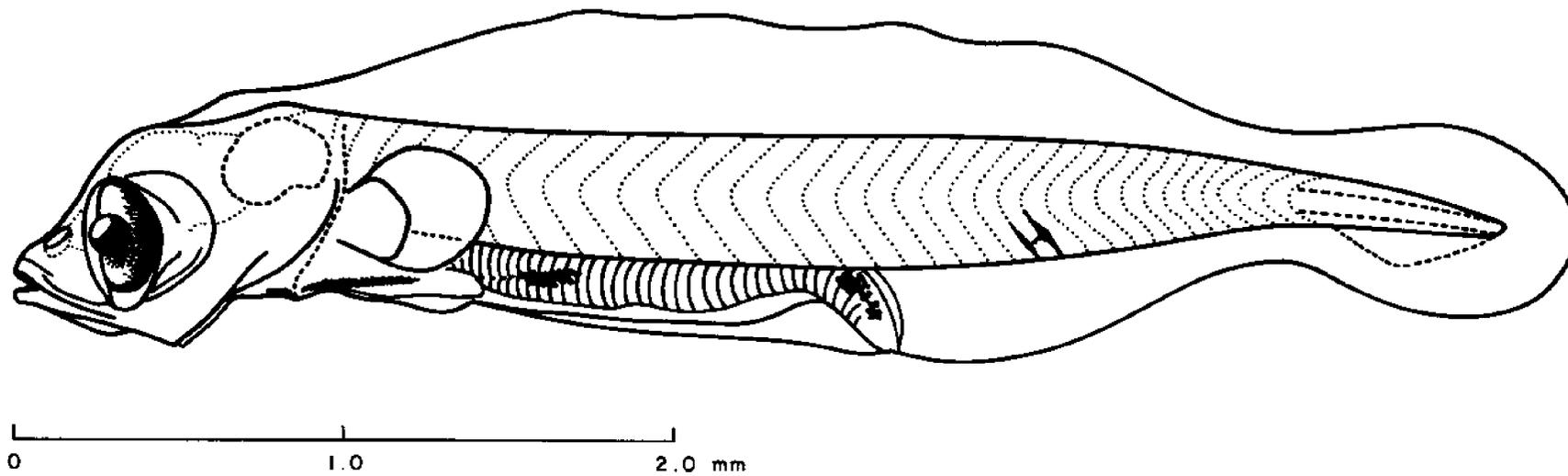


Figure 40. *Hygophum proximum*, 4.5 mm SL

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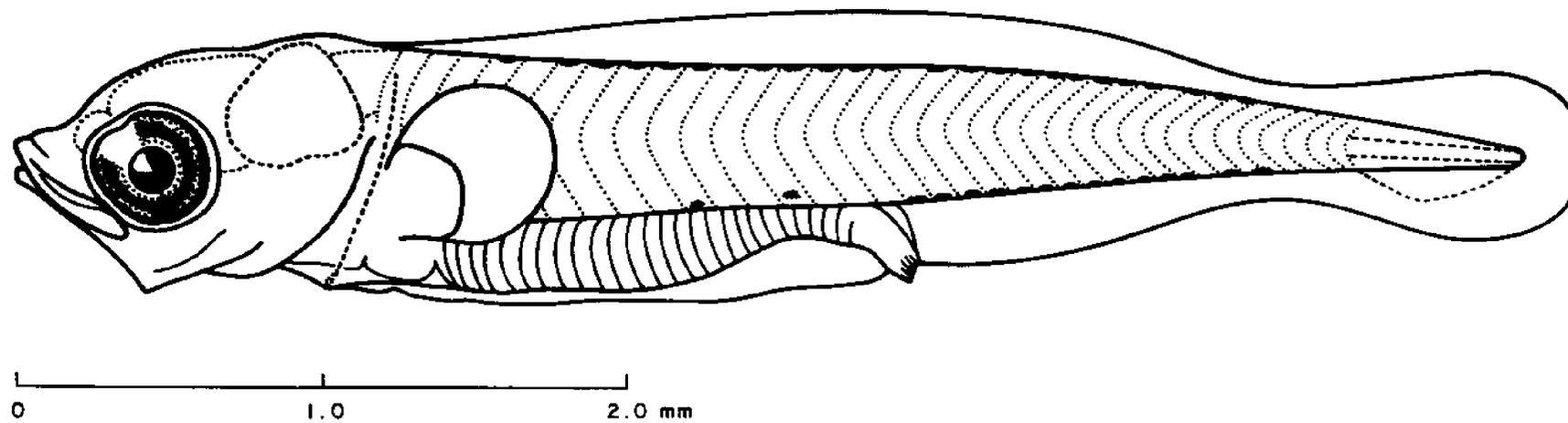


Figure 41. *Lampadena luminosa*, 4.8 mm SL

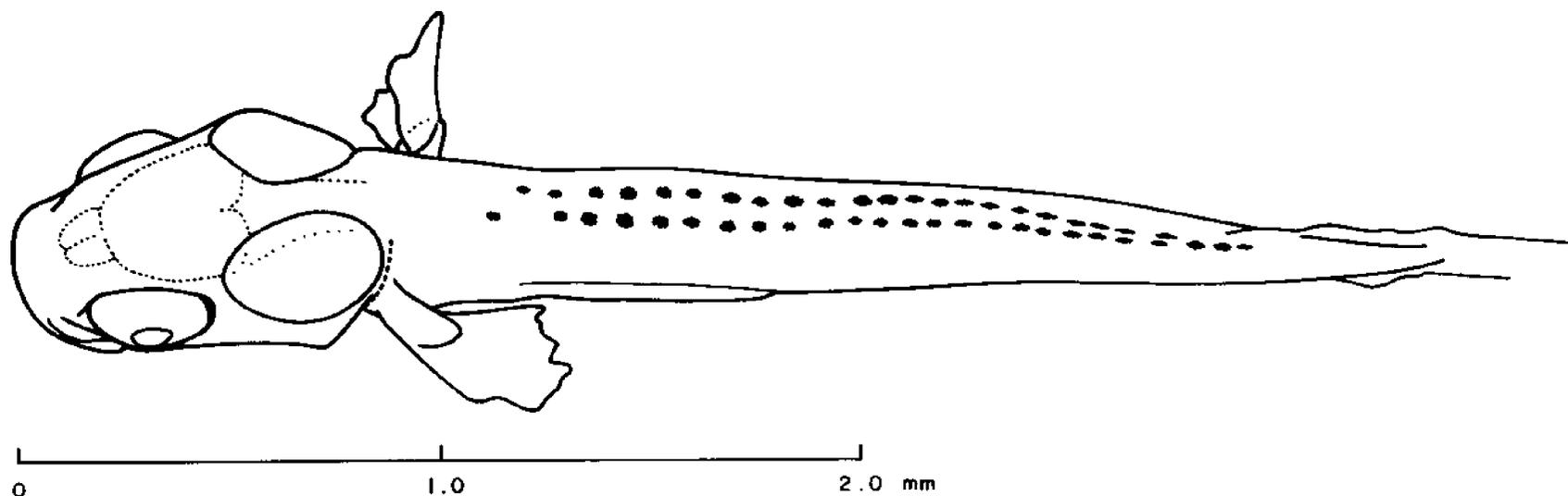


Figure 42. *Lampadena luminosa*, 4.8 mm SL, dorsal view

(Figure 41). A double row of melanophores (usually one pair per myomere) lies along the dorsal midline, beginning just behind the pectoral fin and extending caudad to the level of the caudal anlage. The last two or three melanophores lie in a single row (Figure 42). A second double row extends along the ventral midline from the first or second postanal myomere (usually one pair per myomere) to the caudal fin anlage. The last two or three melanophores usually lie in a single row. One to four pairs of melanophores overlie the posterior half of the gut, but none lies on the hindgut immediately above the anus (Figure 41).

By ca. 5.5 mm SL the notochord is slightly flexed and eight caudal fin rays are discernible, pectoral fin rays are developing, dorsal and anal fin anlagen are present, and the body depth is increasing. The pigment pattern is similar to that of smaller larvae, except that the anterior one to five melanophore pairs on the dorsal midline have disappeared. At ca. 6.5 mm SL the caudal rays number 12, and up to eight more melanophore pairs have been lost from the dorsal midline.

Lampanyctus nobilis

The myomere formula is 7 + 29–30 for larvae smaller than ca. 4 mm SL, 9 + 27–28 for larvae ca. 4.5 mm SL, 12 + 24–25 by ca. 5.5 mm SL, and 16 + 20–21 at ca. 7.5 mm SL.

The *L. nobilis* larvae sampled were, for the most part, ca. 3 to 7.5 mm SL. It was found that they have nearly round eyes, are deep-bodied with large heads and somewhat elongate jaws, have very short guts (smaller size larvae) and have internal melanophores on the fore-, mid-, and hindbrain, on the gas bladder, along the cleithra, and externally at the tip of the lower jaw and on the gular membrane.

The smallest larvae lack fin anlagen, but otherwise have the characteristic *L. nobilis* features. Their pigment consists of an internal melanophore on the anterior center of the forebrain, another on the anterior center of the midbrain, and a third at the junction of the mid- and hindbrain. The third melanophore, typically a pair with one on each side of the anterior hindbrain (E.H. Ahlstrom, 1974: personal communication), was always single in all of the specimens collected during this study. A single melanophore lies at the tip of the lower jaw and another on the central gular membrane. The upper surface of the gas bladder is pigmented. The cleithral pigment is V-shaped and open caudad (Figure 43).

At ca. 3.5 mm SL the caudal anlage is present (Figure 43). By ca. 5.5 mm SL the notochord has begun to flex, eight caudal rays are discernible, dorsal and anal anlagen are developing, and two small spines can be seen at the angle of the preopercle. The pigment pattern does not change between ca. 3 and 5.5 mm SL,

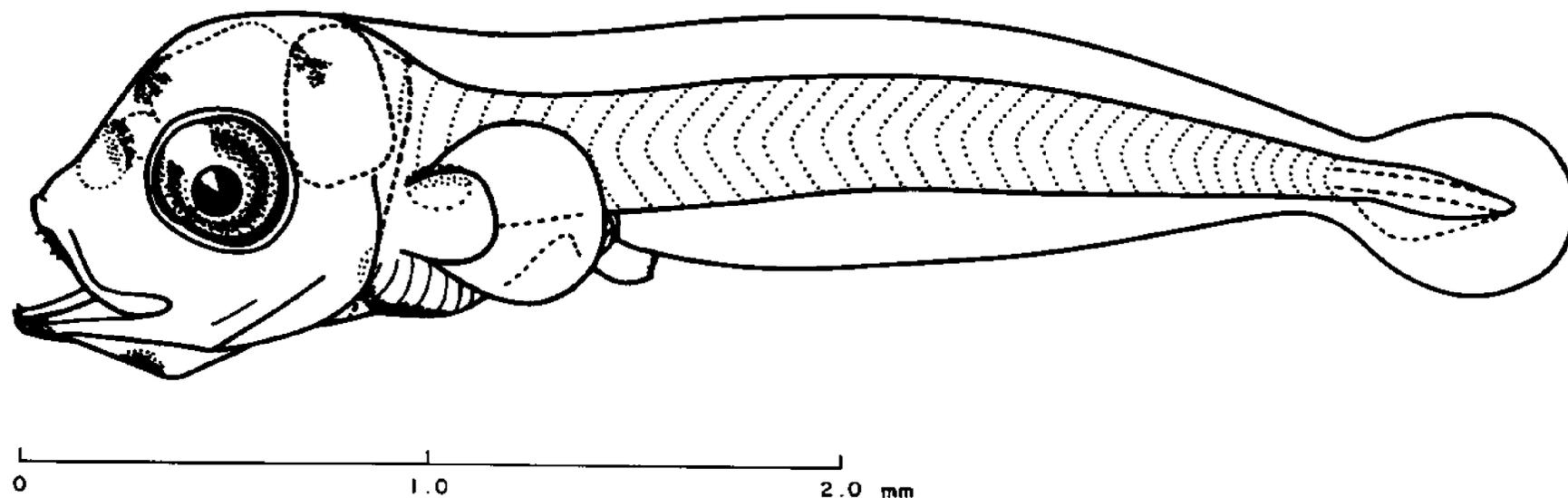


Figure 43. *Lampanyctus nobilis*, 3.6 mm SL

except that by 5.5 mm SL a row of three melanophores lies along the longitudinal axis of the gular membrane.

By ca. 7.5 mm SL the dorsal and anal fins are nearly formed (D: 13; A: 16), and pelvic buds are present. The jaws remain fairly elongate. The pigment changes only by the addition of another melanophore to the gular membrane series.

Identification

Ceratoscopelus warmingi larvae are most likely to be confused with *Bolinichthys* sp. larvae. These species can be distinguished by the melanophores at the mid- and hindbrain junction, which is normally present in larger (5 mm) *Bolinichthys* sp. and absent in *C. warmingi*. Another melanophore found ventrally on the hindbrain—although sometimes difficult to see—is present in *Bolinichthys* sp. and absent in *C. warmingi*. The pigment above the anus is typically a single melanophore in *Bolinichthys* sp. and a pair of melanophores in *C. warmingi*. *Bolinichthys* sp. larvae are somewhat deeper-bodied and have more rounded eyes than *C. warmingi* larvae.

Small *Diaphus* spp. larvae may also resemble *C. warmingi* larvae; however, these can be differentiated by the melanophores which lie laterally along the gut of *Diaphus* spp. (Figure 39) and which are absent in *C. warmingi*.

The *Diaphus* spp. larvae described above belong to the sub-genus *Diaphus*; other species were rarely encountered during this study. See Moser and Ahlstrom (1974) for more discussion on Myctophidae.

Hygophum proximum larvae resemble *Diogenichthys atlanticus* and *Benthoosema* spp. larvae, except that the latter two do not have the myoseptal pigment characteristic of *H. proximum*. Both *D. atlanticus* and *Benthoosema* spp. have melanophores along the ventral midline posterior to the anus; *H. proximum* lacks these. *D. atlanticus* lacks choroid tissue below the eye, which the others have, and *Benthoosema* spp. have somewhat more rounded eyes than either *H. proximum* or *D. atlanticus*. The choroid tissue mass below the *Benthoosema* spp. eye is much more rounded than that of *H. proximum*.

These genera are described and further diagnostic characteristics are cited in Moser and Ahlstrom (1970).

Hygophum reinhardti resembles *H. proximum*, but it is usually more heavily pigmented. It is also more slender and has narrower eyes on short stalks.

Lampadena urophaos (the most common *Lampadena* species) resembles *Lampadena* sp., but can be easily distinguished by its pigment pattern: the dorsal and ventral midline pigments consist of single large melanophores, usually one on each midline, paired at about the midpoint between the anus and peduncle in larvae smaller than ca. 6 mm SL. These middorsal and midventral melanophores increase in number with increasing larval size. A single melanophore overlies the midpoint of the gut, and another lies on the hindgut just above the anus.

Taaningichthys minimus is similar to *Lampadena* (Moser and Ahlstrom, 1972), although it resembles *L. urophaos* more closely than *Lampadena* sp. *T. minimus* larvae are more slender than *Lampadena* larvae, have an internal series of melanophores overlying the notochord and an external melanophore overlying the hindbrain which the *Lampadena* larvae lack, and have only one middorsal and one midventral melanophore each, both of which lie opposite one another just anterior to the peduncle.

Lampanyctus nobilis resembles scombrid, scombrolabracid, and some gempylid larvae, but can be easily distinguished by its convoluted gut (lacking in the others) and its very small preopercular spines (large in the others). The *L. nobilis* pigment pattern is another distinguishing characteristic.

The various *Lampanyctus* species are more difficult to distinguish. *L. nobilis* and *L. niger*, for example, resemble one another quite closely. They differ in head pigment: *L. niger* lacks the melanophore between the mid- and hindbrain and usually has a pair on the anterior midbrain (one at the center of each hemisphere). Larger *L. niger* larvae may have pigmentation on the pectoral base and fin, whereas *L. nobilis* does not. The gular membrane pigment is usually absent in *L. niger*. Unfortunately, at least six species of *Lampanyctus* occur in Hawaii, two of which closely resemble *L. nobilis* as adults (Clarke, 1973). Since the larvae of all six species have not been identified in practice, it is difficult to tell them apart.

Lampanyctus sp. 1 larvae are easier to distinguish. They are deeper-bodied and have much blunter snouts than the other species. They have 34 myomeres. *Lampanyctus* sp. 1 larvae develop quickly: a 3.8-mm SL specimen has dorsal, anal, and caudal anlagen, while a 5.3-mm SL specimen has its complete fin complement (D: 12–14; A: 16–19; P: 13–15). The underside of the pectoral fin base is pigmented, as are the central pectoral fin rays. A series of four melanophores overlies the gut, and single melanophores lie below the gut just posterior to the cleithra and below the hindgut just anterior to the anus. Single melanophores may lie at the tips of the upper and lower jaws.

In addition to the three *Lampanyctus* species mentioned above, two unidentified kinds are not uncommon. One is characterized by having elongate jaws, 32 to 34 myomeres, a typical *L. niger*-type brain pigment pattern, a single melanophore at the tip of the upper jaw, and extremely large pectoral fins. The second is typified by being deep-bodied, and having 35 to 36 myomeres and very elongate jaws. The head pigment is distinctive: ca. 3.5 to 4 mm SL larvae have a single internal melanophore at the anterior center of the forebrain, one at the anterior center and another at the posterior center of each midbrain hemisphere, and one or two anteriorly on the hindbrain. An internal melanophore lies just posterior to the side of each eye at about the level of mideye, and an external melanophore overlies the posterior central midbrain. Single melanophores may lie at the tips of the upper and lower jaws. The dorsal surface of the gas bladder is pigmented. An internal pair of melanophores lies on the foregut and a single embedded melanophore overlies the hindgut. A single melanophore may lie on the underside of each pectoral fin base, another may lie in the finfold below the hindgut, and one may lie under each operculum.

Literature

Clarke (1973), Moser and Ahlstrom (1970, 1972, 1974),
Pertseva-Ostroumova (1974)

EXOCOETIDAE (Malolo)

Exocoetids are common in Hawaiian waters. However, their larval taxonomy is poorly known and most can be tentatively identified only to the generic level at best.

Characteristics common to larvae of this family include a moderately high myomere count (between 35 and 52); well-developed fins, often at even the smallest sizes; a principal caudal ray count of 7 + 8 at all sizes; a moderately short, deep body (except for *Oxyporhamphus* which is usually long and slender); a short snout (except for *Oxyporhamphus* which has elongate jaws, with the lower one being the more elongate of the two); a gut extending one-half the length of the body or more; and pelvic fins originating far caudad, slightly ahead of the anus. They are often heavily pigmented, although this is quite variable according to species.

Exocoetid eggs are spherical, and they either are planktonic or attach themselves to a floating substrate by long filaments. A review of the earlier literature on these eggs is found in Breder, Jr., and Rosen (1966).

The following two *Cypselurus* spp. illustrate typical features of exocoetid larvae, as well as the extremes of pigmentation likely to be encountered.

Cypselurus sp. 1

Adult meristics

D: 13–14; A: 8–9; P: 13–14; V: 6; C: 15; myomeres: 45

Larvae

Cypselurus sp. 1 larvae of ca. 3.5 mm SL (Figure 44) are moderately deep-bodied, with large eyes and short snouts. They have no remaining yolk at this size. The caudal fin is rounded, the anal fin is completely formed, and the dorsal and pelvic fins are nearly fully formed. About one-half the adult complement of pectoral rays is discernible. The entire body is heavily pigmented, except for the branchial region and peduncle which are only lightly pigmented (Figure 44).

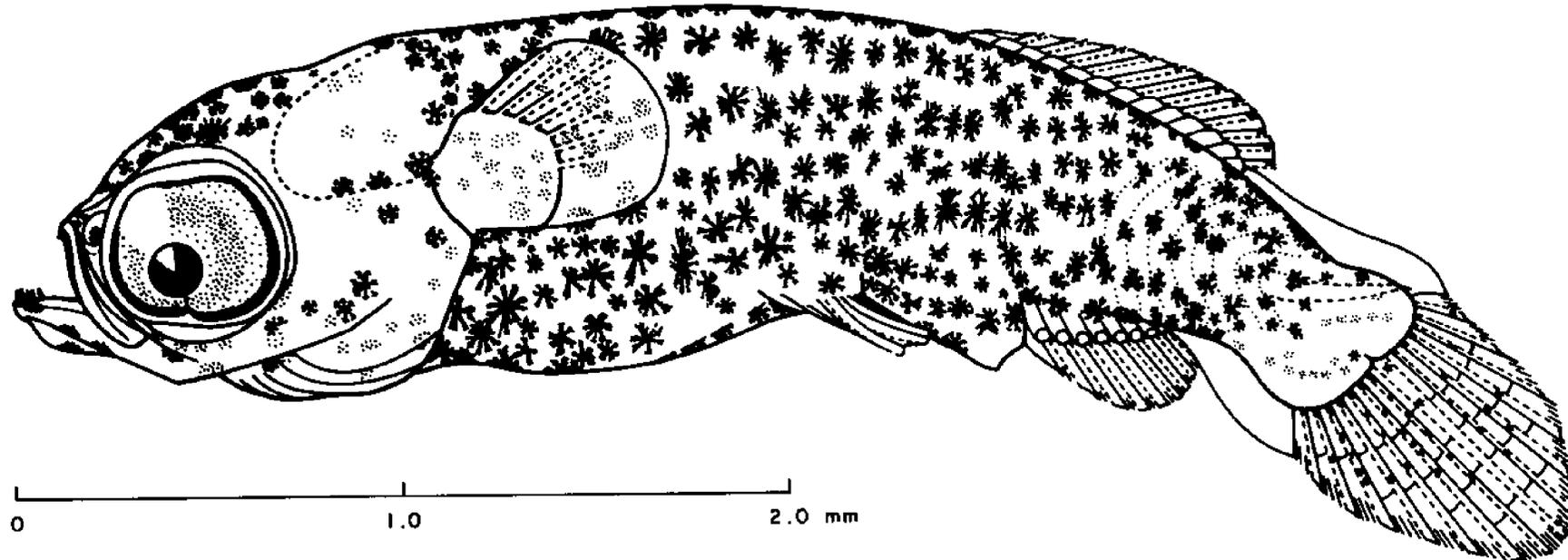


Figure 44. *Cypselurus* sp. 1, 3.6 mm SL

By ca. 4.5 mm SL the fin ray complement is completely formed, the pelvic fin rays have nearly extended to the anus, and the branchial region has become more heavily pigmented. The peduncle remains lightly pigmented.

Cypselurus sp. 2

Adult meristics

D: 14; A: 11; P: 11; V: 6; C: 15; myomeres: 22 + 18–19

Yolk sac larvae

Cypselurus sp. 2 larvae of ca. 3.4 mm SL (Figure 45) are more slender than *Cypselurus* sp. 1 larvae and have large eyes, a short snout, and an appreciable amount of yolk remaining. The typical rounded caudal fin is formed, but the dorsal and anal fin rays are unossified. The pelvic fin is nearly completely formed, and perhaps one-half (i.e., seven) of the adult complement of pectoral fin rays is discernible. One to a few external melanophores overlie the midbrain region; others are scattered dorsally and laterally over the gut. Internal melanophores sometimes lie along the distal edge of the peduncle. Trunk pigment is confined to double rows of melanophores along the dorsal and ventral midlines, with the

dorsal pigment usually originating at about myomere six or seven, and both usually extending caudad onto the peduncle (Figure 45).

Larvae

The characteristics of the largest larvae sampled during the study, (ca. 4 mm SL) had changed little from the yolk sac stage. Dorsal, anal, and pelvic fin rays are ossified, but the pectoral fin is still incomplete. The pelvic fin rays extend nearly to the level of the anus. A few more melanophores are present near the symphysis of the cleithra.

Identification

In addition to the *Cypselurus* spp. above, larvae of two other *Cypselurus* spp. and *Parexocoetus brachypterus* can be recognized at present. Of these, *P. brachypterus* is the more common.

P. brachypterus is moderately slender, with a short snout and large eyes, and has a gut extending about two-thirds the length of the body. Fin ray counts are: D: 13; A: 13–14; P: 13. These are completely formed by ca. 3.5 mm SL. Larvae of this size are heavily pigmented dorsally (except for the entire dorsal

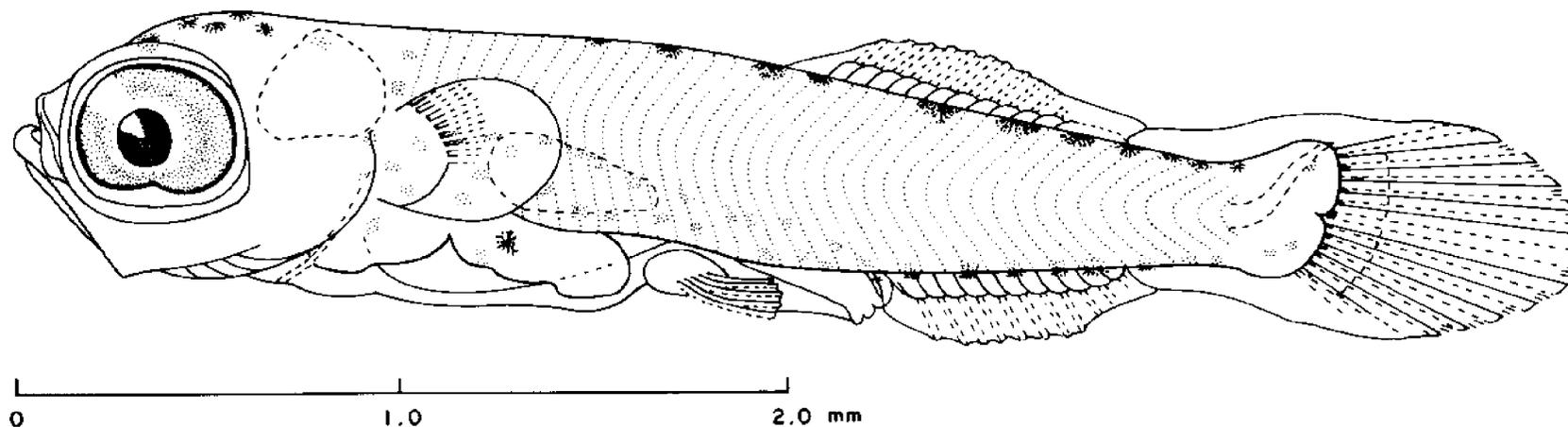


Figure 45. *Cypselurus* sp. 2, 3.4 mm SL. (Note yolk overlying gut anteriorly.)

midline which lacks pigment) and laterally on the preanal myomeres. Postanal pigmentation is heavy dorsally and ventrally, with a series of melanophores along the midlateral line and a few others along the myosepta. The peduncle is usually unpigmented. The gut is heavily pigmented dorsally and anteriorly in the cleithral area. The head is heavily pigmented except for the lower jaw, gular membrane, and branchial region.

By ca. 7 mm SL the pectoral fin rays have lengthened only to the level of the pelvic origin, and the pelvic fin rays extend to the level of the anus. The caudal fin is typically exocoetid. The body is uniformly heavily pigmented, except for the lower jaw, gular membrane, and branchial region which are lightly pigmented, and the peduncle which remains unpigmented.

Cypselurus spp. 3 and 4 resemble *Cypselurus* sp. 2, except that the first two have a middorsal melanophore series. *Cypselurus* sp. 4 lacks the ventral postanal pigment, but has a few myoseptal melanophores anteriorly. Fin ray counts for *Cypselurus* sp. 3 are: D: 4, A: 11–12. Fin ray counts for *Cypselurus* sp. 4 are: D: 15; A: 10. The pectoral and pelvic fins were not fully formed in specimens sampled during this study, even though the larger *Cypselurus* sp. 3 had very long pelvic and pectoral fins.

Exocoetid larvae resemble belonid, hemirhamphid, scomberesocid, and mugilid larvae. However, belonids, hemirhamphids, and scomberesocids are more elongate than most exocoetids (*Oxyporhamphus* is the exception) and have more myomeres (usually 35 to 50 in exocoetids and more than 50 in the others). Mugilids are easily distinguished by their lower (24) myomere counts and by the position of their fins, when present. Mugilids have no fin rays at sizes below ca. 5 mm SL.

Literature

Breder, Jr., and Rosen (1966), D'Ancona (1931), Hubbs and Kampa (1946), Uchida et al. (1958)

ATHERINIDAE

Pranesus insularum (iao)

Adult meristics

D: VI + I, 11–12; A: I, 17; P: 14–15; V: I, 5; C: 17; vertebrae: 42–43

Eggs

P. insularum eggs are spherical and attached to a substrate by long tendrils covering the chorion. Nearly ripe ovarian eggs are 1.05 to 1.42 mm in diameter, with many small oil droplets (Chase, 1969).

Yolk sac larvae

Throughout their larval life, *P. insularum* are long and slender, with a very short coiled gut, a myomere formula of 5 + 37–38, and a characteristic row of three large external melanophores overlying the mid- and hindbrain region (Figures 46 and 47). Larvae are relatively well-developed at hatching (ca. 4 mm SL), with pigmented eyes, functional jaws, caudal fin anlage, and all characteristic features. Also, a small amount of yolk is present and internal melanophores overlie the gut dorsally.

Larvae

Morphological changes between hatching and ca. 5.5 mm SL (Figure 46) are small: dorsal and anal fin anlagen appear; the pectoral fins remain quite small; and three branchiostegal rays are discernible. The notochord remains straight.

Pigmentation changes more extensively: the typical head pigment is supplemented by an internal melanophore at the center of the operculum and another at the bottom of the otic capsule. The gut becomes heavily pigmented dorsally and dorsolaterally, and a melanophore lies ventrally on the hindgut near the anus. One to four melanophores lie on the dorsal midline, the first at myomere four or five and others extending no further caudad than the origin of the dorsal fin anlage. The dorsal midline of the peduncle is pigmented. One to four melanophores lie on the midlateral line between the dorsal fin origin and the peduncle (Figure 46).

By ca. 9 mm SL the caudal fin is fully developed and the anal and second dorsal fins are nearly completely formed although the first dorsal fin, pelvic fins, and pectoral rays have not begun forming yet. Branchiostegal rays number five.

An additional melanophore appears under the operculum and in the otic capsule. The gut is completely pigmented, except for a small ventral area in some specimens. Two or more melanophores lie along the dorsal midline and one or more lie along the midlateral line between the origin of the second dorsal and the peduncle. Three melanophores are embedded over the notochord just anterior to the peduncle.

At ca. 10.5 mm SL the anal and second dorsal fins are fully developed and four pectoral rays are discernible, but the pelvic fins and the first dorsal fin are absent. The number of midlateral melanophores increases, but the series remains bounded anteriorly by the origin of the second dorsal and posteriorly by the peduncle. The internal series overlying the notochord has expanded to include the entire notochord. A pair of internal melanophores underlies the urostyle.

The pelvic fins and first dorsal fin are formed at ca. 14.5 mm SL. The pelvic fins are located anteriorly, originating at myomere nine. The first and second dorsal fins are separated by about six myomeres. The gut is beginning to elongate, giving a myomere formula of 8 + 35.

The head pigment includes the characteristic three melanophores; melanophores on the lower jaw, at the nostrils, and under the entire operculum; a pair internally over the forebrain; and others surrounding the hindbrain. The gut is entirely pigmented. The midlateral series extends caudad from the level of the origin of the first dorsal fin. A pair of elongate melanophores lies along the distal edge of the peduncle.

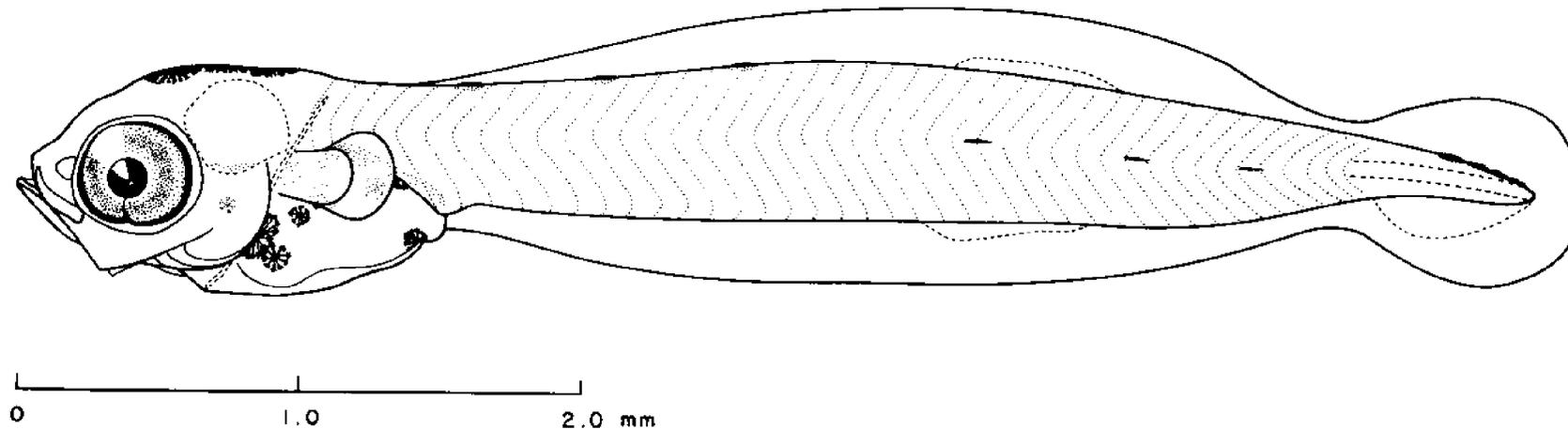


Figure 46. *Pranesus insularum*, 5.4 mm SL

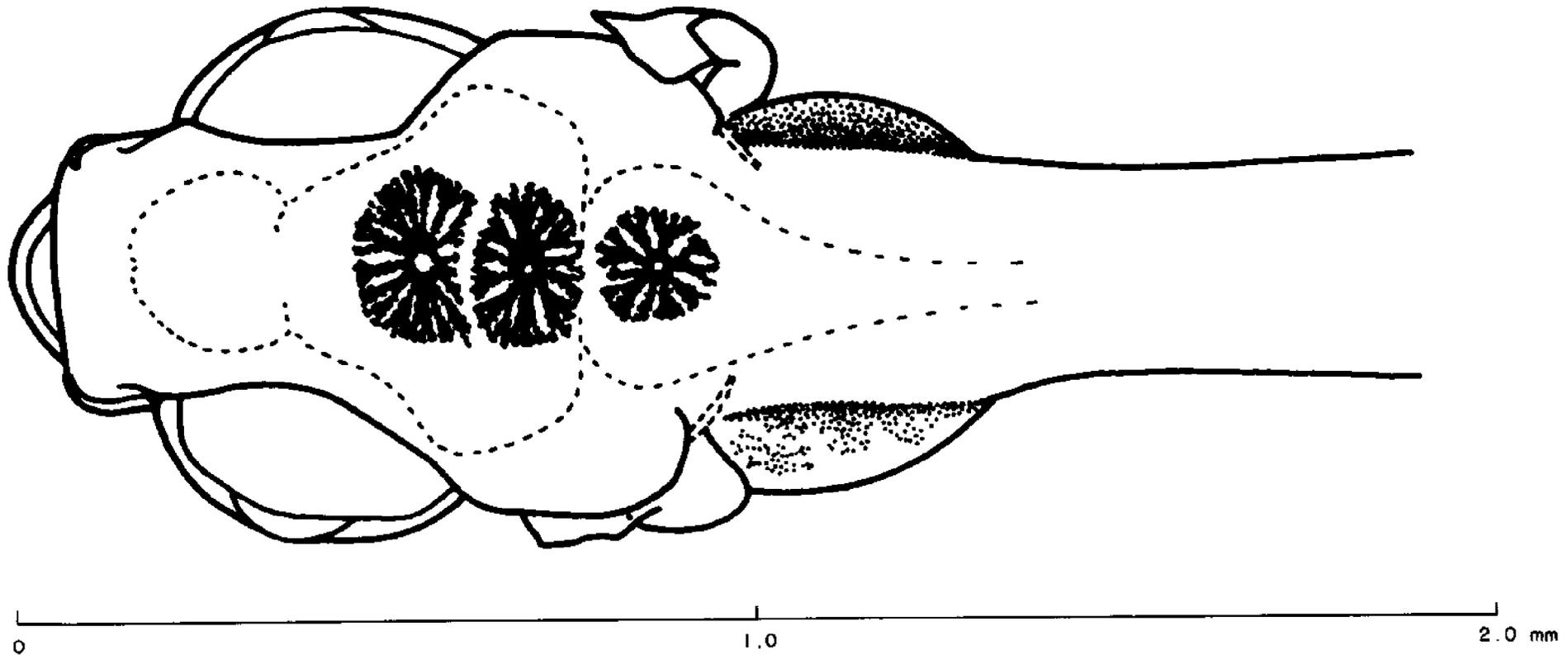


Figure 47. *Pranesus insularum*, 5.4 mm SL, dorsal view of head

Iso hawaiiensis

Adult meristics

D: IV–V + 1, 16; A: I, 22–24; P: 12–13; V: I, 5; C: 17; vertebrae: 35–38

Eggs

I. hawaiiensis eggs have not been described in the literature. They probably resemble those of *P. insularum*.

Larvae

I. hawaiiensis is elongate, but has a deeper body than *P. insularum*, with a short, coiled gut. The myomere formula throughout most of the larval life is 5 + 30–33 (Figure 48). The snout is very short and the mouth quite oblique. The characteristic head pigment consists of a single expanded melanophore overlying the midbrain region and one or two much smaller ones above the hindbrain

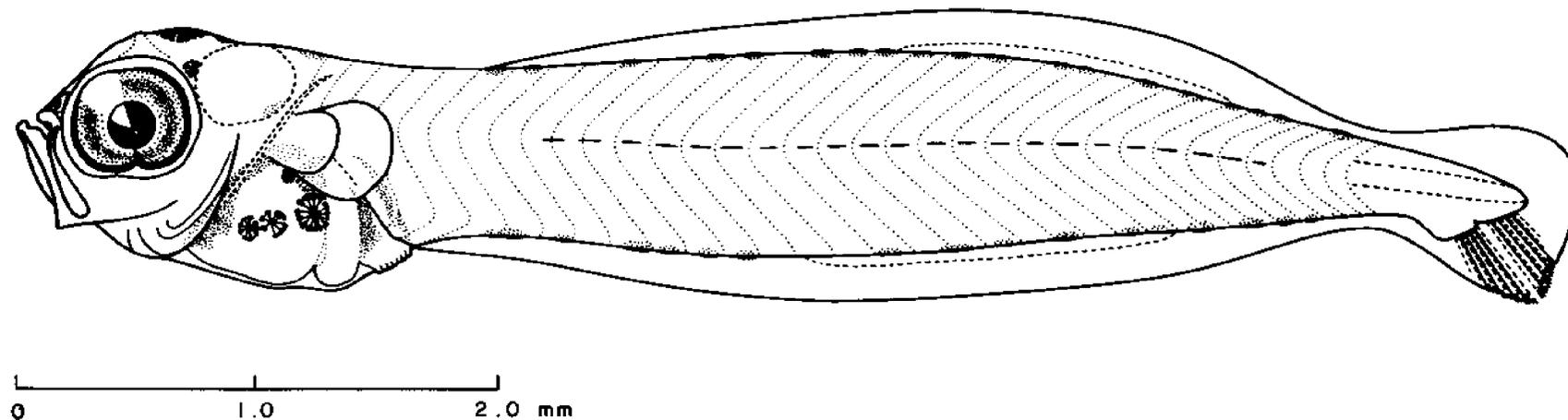


Figure 48. *Iso hawaiiensis*, 6.2 mm SL

(Figure 49). The melanophore series extending the length of the dorsal, lateral, and ventral midlines are typical at all sizes, although any series (especially lateral and ventral) may be reduced and the ventral series may be absent in a given fish.

Larvae of ca. 4.5 mm SL are beyond the yolk sac stage and have dorsal, anal, and caudal anlagen. They also have four branchiostegal rays. The middorsal melanophore series extends from the first or second myomere to about one or two myomeres anterior of the peduncle, the ventral series from the anus to the same position caudad, and the midlateral series from about the origin of the dorsal anlage to about three or four myomeres anterior of the peduncle. The gut is pigmented dorsally.

By ca. 6 mm SL (Figure 48) few changes occur: 10 caudal rays are discernible although flexion has not yet begun; the gut pigment has extended anteriorly and laterally; the midlateral melanophore series has extended cephalad to within a few myomeres of the level of the anus; and melanophores are present on the nostrils and otic capsules.

The caudal fin is formed in ca. 7.5 mm SL larvae, and the anal and second dorsal fins are nearly developed (these are fully formed at ca. 8.5 mm SL). The pelvic, pectoral, and first dorsal fins are absent. The gut is heavily pigmented laterally. Further development proceeds as in *P. insularum*.

Identification

P. insularum is similar to *Iso hawaiiensis*. These may be distinguished by myomeres (35 to 38 in *I. hawaiiensis*, 42 to 43 in *P. insularum*), by the higher dorsal and anal fin ray counts of *I. hawaiiensis* (or the much longer anlagen in smaller larvae), by the heavier pigmentation of *I. hawaiiensis* (including a series of melanophores along the ventral midline which *P. insularum* lacks), by differences in the characteristic head pigmentation patterns (cf. Figures 47 and 49), and by the more oblique mouth and more robust body of *I. hawaiiensis*.

Small *P. insularum* and *Enchelyurus brunneolus* (Blenniidae) larvae superficially resemble one another. These may be distinguished most easily by numbers of myomeres (35 in *E. brunneolus*), by the long spine at the preopercular angle of *E. brunneolus*, and by the midventral pigment posteriorly on the tail of *E. brunneolus*.

Literature

Chase (1969), Kuntz and Radcliffe (1917), Vialli (1937a)

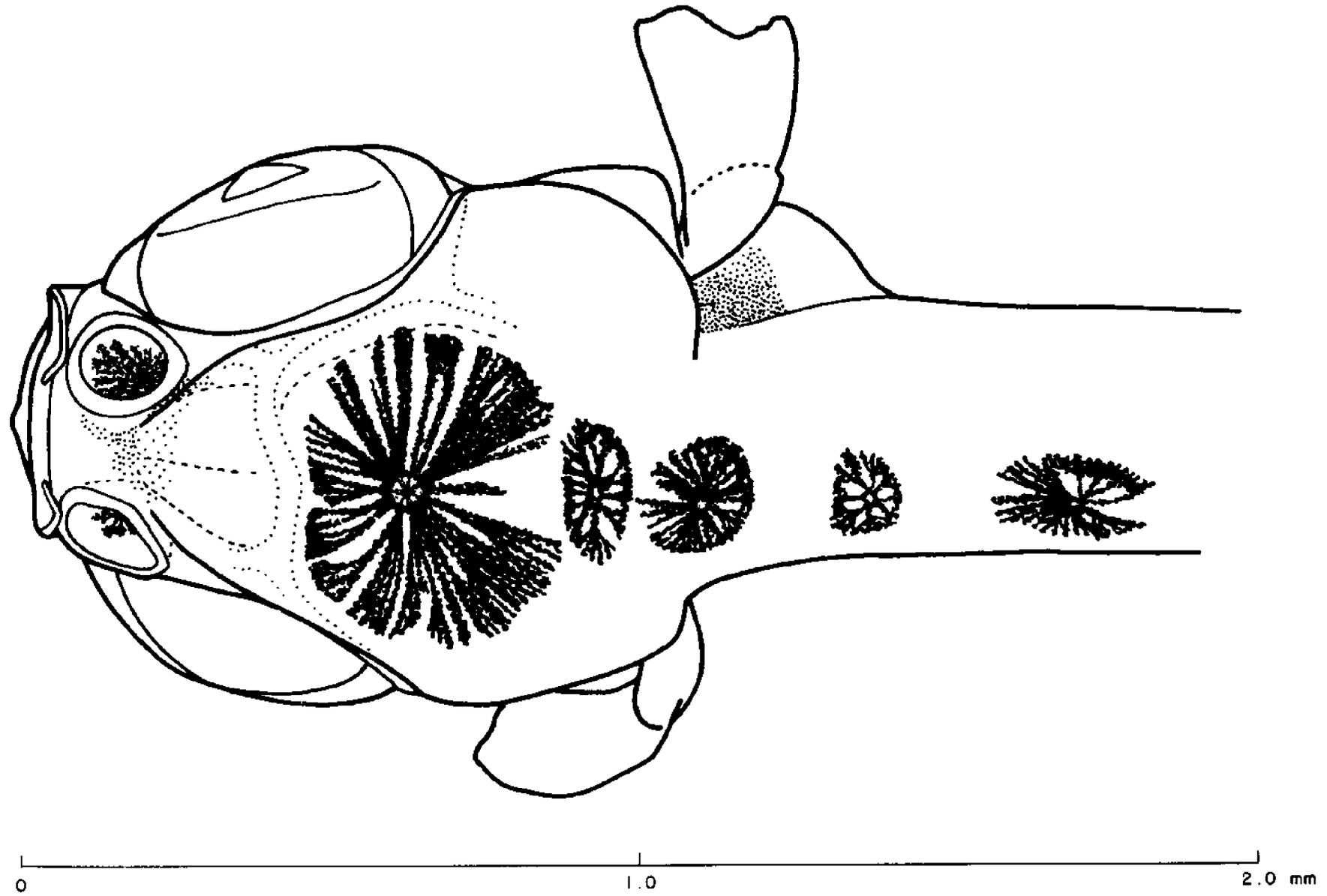


Figure 49. *Iso hawaiiensis*, 6.9 mm SL, dorsal view of head

KYPHOSIDAE

Kyphosus vaigiensis (nenué)

Adult meristics

D: XI, 14; A: III, 12–13; P: 18–20; V: I, 5; C: 17; vertebrae: 26

Eggs

K. vaigiensis eggs are planktonic, spherical, 1.0 to 1.1 mm in diameter, with a single 0.25-mm oil droplet. They are illustrated as *K. cinerascens* in Watson and Leis (1974).

Larvae

K. vaigiensis larvae lack outstanding features. They have small preopercular spines at sizes larger than ca. 4 mm SL and a myomere formula of 10 + 16 at all sizes. Single rows of expanded melanophores lying along the dorsal and ventral midlines are retained throughout most of the larval period.

A reared 3-mm SL larva (actually a yolk sac larva since it retains the oil droplet) has typical characteristics (Figure 50). It has pigmented eyes and functional jaws. The gas bladder is present anteriorly, but is usually difficult to see in small specimens. Fin anlagen are absent. A small melanophore lies at the tip of the snout, another internally at the anterior center of the forebrain, and four externally in a diamond-shaped pattern over the mid- and hindbrain region. A few large melanophores extend along the dorsal midline from myomere 1 to myomere 22 or 23. The ventral midline series likewise extends from just behind the anus to myomere 22 or 23, with a series of much smaller melanophores continuing caudad onto the peduncle. The posterior two or three melanophores in both midline series are often greatly expanded and may overlap laterally to form a band around the tail. (In living specimens a band of xanthophores occurs here in addition to the melanin.) A series of melanophores overlies the gut dorsally, the dorsal surface of the gas bladder is pigmented, and one or two melanophores are located anteriorly on the oil droplet. A melanophore lies under the cleithrum on each side, just above the level of the pectoral base.

Pigment changes, with increasing size, include the proliferation of melanophores along the dorsal and ventral midlines, dorsally and laterally over the gut, on top of the head, and on the snout and upper jaw. Dorsolateral melanophores

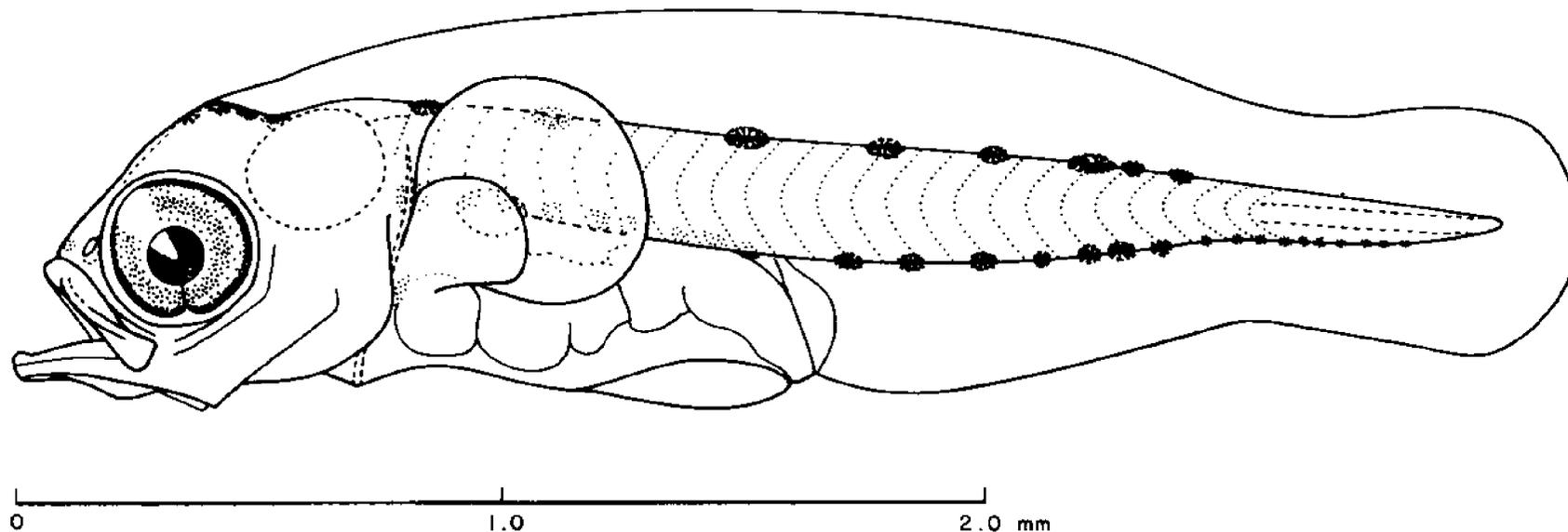


Figure 50. *Kyphosus vaigiensis*, 3.0 mm SL. (Note oil droplet just below level of pectoral base.)

appear along the body synchronously with, or slightly in advance of, fin anlagen (ca. 4.5 mm SL). Larval development is further described in Watson ["Larval development of the nenu, *Kyphosus vaigiensis* (Quoy and Gaimard)," in preparation].

Identification

Myomere counts and the characteristic dorsal and ventral melanophore series allow ready identification of *Kyphosus* larvae. Unfortunately, at least two species, *K. vaigiensis* and *K. biggibus*, occur in Hawaiian waters. How the larvae differ is unknown; the identification of *K. vaigiensis* was made possible by rearing larvae from eggs.

Literature

Moore (1962), Uchida et al. (1958), Watson ["Larval development of the nenu, *Kyphosus vaigiensis* (Quoy and Gaimard)," in preparation], Watson and Leis (1974)

MULLIDAE

Mullid sp.

Adult meristics

D: VII + I, 8; A: I, 7; V: I, 5; C: 15; myomeres: 24

Eggs

Mullid eggs from Hawaiian waters have not been described in the literature. Marinaro (1971) attributed a planktonic, spherical, 0.8 mm diameter egg with a single oil droplet to *Mullus* sp.

Larvae

Mullid larvae are slender, have a short gut—particularly at smaller sizes, lack spines on the head, and have a characteristic triangular melanophore pattern on the head, a series of melanophores embedded over the notochord, and a series along the lateral and ventral midlines.

Larvae of ca. 3.5 mm SL have pigmented eyes, functional jaws, and a myomere formula of 5 + 19. Pelvic fin buds and dorsal, anal, and caudal fin anlagen are absent. The typical triangular melanophore pattern is present in the midbrain region: an external melanophore lies over the center of each midbrain hemisphere and a third lies posteriorly between the hemispheres. A series of 3 to 12 (most often 8 to 11) melanophores lies along the postanal ventral midline, usually extending from myomere 13 to the peduncle. A few internal melanophores overlie the notochord, and the midlateral series is restricted to three or fewer melanophores on adjacent myomeres, most often between myomeres 19 and 22. This series may be absent in some specimens. The gut is pigmented dorsally.

At ca. 4 mm SL the dorsal and anal fin anlagen begin to develop and by ca. 5 mm SL (Figure 51) the caudal fin anlage is present, eight caudal fin rays are discernible, and the notochord is beginning to flex. The myomere formula is 6 + 18. The midventral melanophore series is quite variable, but some pigment is always present posterior to the origin of the anal anlage. The midlateral series usually consists of three or four melanophores, with one or two on the middorsal line above the midlateral series in some specimens. A few more melanophores overlie the notochord and scattered melanophores extend laterally over the gut. The typical triangular melanophore pattern in the midbrain region remains (Figure 52). The gut becomes further elongated by ca. 6 mm SL: the myomere formula

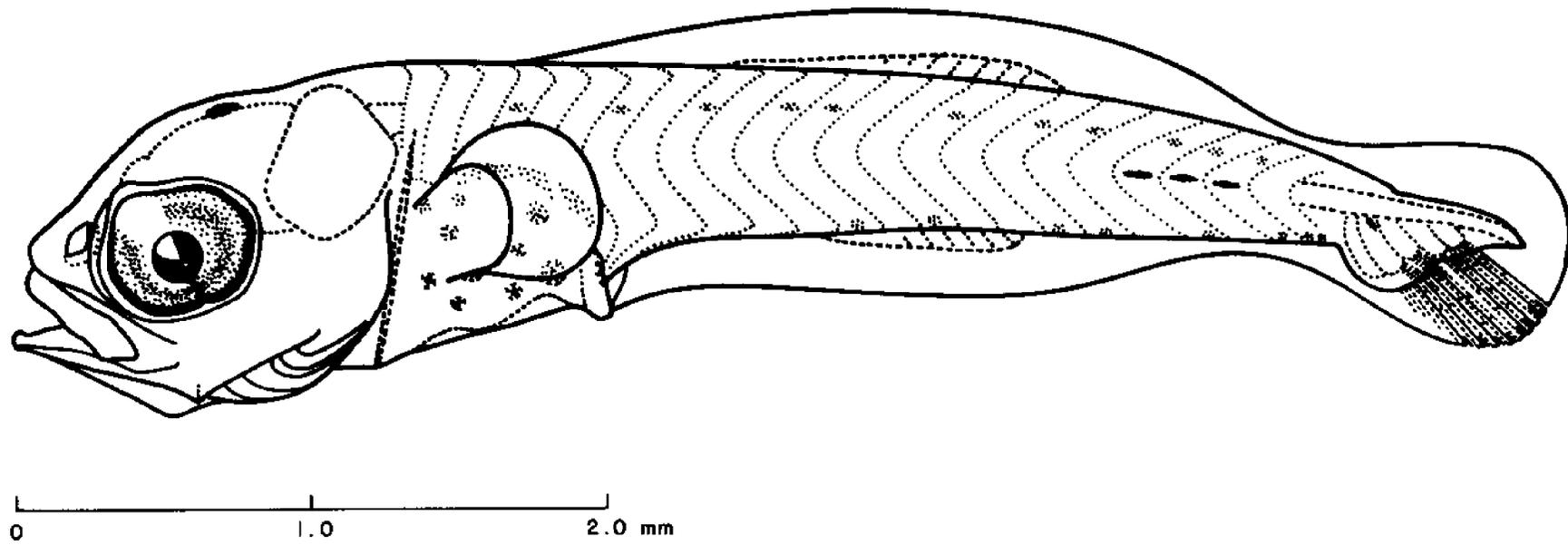


Figure 51. Mullid sp., 5.1 mm SL

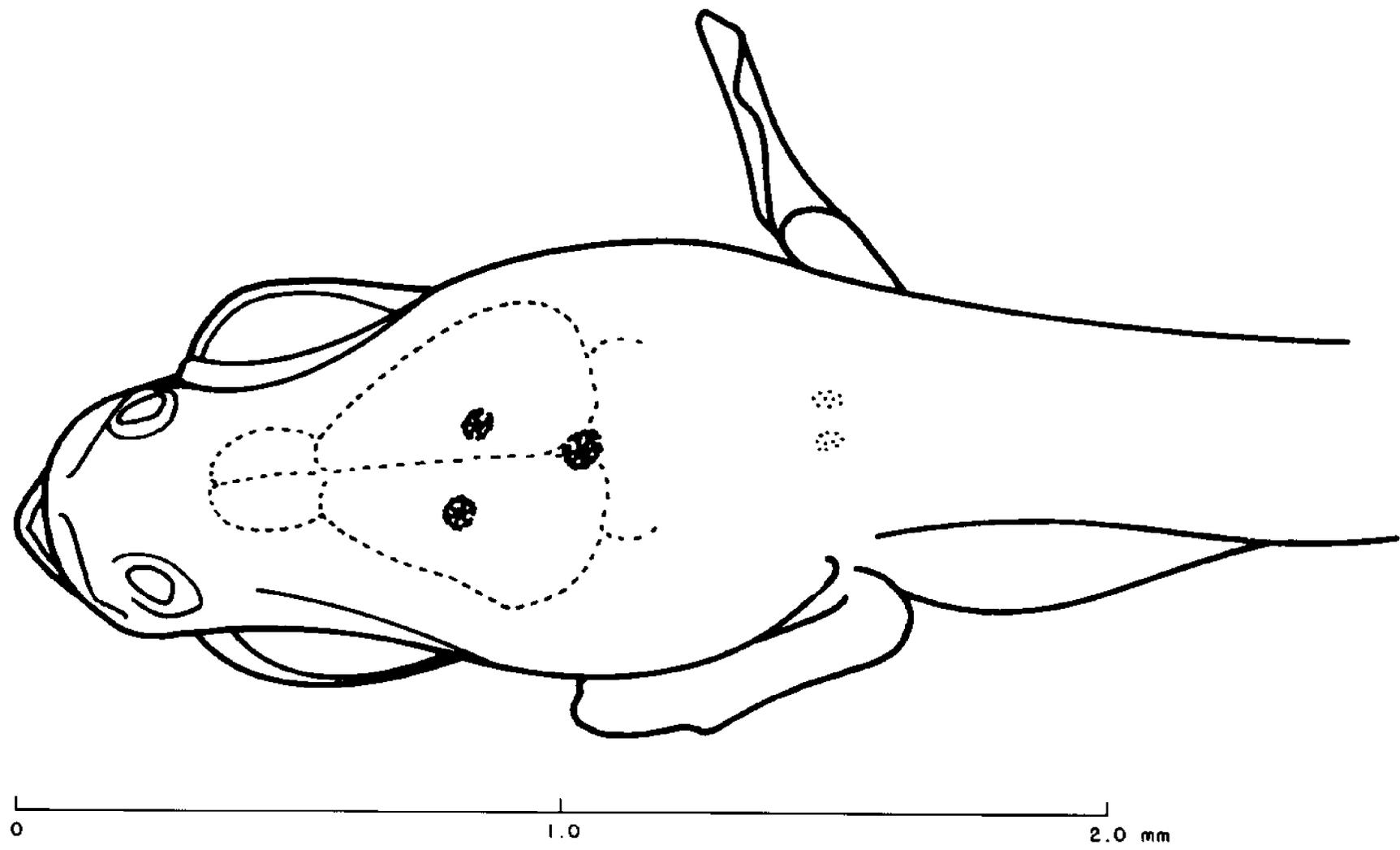


Figure 52. Mullid sp., 5.1 mm SL, dorsal view of head

is 8 + 16. The notochord is flexed, the anal and primary caudal fin rays are ossified, and the dorsal fin is partially ossified (D: IV + 9 elements). The midlateral melanophore series extends from the level of the anus onto the peduncle, the midventral series extends from the origin of the anal fin to the peduncle, and two rows of melanophores lie on either side of the dorsal midline from just behind the head to the peduncle. The head is more heavily pigmented but the characteristic three melanophores remain visible.

At ca. 7 mm SL, larvae are beginning to acquire pectoral fin rays (P: 5–7). All dorsal elements are present, although the spine in the second dorsal fin is indistinguishable from the rays. An additional row of dorsolateral melanophores is developing along the anterior body, and the branchial region is becoming heavily pigmented internally.

The main changes occurring in larvae from 7 to 8 mm SL (Figure 53) are the final development of the pectoral fins and the increasing pigmentation. The myomere formula is 10 + 14. The midlateral melanophore series extends the length of the body, three or more series of melanophores lie dorsally and dorsolaterally along each side of the midline, and myoseptal melanophores are developing, particularly on the anterior epimeres. The characteristic three midbrain melanophores remain visible (Figure 54).

Identification

Mullid larvae are recognized by the short gut, the characteristic head pigment, the midventral and midlateral pigment, and the melanophores overlying the notochord. Larger specimens may be identified by fin ray counts as well. They are unlikely to be confused with larvae of other families.

Distinction between species within the family has thus far been based on small differences in pigmentation. No Hawaiian larva has been attributed to a particular species, nor has it been determined that the larval types are monospecific. The number of mullid species in Hawaiian waters far exceeds the number of larval types recognized during this study.

Literature

Caldwell, M.C. (1962), Marinaro (1971), Montalenti (1937), Uchida et al. (1958)

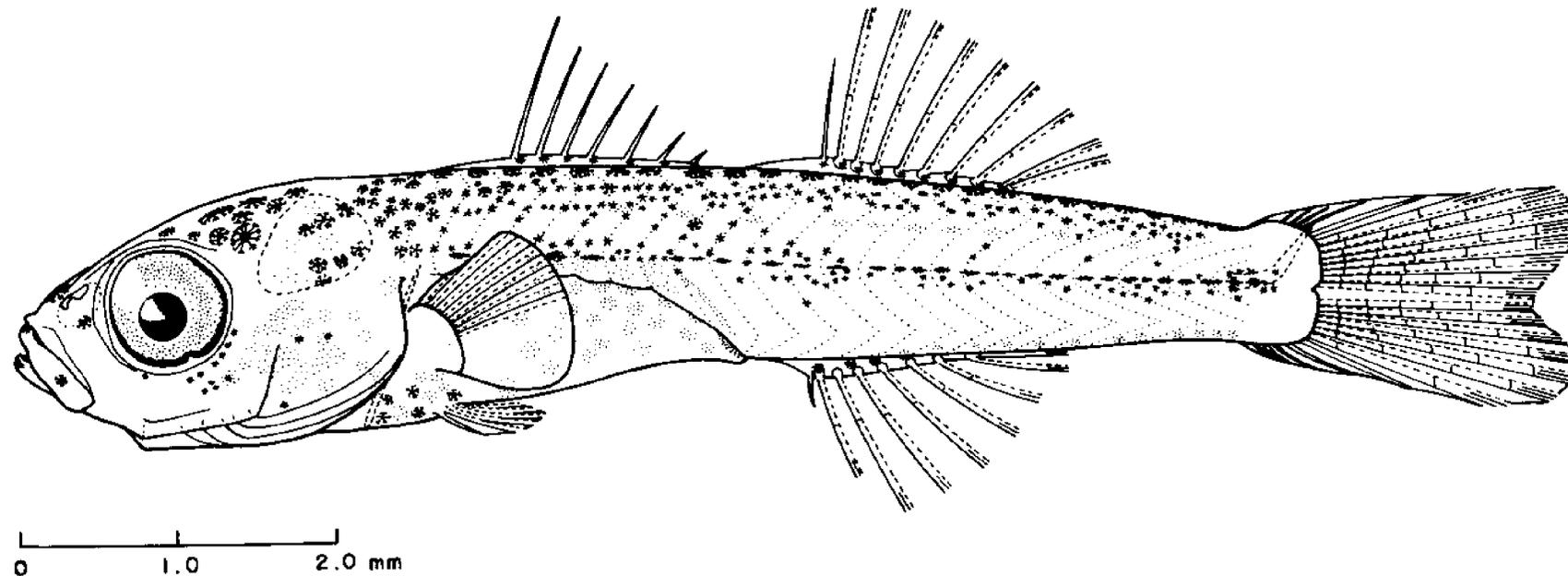


Figure 53. Mullid sp., 8.2 mm SL

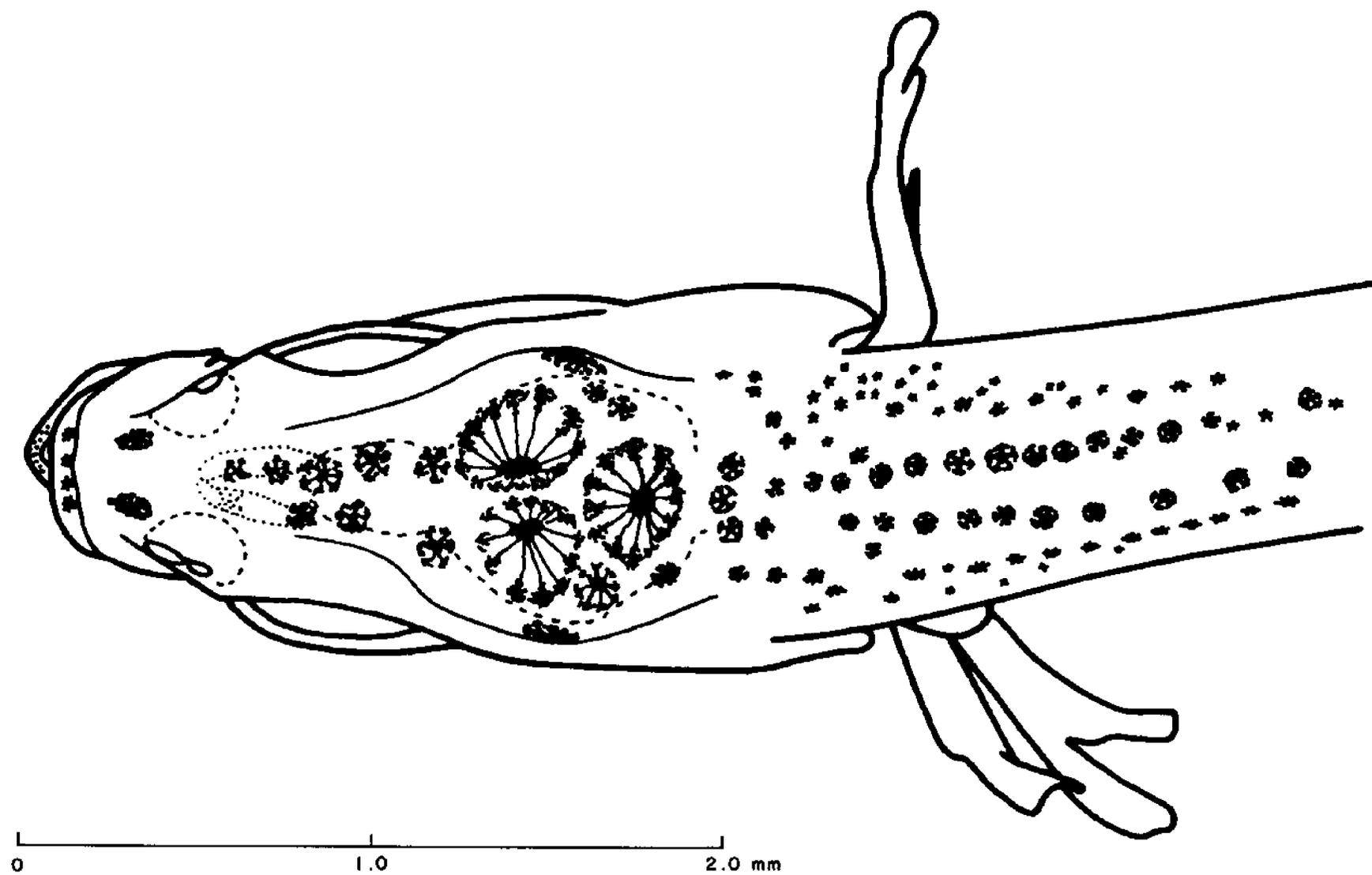


Figure 54. Mullid sp., 8.2 mm SL, dorsal view of head

SERRANIDAE

Serranid Sr-5 (Anthiinae)

Meristics

The following fin ray counts are for a 5-mm SL specimen. All fins are incomplete.

D: X, 16 (or XI, 15); A: 11 elements (probably III, 8); V: 1, 5; C: notochord just beginning to flex; myomeres: 24–25

Eggs

Serranid eggs from Hawaiian waters have not been described in the literature. Spherical pelagic eggs with a single oil droplet have been reported for

some genera in other localities (Kendall, 1972; Ukawa et al., 1966); these genera are not represented in Hawaii.

Larvae

Sr-5 larvae of ca. 2.5 mm SL (Figure 55) are moderately deep-bodied and nearly enclosed in a dermal sac. The gas bladder is conspicuous. The gut extends nearly one-half the length of the body, giving a myomere formula of 10 + 15. Caudal and anal fin anlagen are absent, but pelvic fin buds and the anlage of the spiny dorsal fin are present. A single spine is present at the angle of the preopercle. The dorsal surface of the gas bladder is pigmented, melanophores lie dorsally over the central gut region, and a single melanophore lies dorsally on the hindgut just above the anus. A single row of melanophores extends along the dorsal midline between myomere 8 or 9 and myomere 12 or 13. Melanophores lie on the midlateral line from the level of the center of the middorsal series to myomere 18 or 19. Two or three others lie in the anterior ventral finfold below the two midline series.

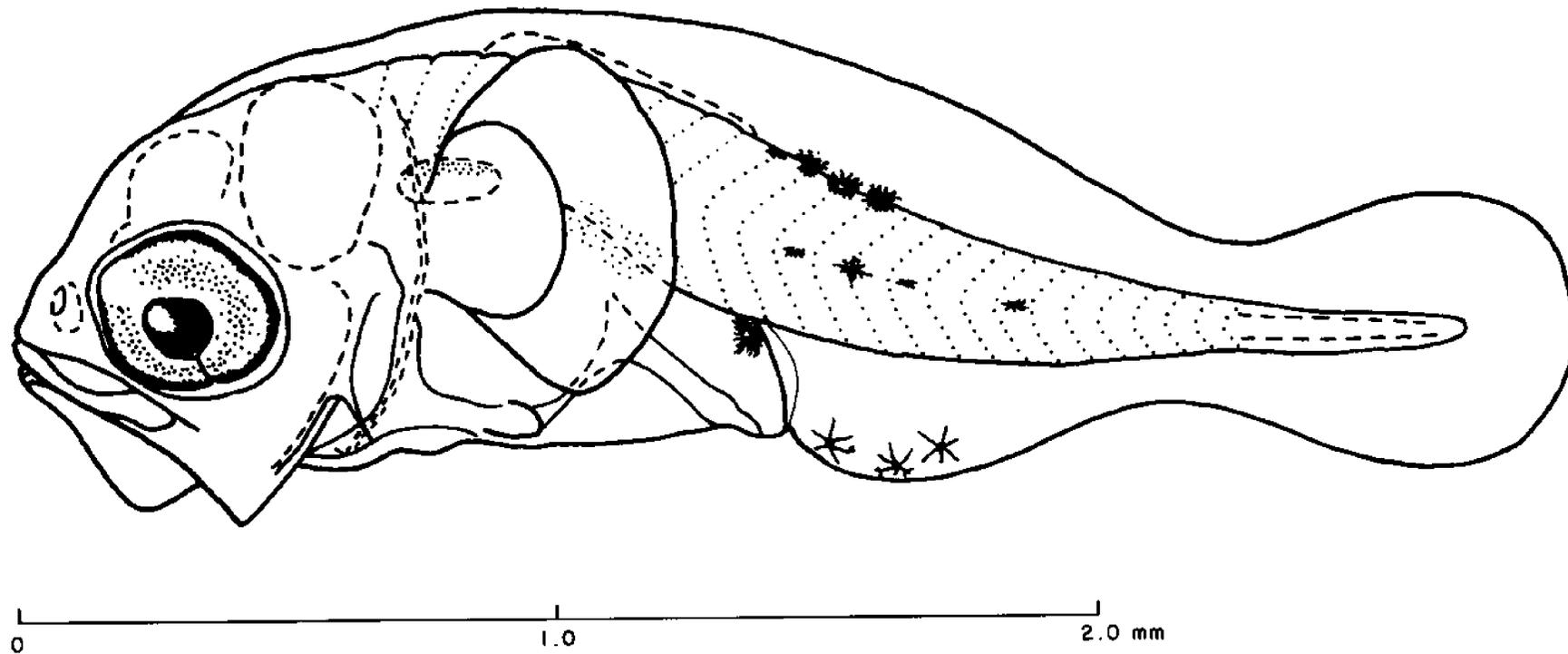


Figure 55. Serranid Sr-5, 2.7 mm SL

At ca. 3.5 mm SL the soft dorsal and anal fin anlagen are beginning to develop, three spines are present along the preopercle, and a single dorsal spine and large spine at each pelvic base are present. The caudal fin anlage is absent. The entire dorsal surface of the gut is pigmented, and the ventral melanophores now lie along the postanal midline near the terminus of the anal fin anlage.

At 4.3 mm SL four dorsal spines are present; the second of these is quite long. The caudal fin anlage is present although the notochord remains straight. Incipient dorsal, anal, pelvic, and caudal fin rays are discernible. Small teeth are visible in the upper jaw. The pigmentation is similar to that of smaller larvae, except that melanophores now lie along the developing pelvic fin rays, the mid-lateral and midventral melanophore series lie more caudad—at about the level of the posterior one-third of the anal fin, and the middorsal series is absent. An internal melanophore may overlie the notochord anteriorly.

Identification

Young larvae of some anthiine serranids (less than ca. 3.5 mm SL) resemble some small scorpaenids. The serranids differ by having a conspicuous preopercular spine which is not present in early scorpaenids. The serranids also have pelvic buds and the spiny dorsal fin anlage very early, while in the scorpaenids, the soft dorsal anlage develops first and at a larger size.

Lutjanid larvae closely resemble serranid larvae, but may be distinguished at larger sizes by fin ray counts (usually 9 to 11 soft dorsal fin rays in Hawaiian lutjanids vs. 13 to 21 in serranids). It may also be possible to distinguish between them by determining whether the posterior maxillary slips under the preorbital (Lutjanidae) or not (Serranidae). Smaller lutjanid larvae may be distinguished from at least Sr-5 by their lack of a dermal sac or sac-like finfold.

In Hawaii the family Serranidae is represented primarily by members of the Anthiinae. Larvae of other serranid subfamilies (e.g., Epinephelinae) differ substantially from the anthiines, and other literature sources (e.g., Aboussouan, 1972) should be consulted when attempting to identify them.

Literature

Aboussouan (1972), Bertolini (1933b), Fourmanoir (1971a), Kendall (1972), Presley (1970), Ukawa et al. (1966)

APOGONIDAE

Foa brachygramma (upapulu)

Adult meristics

D: VII + I, 9; A: II, 7–8; P: 11–12; V: I, 5; C: 15; vertebrae: 24

Eggs

F. brachygramma egg masses are orally brooded by the male. According to Breder, Jr., and Rosen (1966), this form of incubation appears to be characteristic of the family.

Yolk sac larvae

F. brachygramma larvae are a little less than 2.5 mm SL at hatching. They have pigmented eyes, functional jaws, and a small amount of yolk. They are rather slender and round-headed, but soon become deeper-bodied and less round-headed. Two or three expanded melanophores lie along the postanal ventral midline, a melanophore is located on the "yolk sac," and a pair of melanophores is situated on the hindgut above and below the anus. The pectoral fin is heavily pigmented along its distal margin.

Larvae

There is little change between day 4 larvae of ca. 2.5 mm SL (Figures 56 and 57) and the yolk sac stage larvae. Day 4 larvae remain slender, but their jaws are more elongate and the gas bladder is quite conspicuous. The myomere formula is 7 + 17. Fin anlagen are absent. A series of small melanophores lie midventrally on the peduncle. A single melanophore occurs on each side at the articular, and the pectoral pigment extends over the distal half of the pectoral fin (Figure 56). The gut and midventral melanophores are quite expanded (Figure 57).

By day 12, larvae of ca. 4.5 mm SL (Figure 58) are moderately deep-bodied and have pelvic fin buds and dorsal, anal, and caudal fin anlagen. The pectoral fins are moderately large, with eight to ten ossified rays. The spiny and soft dorsal fin anlagen are separate. Incipient dorsal and anal soft rays are discernible. Six incipient caudal fin rays are present, although the notochord remains straight. Three small spines can be seen at the preopercle. The myomere formula is 8 + 16. The midventral pigment has expanded into a series of internal melanophores, extending the length of the postanal midline. Pigment is retained on the articular, on the gas bladder, on the hindgut, and midventrally on the gut at the level of the

pelvic fin origin. A melanophore appears at the symphysis of the cleithra. An internal melanophore may overlie the notochord just behind the hindbrain. The distal one-third to one-half of the pectoral fin is heavily pigmented between the rays (Figure 58).

By ca. 9 mm SL the body is a little deeper and all fins are completely formed. Two preopercular spines are visible. The gut is fully elongate, giving a myomere formula of 10 + 14. The pigment remains essentially unchanged, except that the midventral series is reduced to one or two melanophores lying posterior to the anal fin.

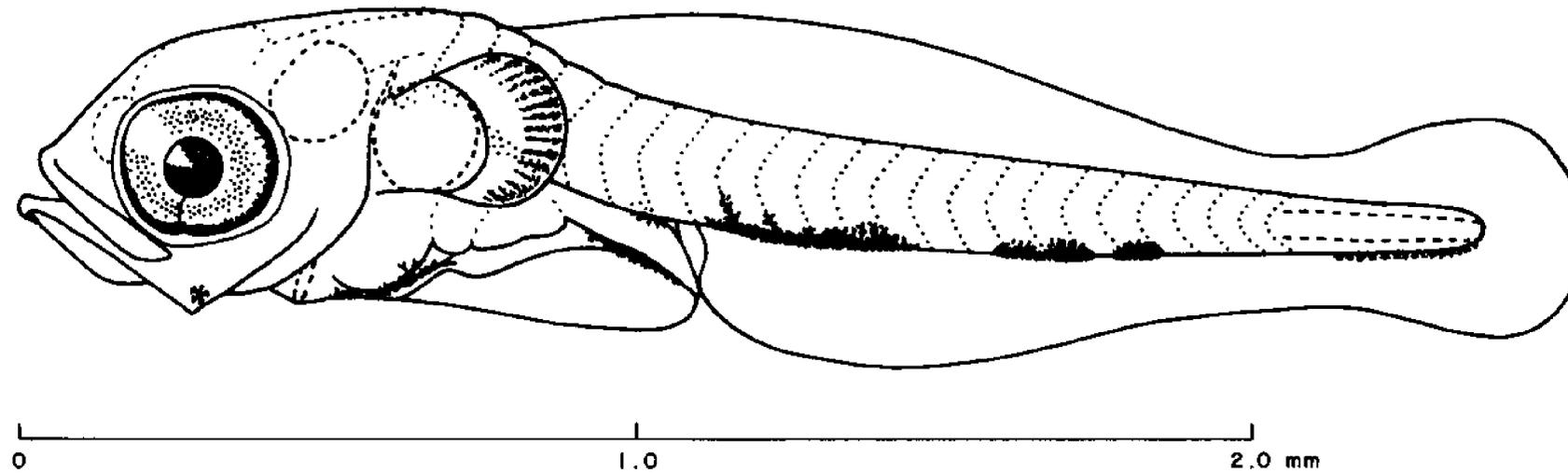


Figure 56. *Foa brachygramma*, day 4, 2.4 mm SL

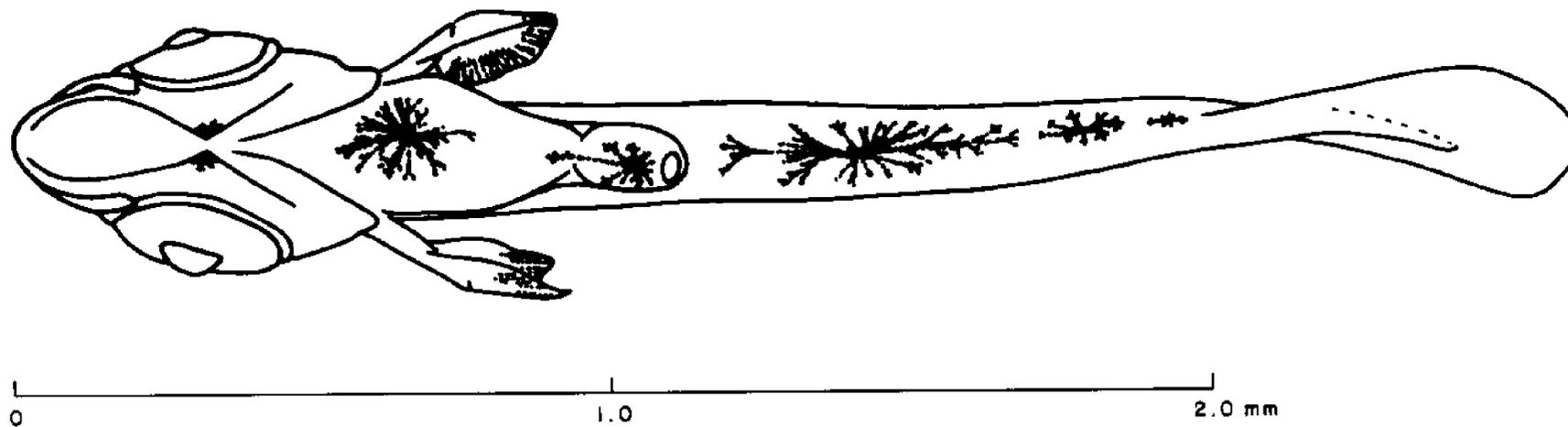


Figure 57. *Foa brachygramma*, day 4, 2.4 mm SL, ventral view

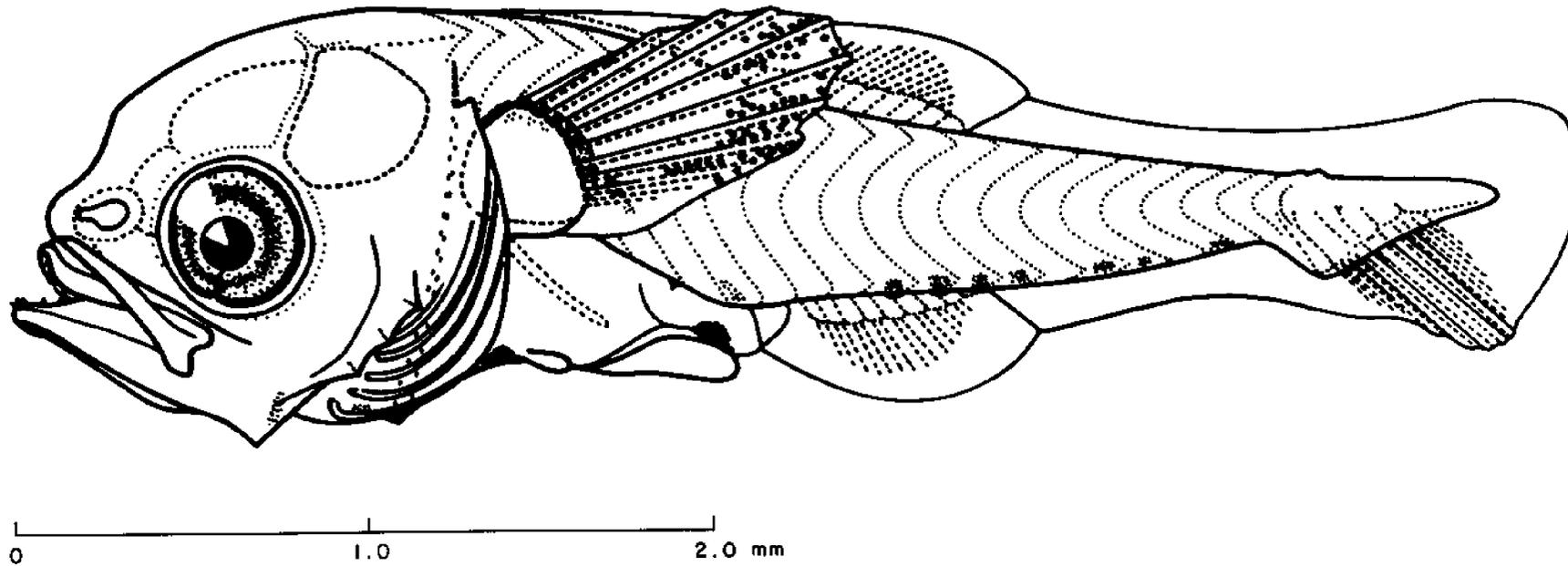


Figure 58. *Foa brachygramma*, day 12, 4.2 mm SL

Identification

Apogonid larvae are recognized by myomere counts and by the presence, in most cases, of pigment on the ventral side of the gut, along the postanal mid-ventral line, and along the distal margin of the pectoral fin. At larger sizes fin ray counts are helpful for identification. The gas bladder is usually quite prominent.

F. brachygramma is a typical apogonid with respect to the characteristics given above. However, small larvae are at times confused with small gobiids and pomacentrids. Both gobiids and pomacentrids usually have one or two more myomeres than apogonids, however. Gobiids may also have slightly longer guts than apogonids and are usually a little more slender, while pomacentrids are deeper-bodied with shorter guts. The gas bladder is usually smaller and located more anteriorly (if visible at all) in pomacentrids. Pomacentrids are typically heavily pigmented in the gut region and, to a lesser extent, on the head, but lack the pigmented pectoral fins and usually the midventral abdominal pigment of

apogonids. Most gobiids likewise lack the abdominal pigment of apogonids, and all gobiids lack the pectoral pigment. At larger sizes, the three families can be distinguished from each other by body proportions and fin ray counts.

Small apogonid larvae are difficult to distinguish from one another: identifying characteristics are usually limited to minor pigmentation differences. Among the small larvae only *F. brachygramma* can be attributed to a particular species at present. When fin rays are developed, identification is somewhat simpler.

Literature

Bertolini (1933a), Breder, Jr., and Rosen (1966), de Gaetani (1937), Fahay (1975)

CARANGIDAE

Carangids are well-represented in Hawaiian waters and their larvae are easy to recognize. They are deep to moderately deep-bodied, have 24 myomeres (except *Scomberoides*, which has 26), have serrated crests on the dorsal midline at the back of the head (except *Caranx mate*), have spiny preopercular margins, and have pigmentation along the dorsal, lateral, and ventral midlines (except occasionally at the smallest sizes when there are more). Metamorphic and later stage specimens have a characteristic anal fin spine formula of II + I. The following four species are among the most common carangid larvae taken in near-shore Hawaiian waters.

Caranx (=Atule) mate (omaka)

Adult meristics

D: VIII + I, 21–23; A: II + I, 17–19; P: i, 20–21; V: I, 5; C: 17; vertebrae: 24.

In this, and all following carangid dorsal fin counts, the small, embedded, forward-pointing first dorsal spine is omitted.

Eggs

C. mate eggs are planktonic, spherical, and 0.70 to 0.75 mm in diameter, with a single oil droplet (0.20 mm in diameter) and a weakly segmented yolk. Egg development is described and illustrated in Miller and Sumida (1974); diel and seasonal abundance are discussed in Watson and Leis (1974).

Larvae

Only illustrations of *C. mate* larvae are included here (Figures 59 through 61); a detailed description of development is given in Miller and Sumida (1974).

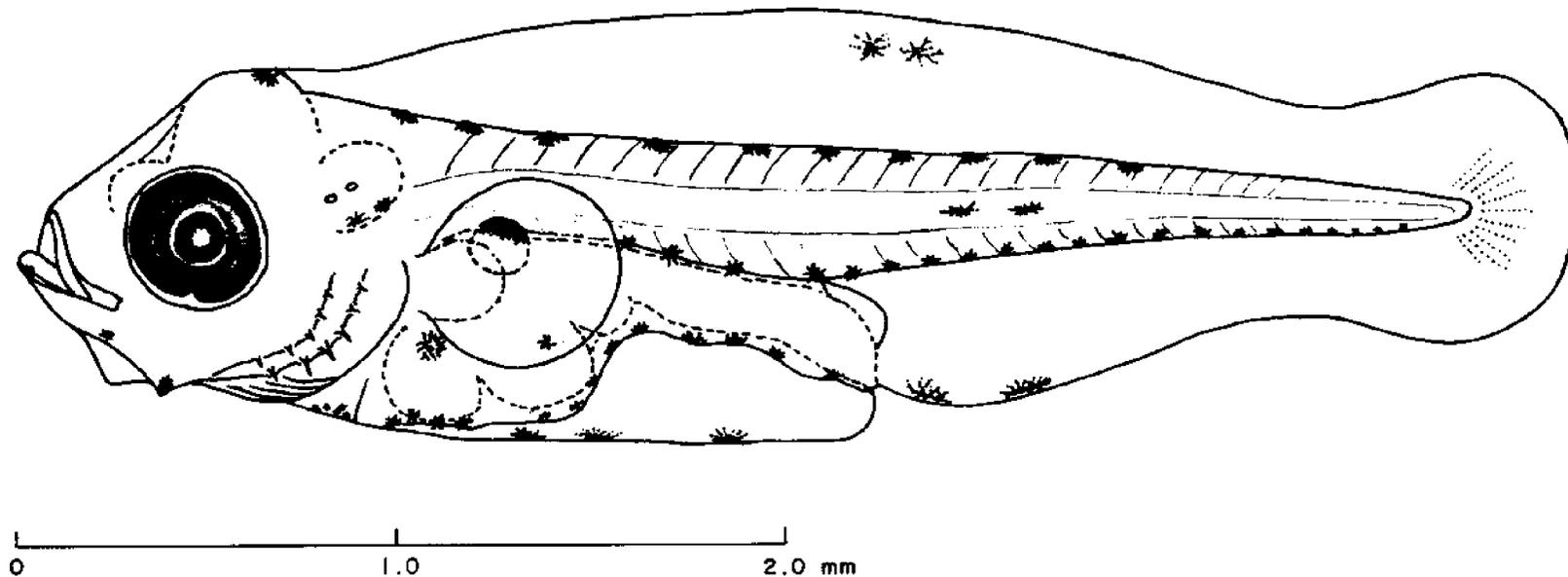


Figure 59. *Caranx (=Atule) mate*, day 6, 3.1 mm SL. (From Miller and Sumida, 1974)

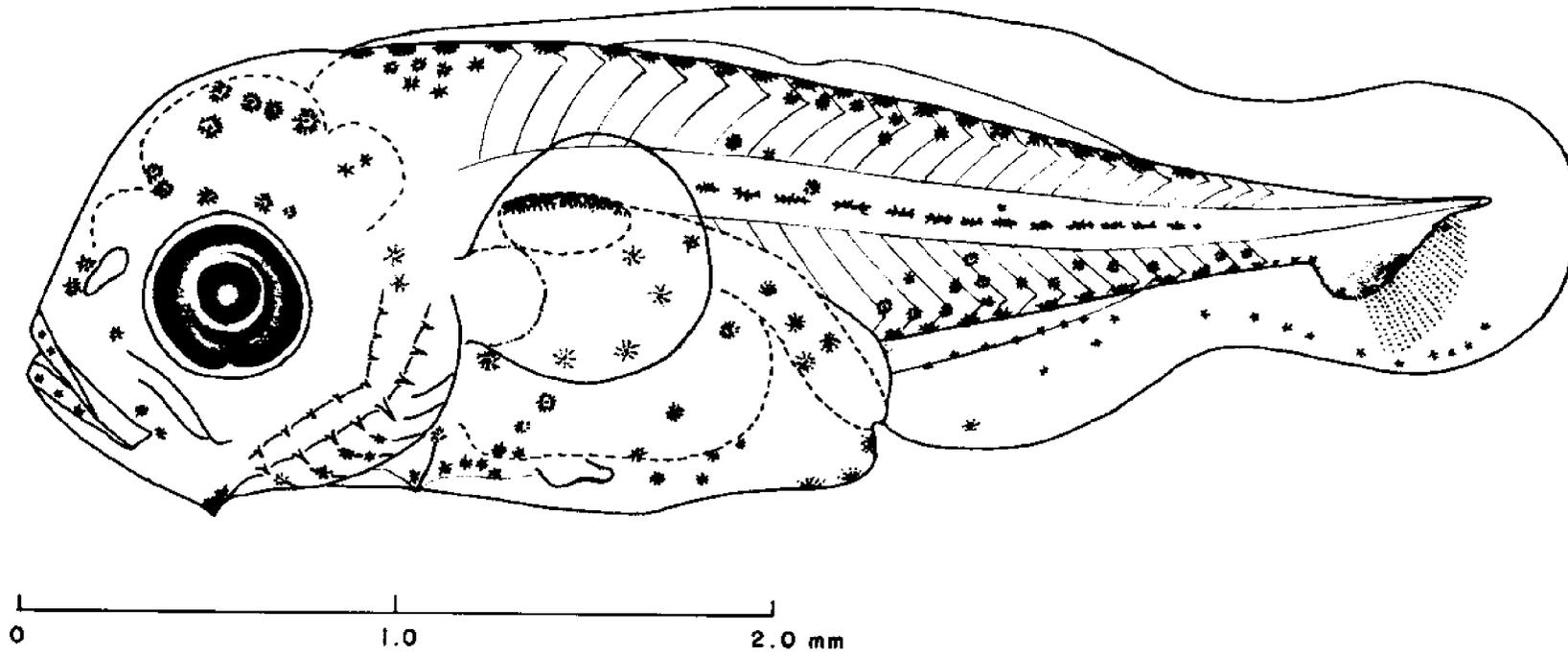


Figure 60. *Caranx* (= *Atule*) *mate*, day 12, 4.0 mm SL. (From Miller and Sumida, 1974)

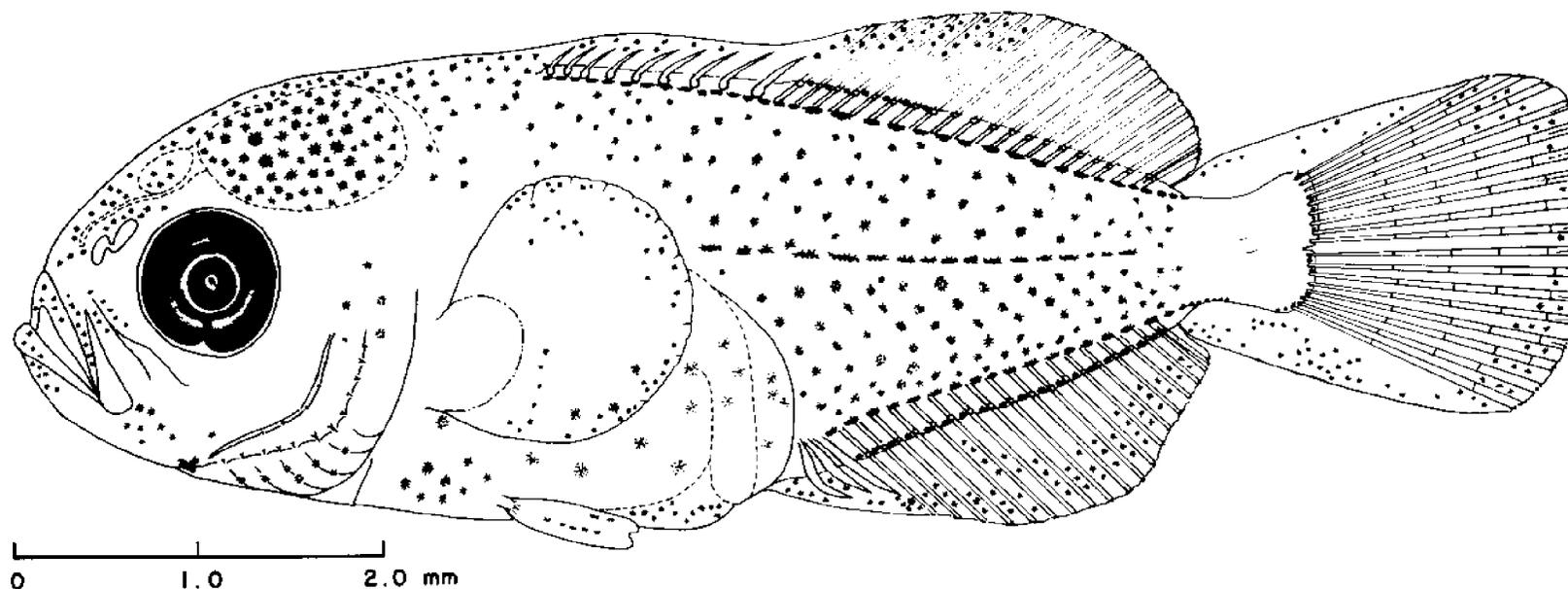


Figure 61. *Caranx* (=Atule) *mate*, day 18, 7.7 mm SL. (From Miller and Sumida, 1974)

Gnathanodon speciosus (pa'opa'o)

Adult meristics

D: VII + I, 18–21; A: II + I, 15–17; P: i, 19–22; V: I, 5; C: 17; vertebrae: 24

Eggs

G. speciosus eggs are planktonic, spherical, and 0.80 to 0.90 mm in diameter, with a single yellowish oil droplet (0.23 to 0.30 mm in diameter) and a weakly segmented yolk. They are described further in Miller ["Development of eggs and larvae of *Gnathanodon speciosus* (Carangidae)," in preparation]; diel and seasonal abundance are discussed in Watson and Leis (1974).

Larvae

Only illustrations of *G. speciosus* larvae are included here (Figures 62 and 63); development is described in detail in Miller ["Development of eggs and larvae of *Gnathanodon speciosus* (Carangidae)," in preparation].

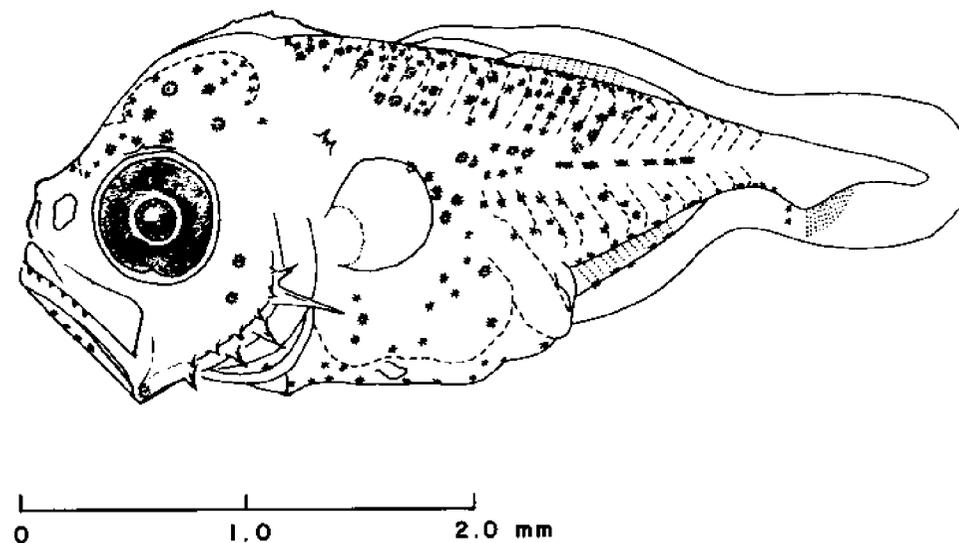


Figure 62. *Gnathanodon speciosus*, day 10, 4.0 mm SL

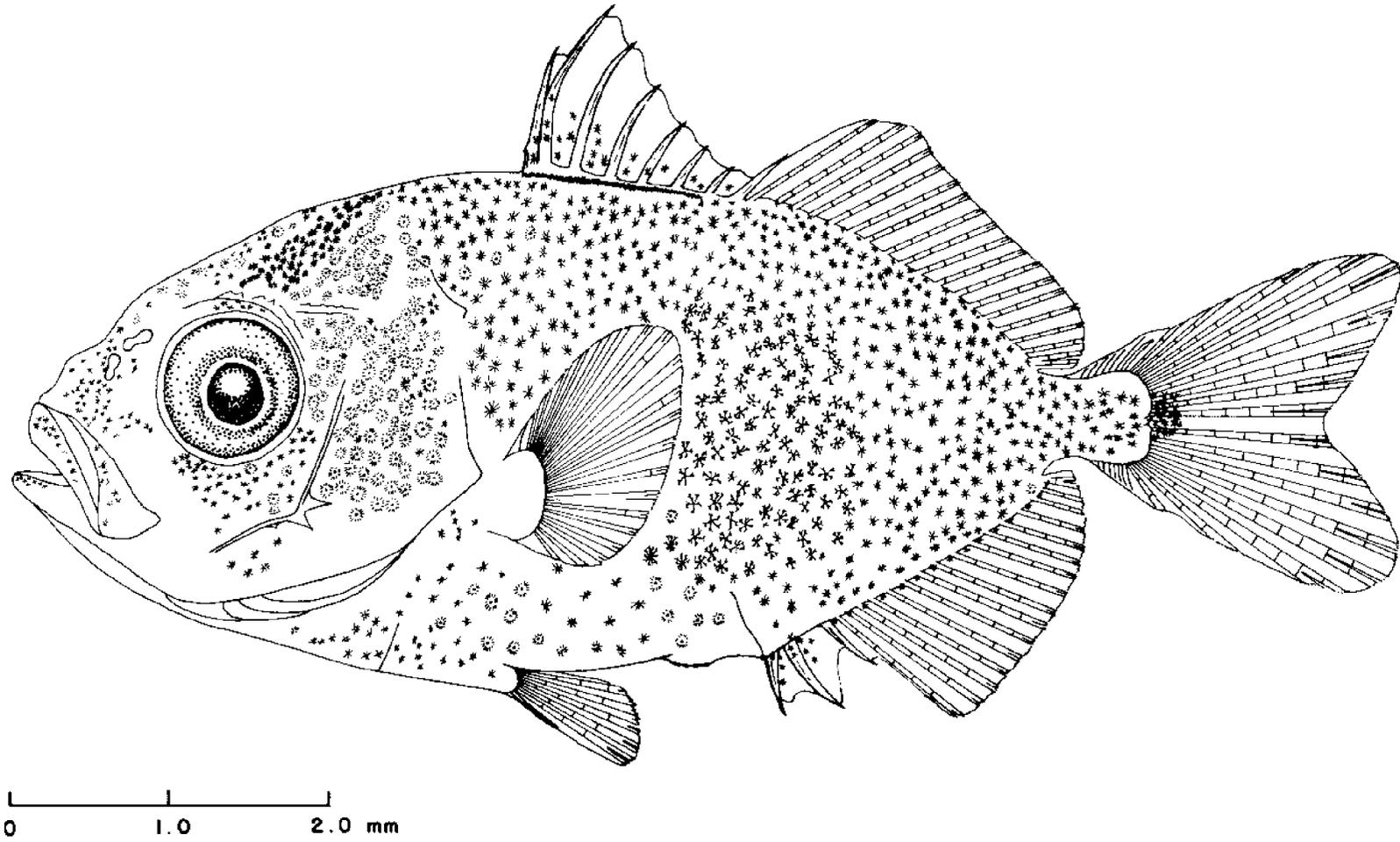


Figure 63. *Gnathanodon speciosus*, day 38, 14.4 mm SL

Seriola sp. (kahala)

Adult meristics

D: VII + I, 30–36; A: II + I, 19–21; P: i, 19–21; V: I, 5; C: 17; vertebrae: 24

Eggs

Seriola sp. eggs from Hawaiian waters have not been described in the literature. Artificially fertilized eggs from *Seriola quinqueradiata* which are buoyant and spherical and with a single oil droplet are described in Uchida et al. (1958).

Larvae

Seriola sp. larvae are moderately deep-bodied and large-headed; have pterotic, supraocular, and large preopercular spines; have the crest very reduced or absent; are heavily pigmented dorsally with fewer melanophores laterally and ventrally; and have a high soft dorsal fin ray count.

A 5.8-mm SL larva (Figure 64) has all of the characteristic features plus all unpaired fin anlagen, pelvic fins, and developing pectoral fin rays. Incipient pelvic fin rays and eight ossified caudal fin rays are visible, but the notochord remains straight. Two rows of preopercular spines are present: a lower row of four long spines and an upper row of three small spines. The spine at the angle of the lower

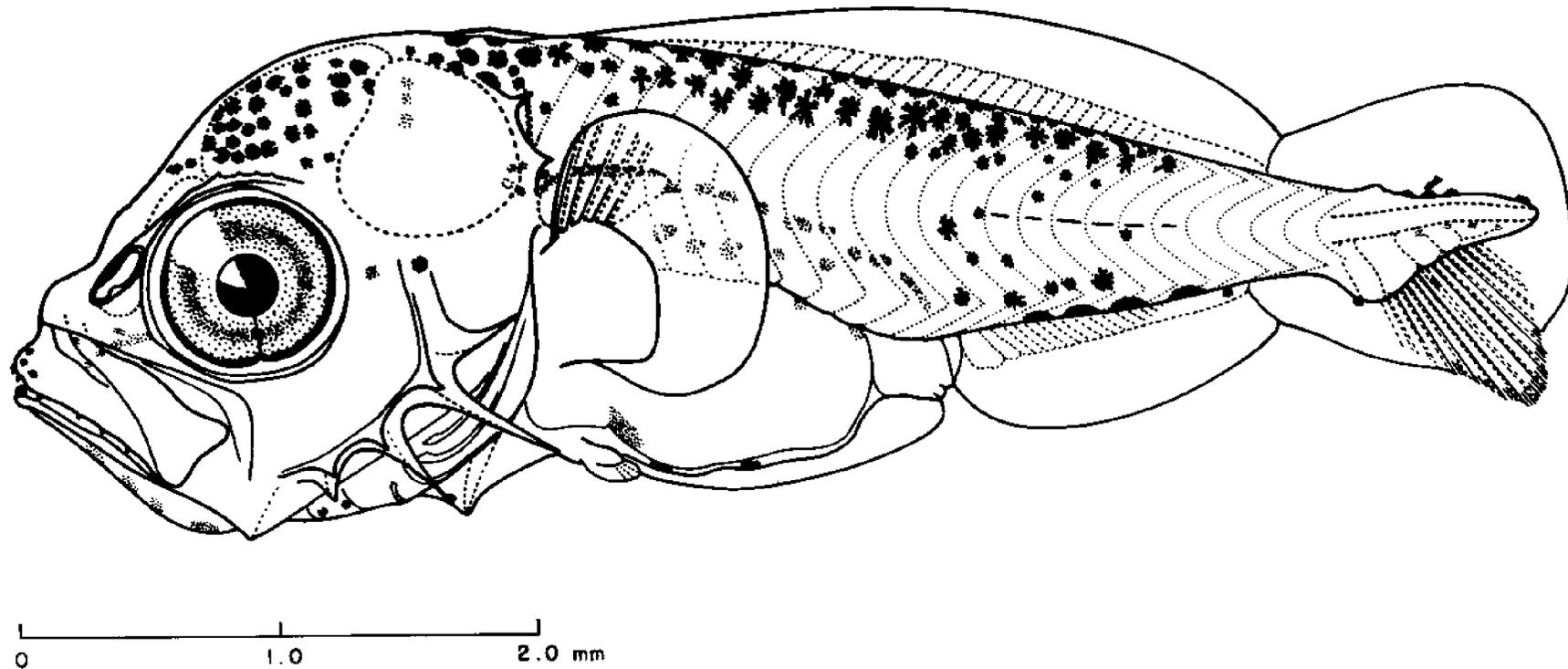


Figure 64. *Seriola* sp., 5.8 mm SL

row is longest, as is typical of carangids. Two small pterotic spines are present, but are often difficult to see. The crest and the supraorbital spines are very small.

The head is heavily pigmented over the midbrain region and at the tips of the upper and lower jaws. A row of melanophores lies along the midline of the gular membrane. The opercular membrane is pigmented in the region of the lower two branchiostegals. One or two melanophores lie near the upper end of the preopercle. Internal melanophores lie along the junction of the mid- and hindbrain. The dorsal and dorsolateral portions of the body are heavily pigmented from the level of the otic capsule to near the terminus of the dorsal fin anlage. A series of small melanophores lies along the dorsal midline of the peduncle. Melanophores are scattered laterally on the body, primarily along the myosepta between the anus and the terminus of the dorsal fin anlage. A series of midlateral melanophores extends nearly the length of the anal fin anlage. Ventral pigment consists of paired melanophores lying along the anal fin anlage. A few melanophores lie along the peduncle. The gut is covered dorsally and dorsolaterally with scattered melanophores, an internal one lies anteroventrally on the midgut, and two or three external melanophores lie below the midgut. The gas bladder is pigmented dorsally.

60 Larger larvae differ by being more heavily pigmented ventrally and and by having developing fin rays.

Trachurops (=Selar) crumenophthalmus (akule)

Adult meristics

D: VIII + I, 24–26; A: II + I, 20–22; P: i, 21–22; V: I, 5; C: 17; vertebrae: 24

Eggs

T. crumenophthalmus eggs have not been recognized in Hawaiian waters. Delsman (1926a) attributed a planktonic, spherical, 0.78 mm diameter egg with a single yellowish oil droplet to *Caranx (=Trachurops) crumenophthalmus*.

Larvae

T. crumenophthalmus larvae are moderately deep-bodied, have a serrated dorsal crest—particularly in the 3 to 8 mm SL size range, have many preopercular spines, have pterotic and supraocular spines at the larger sizes, have relatively

high dorsal soft fin ray counts, and have characteristic middorsal, midlateral, and midventral pigment bands at about the level of the anal fin.

At ca. 3.5 mm SL (Figure 65), *T. crumenophthalmus* larvae have pelvic fin buds and soft dorsal, anal, and caudal fin anlagen. Eight incipient caudal fin rays are discernible, but all other fin rays are absent. The notochord is straight. The gut extends nearly one-half the length of the body, giving a myomere formula of 10 + 14. The preopercular spines are in two rows of six each: the upper spines are short and the lower ones long, especially the spine at the angle of the preopercle. The dorsal crest is distinct. Supraocular and pterotic spines are absent. A few external melanophores are scattered over the head in the midbrain region, the tips of the upper and lower jaws are pigmented, and internal melanophores lie on the posterior forebrain and midbrain. The articular is pigmented in some specimens. The gas bladder and the entire gut are pigmented dorsally. A few small melanophores are scattered over the caudal fin anlage, and a series of small melanophores lies along the ventral midline just anterior to the peduncle. A row of melanophores lies on either side of the dorsal midline along the dorsal fin anlage, and similar rows lie along the anal fin anlage. One or more melanophores usually lie along the midlateral line between the middorsal and midventral series (Figure 65). This midlateral pigment may be lacking in smaller larvae.

At ca. 4.5 mm SL the notochord is beginning to flex and incipient dorsal and anal soft fin rays are discernible. The midline melanophore series extend caudad, but remain bounded by the limits of the dorsal and anal fins. An internal series of melanophores may overlie the posterior notochord, although this is variable.

By ca. 5.5 mm SL the notochord is flexed, 17 ossified caudal fin rays are present, and the dorsal and anal fin rays are becoming ossified. Pterotic and supraocular spines are absent. The dorsal and ventral midline melanophore series extend nearly the lengths of their respective fins; the midlateral series extends caudad from about the midpoint of the anal fin. Myoseptal melanophores outline the posterior hypomeres included in the midline series. The distal margin of the peduncle is pigmented, and internal melanophores underlie the urostyle. The amount of pigment over the midbrain region and on the upper and lower jaws is increased.

At ca. 6.5 mm SL the myoseptal pigment extends further anteriorly along the hypomeres and the peduncle is more heavily pigmented. A series of melanophores extends along the ventral margin of the lower jaw.

At ca. 8 mm SL the pectoral, dorsal, and anal fins are almost completely formed. The crest and preopercular spines are reduced. The pterotic and

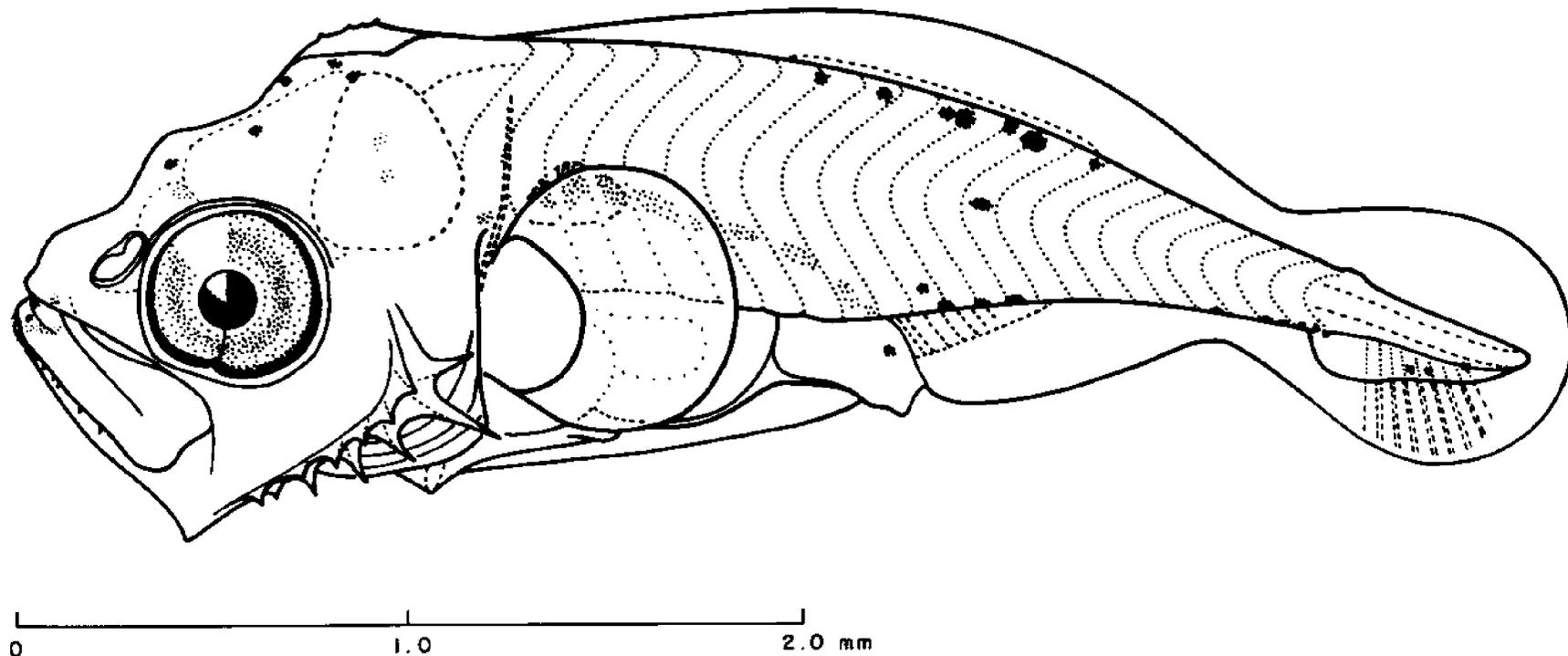


Figure 65. *Trachurops* (=Selar) *crumenophthalmus*, 3.8 mm SL

supraocular spines are small. Additional melanophores include one centrally on the snout, another near the upper end of the preopercle, one at the symphysis of the cleithra, and a series ventrally on the gut just above the pelvic fin. Paired melanophores lie at the base of nearly every dorsal element, with similar pairs at the bases of the soft rays of the anal fin. The midlateral melanophore series is bounded by the limits of the anal soft fin rays, and the myoseptal pigment is limited to the hypomeres in this same region (Figure 66).

Further changes include the full development of all fins and loss of the crest and reduction of the preopercular spines during metamorphosis.

Identification

Carangid larvae are readily recognized by their combination of moderately deep to deep bodies, 24 myomeres (except *Scomberoides*), long preopercular spines (except *Caranx mate*), dorsal crests (except *C. mate*), and a midline melanophore series. Confusion with other families should be minimal, except for the nomeid, *Cubiceps pauciradius*, which superficially resembles *T. crumenophthalmus*. These are easily distinguished by myomere counts (31 in *C. pauciradius*) and by the lack of a dorsal crest or long preopercular spines in *C. pauciradius*. The pomacanthid, *Centropyge*, is carangid-like to at least 6 mm

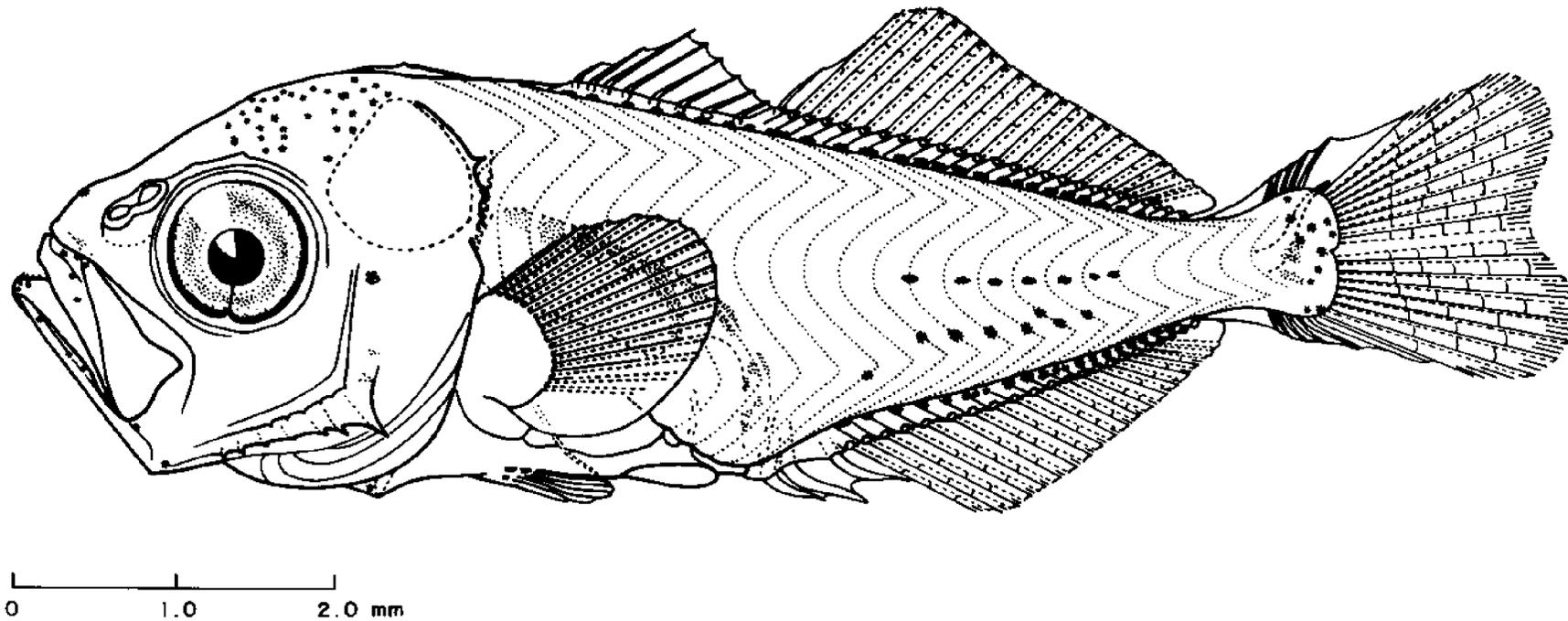


Figure 66. *Trachurops* (= *Selar*) *crumenophthalmus*, 8.1 mm SL

SL, but differs in that its trunk is covered with small dermal spines. The chaetodontid, *Chaetodon*, is also carangid-like to at least 4 mm SL, but is easily distinguished by its single broad, flat, preopercular spine (Leis and Miller, 1976).

Within the Carangidae family, distinction of species is often difficult. The major characteristics are small differences in pigmentation, which vary ontogenetically. (For metamorphic and later stages, fin ray counts are helpful; see Table 4.) However, in this case, six genera and eleven unidentified types (mostly reflexion larvae) are recognizable. Identifiable genera include those described above plus *Decapturus* sp. and *Scomberoides lysan*.

Decapturus sp. larvae resemble *T. crumenophthalmus*, but lack lateral pigment (other than the midlateral series) in sizes below ca. 10 mm SL and do not have myoseptal melanophores at any size. The middorsal series is often discontinuous in smaller larvae (ca. 6 to 7 mm SL). A band of melanophores lies on a line between about the upper pectoral base and mideye. Two internal lateral bands of melanophores lie above and below the external midlateral series posteriorly. The largest specimens have the following fin ray counts: D: VIII + I, 28--30 + 1 finlet; A: II + I, 30 + 1 finlet.

Scomberoides lysan larvae are distinct among Hawaiian carangid larvae in having 26 myomeres. They have large crests, very long preopercular spines, pterotic spines even at small (ca. 4 mm SL) sizes, and are entirely pigmented (most heavily dorsally and dorsolaterally) except at the peduncle. Large specimens have the following fin ray counts: D: VI-VIII + I, 19-21; A: II + I, 17-19.

Larval development of *Elagatis bipinnulatus* is described and illustrated in Okiyama (1970) and Aprieto (1974). *Alectis* larvae are described and illustrated as *Caranx* in Delsman (1926b). The eggs and larvae of *Naucrates ductor* are described and illustrated in Sanzo (1931a).

Literature

Aprieto (1974), Berry (1959), Delsman (1926a, 1926b), Jordan and Evermann (1903), Leis and Miller (1976), Miller and Sumida (1974), Munro (1967), Okiyama (1970), Sanzo (1931a), Shojima (1962), Uchida et al. (1958), Watson and Leis (1974)

TABLE 4. FIN RAY COUNTS OF HAWAIIAN CARANGID SPECIES

Species	Reference*	D	A	P
<i>Alectis ciliaris</i>	2	VI-VII + I, 18-20	II + I, 15-17	i, 19
<i>A. indicus</i>	2	VI + I, 18-19	II + I, 16	i, 17
<i>Carangoides</i> <i>gymnostethoides</i>	1	VII-VIII + I, 28-31	II + I, 24-26	i, 21-22
<i>C. ferdau</i>	3	VII-VIII + I, 26-31	II + I, 22-26	i, 21-23
<i>C. ajax</i>	1	VIII + I, 19	II + I, 16	
<i>C. equula</i>	1	VIII + I, 23-24	II + I, 21-22	20-21
<i>Caranx cheilo</i>	1	VII + I, 24	II + I, 20	
<i>C. helvolus</i>	1	VII-VIII + I, 25-28	II + I, 19-21	
<i>C. ignobilis</i>	1	VIII + I, 18-21	II + I, 15-17	i, 19
<i>C. kalla</i>	2	VII + I, 23-24	II + I, 18-20	i, 17-19
<i>C. lugubris</i>	1	VII + I, 20-22	II + I, 17-19	i, 19
<i>C. mate</i>	1	VIII + I, 20-23	II + I, 17-19	i, 20-21
<i>C. melampygus</i>	2	VIII + I, 22-23	II + I, 17-20	i, 19-20
<i>C. sexfasciatus</i>	2	VII-VIII + I, 19-21	II + I, 16-18	i, 21-22
<i>Decapterus pinnulatus</i>	2	VIII + I, 28-35 + 1	II + I, 27-30 + 1	22-23
<i>D. maruadsi</i>	1	VIII + I, 28-33 + 1	II + I, 26-30 + 1	
<i>Elagatis bipinnulatus</i>	2	VI + I, 24-27 + 2	II + I, 15-17 + 2	
<i>Gnathanodon speciosus</i>	2	VII-VIII + I, 18-21	II + I, 16-17	i, 19-22
<i>Megalaspis cordyla</i>	2	VII-VIII + I, 9-11 + 7-9	II + I, 8-10 + 6-8	21
<i>Naucrates ductor</i>	2	IV-VI + I, 26-28	II + I, 16-17	19
<i>Scomberoides lysan</i>	1	VI-VII + I, 19-21	II + I, 17-19	i, 15-17
<i>Seriola</i> spp.	4	VII-VIII + I, 27-35	II + I, 19-22	i, 18-21
<i>Trachurops</i> <i>crumenophthalmus</i>	1	VIII + I, 25-26	II + I, 22	i, 20-21

*1 = counts made by project personnel; 2 = Munro (1967); 3 = Jordan and Evermann (1903); 4 = Mather (1973: personal communication)

CORYPHAENIDAE

Coryphaena hippurus (mahi mahi)

Adult meristics

D: 58-60; A: 27-28; P: 19; V: 1, 5; C: 17; vertebrae: 30-31

Eggs

C. hippurus eggs are planktonic, spherical, and 1.6 mm in diameter, with a single oil droplet (0.3 to 0.4 mm in diameter) and segmented yolk (Mito, 1960).

Yolk sac larvae

C. hippurus larvae are rather large at hatching: ca. 4 mm SL. They are slender, with rounded heads, unpigmented eyes, undeveloped jaws, and a large yolk sac containing the oil droplet posteriorly. Pectoral fins are present as buds; all other fins are absent. The finfold has a somewhat sac-like appearance. The gut extends just beyond the midpoint of the body. Melanophores are more or less uniformly distributed over the yolk sac, head, and body, except for the peduncle which is unpigmented.

Larvae of ca. 4.2 mm SL (Figure 67) have pigmented eyes, functional jaws, and pectoral fins, but retain part of the oil droplet. At this size the snout has elongated somewhat and the gut has shortened slightly, giving a myomere formula of 15 + 16. The head is rather heavily pigmented dorsally, and melanophores lie along the upper jaw, on the gular membrane, near the articular, and internally in the ventral mid- and hindbrain region. A series of melanophores extends over the isthmus and ventral midline of the gut. Others lie dorsally over the gut and encircle the hindgut. The remainder of the oil droplet is likewise encircled with melanophores. Dorsal, lateral, and ventral midline series of melanophores are often discernible, although substantial numbers of lateral melanophores are present, particularly on the tail. The peduncle remains unpigmented (Figure 67).

Larvae

The oil droplet is assimilated by ca. 5 mm SL. By ca. 8 mm SL (Figure 68), pelvic fin buds and dorsal, anal, and caudal fin anlagen are present. The head is greatly enlarged, the body is deeper but still slender, and preopercular and the first of several supraocular spines are present. The preopercular spines are in two rows of two each. The body is heavily pigmented although the top of the head and the lateral and ventral sides of the gut may be only lightly pigmented or

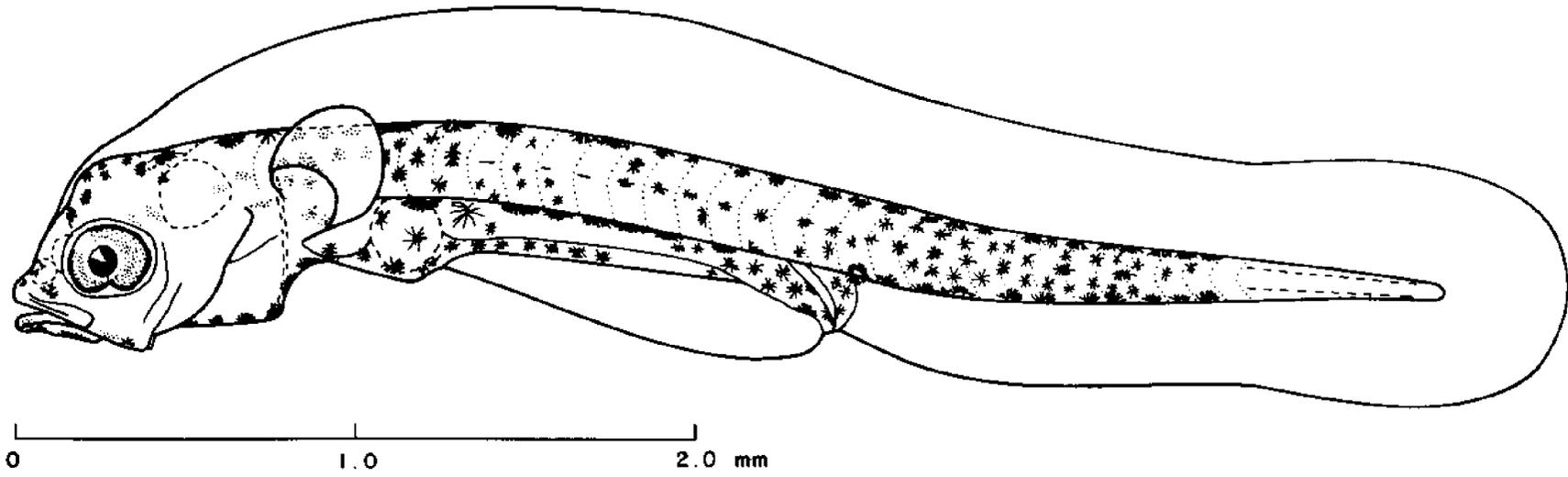


Figure 67. *Coryphaena hippurus*, day 7, 4.2 mm SL. (Note oil droplet.)

64

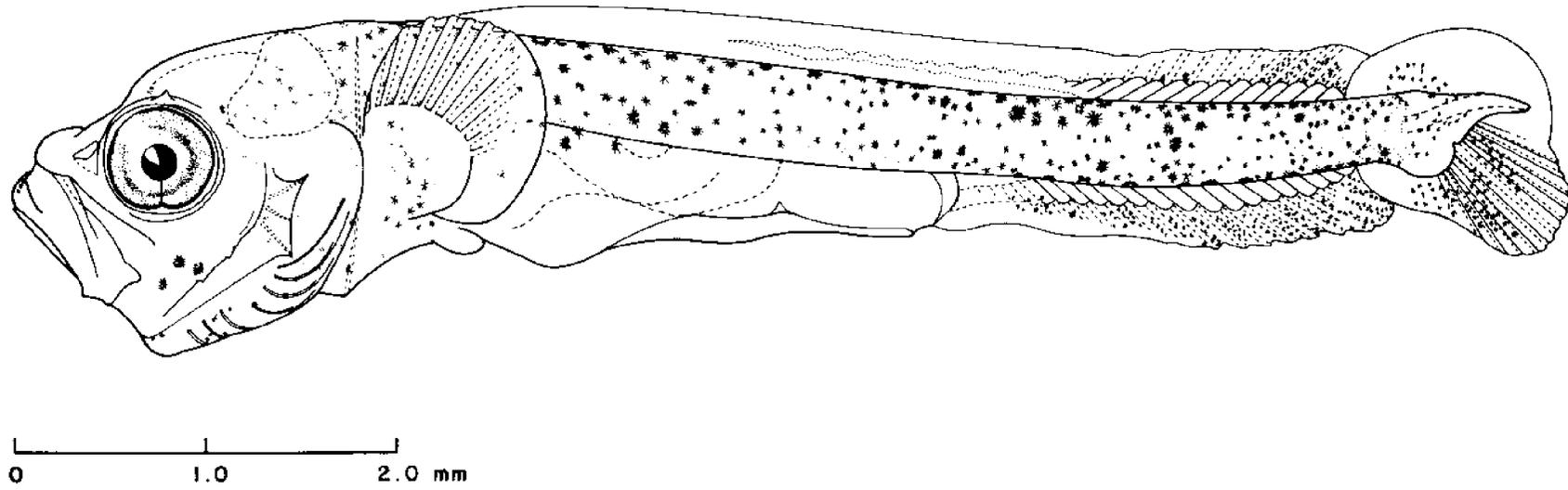


Figure 68. *Coryphaena hippurus*, 7.9 mm SL

unpigmented. The caudal fin rays and membranes between the dorsal and anal fin rays are covered with scattered melanophores. The pectoral fin remains unpigmented, except on its base. The caudal finfold is pigmented dorsally, and the peduncle is covered with scattered melanophores. The typical juvenile pattern of vertical bars along the body is just beginning to form.

Identification

Larval Echineidae resemble *C. hippurus* in being elongate and heavily pigmented and in having a somewhat sac-like finfold. They are most easily distinguished from *C. hippurus* by their more elongate jaws, with large, strongly recurved teeth in the lower jaw.

C. hippurus larvae are also likely to be confused with *Coryphaena equisetis*. The latter is recognized by its 32 to 34 myomeres and by its being uniformly pigmented rather than barred in the metamorphic and juvenile stages (Gibbs and Collette, 1959).

Literature

Aboussouan (1969), Gibbs and Collette (1959), Mito (1960)

POMACENTRIDAE

The pomacentrids are quite common in Hawaiian waters and often well-represented in larval fish collections. However, most are identifiable to generic and specific levels only at the metamorphic or later stages.

Larvae are characterized by their somewhat rounded heads, very short guts, and 26 myomeres and by usually being rather lightly pigmented except on the head and gut. *Abudefduf abdominalis* and *Pomacentrus jenkinsi* are typical pomacentrids with these characteristics.

Abudefduf abdominalis (mao mao)

Adult meristics

D: XIII, 13–14; A: II, 13–15; P: 17–19; V: I, 5; C: 15; vertebrae: 26

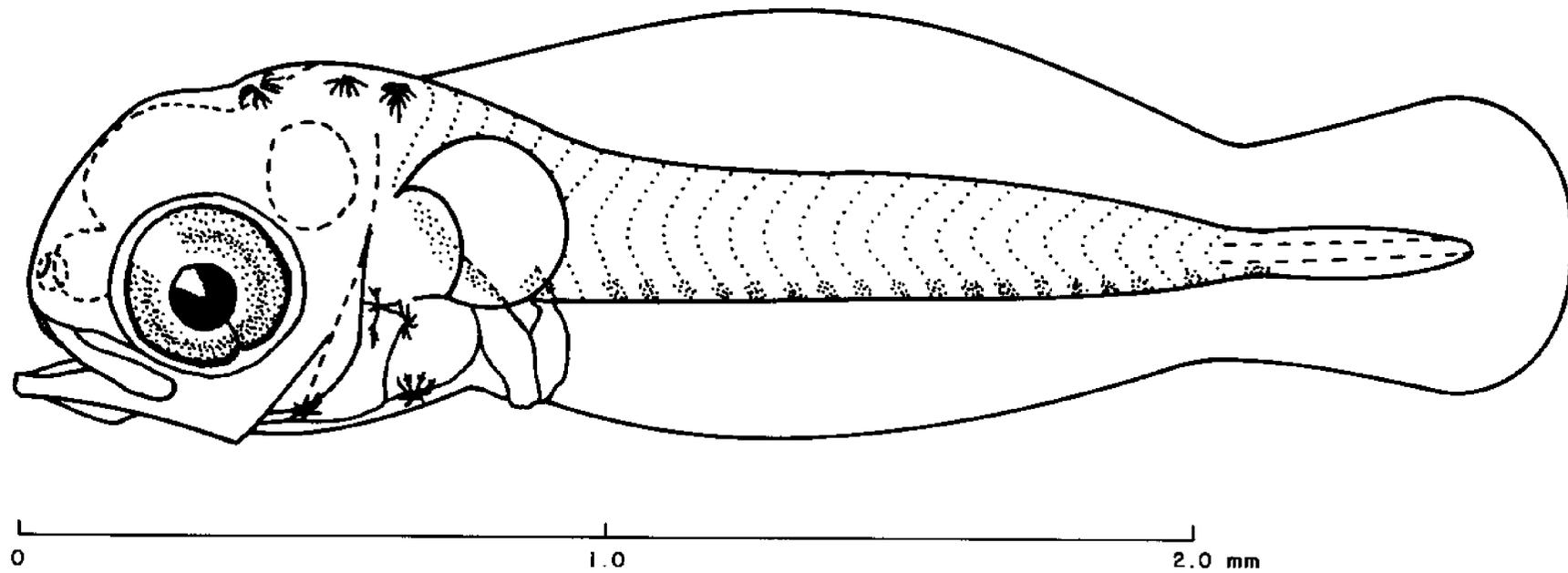
Eggs

A. abdominalis eggs are demersal, attached to a substrate, and brooded by the male. Eggs and reproductive behavior are described in Helfrich (1958).

Larvae

A. abdominalis hatch at ca. 2.5 mm SL (Figure 69) with pigmented eyes, functional jaws, and little or no yolk. Fin anlagen are absent and the gas bladder is not visible externally. The myomere formula is 5 + 21. A series of melanophores lies along the postanal ventral midline. The gut is pigmented dorsally, with a few widely scattered lateral melanophores and one ventrally at the posterior center of the gut. A single melanophore lies at the symphysis of the cleithra. A characteristic series of three expanded melanophores overlies the hindbrain region (Figure 70). An internal melanophore may lie along the posterior margin of the otic capsule, but is difficult to see.

Development proceeds quickly; by ca. 4 mm SL (Figure 71) all fins are present, at least as anlagen, and the pelvic spines, anterior dorsal spines, and incipient caudal fin rays are present. (The genus *Abudefduf* is apparently unique among Hawaiian pomacentrids in that it acquires dorsal spines earlier than soft dorsal fin rays.) The gut has become slightly longer, giving a myomere formula of 8 + 18. The gas bladder is visible anteriorly. Three small preopercular spines are present. The head pigment characteristic of smaller larvae is no longer visible. The mid- and hindbrain are pigmented, and external melanophores often overlie the



66

Figure 69. *Abudedefduf abdominalis*, day 1, 2.5 mm SL

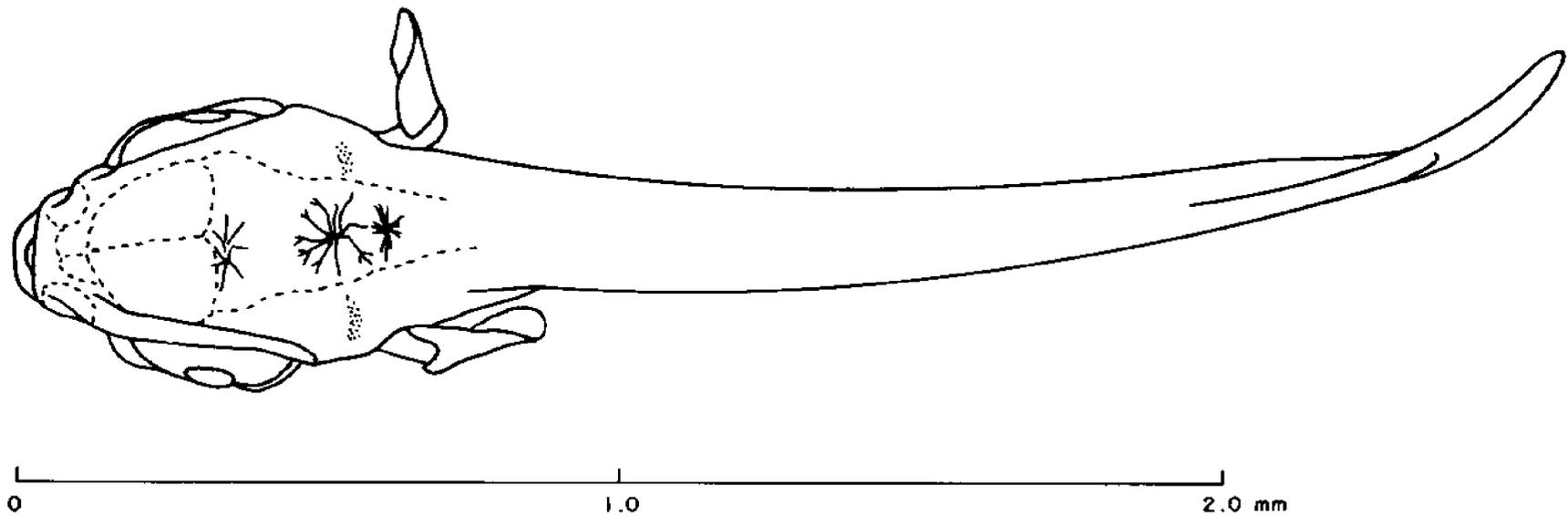


Figure 70. *Abudedefduf abdominalis*, day 1, 2.5 mm SL, dorsal view

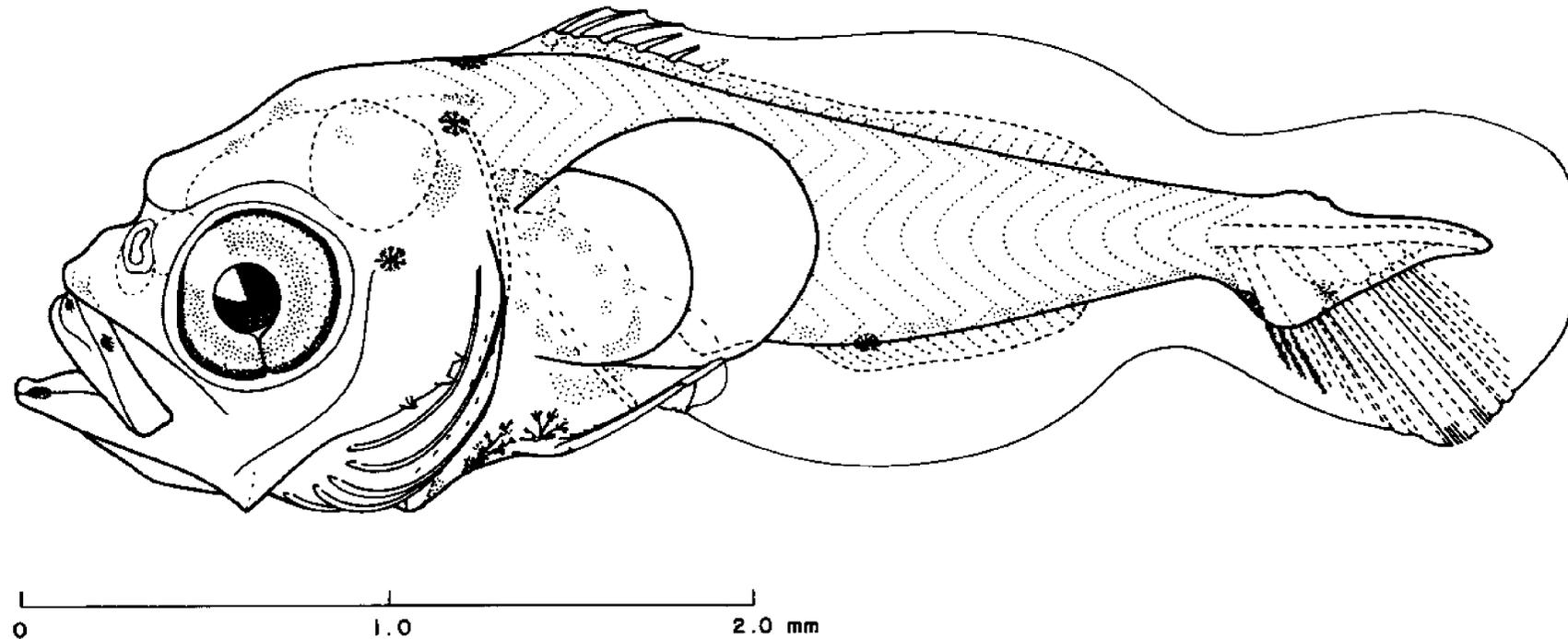


Figure 71. *Abudefduf abdominalis*, day 13, 4.0 mm SL

midbrain region. The jaws are becoming pigmented. Melanophores encircle the gut region and gas bladder. The midventral series is retained. An external melanophore lies on the upper end of each cleithrum. Melanophores lie along the lowermost three or four incipient caudal fin rays (Figure 71).

Incipient dorsal and anal soft fin rays are present by ca. 4.5 mm SL, and all but the pectoral fin are fully formed by ca. 5 mm SL (the pectoral fin is almost fully formed). Specimens of ca. 5 mm SL are becoming deep-bodied and acquiring a typical adult pomacentrid appearance. The branchial region and upper head are heavily pigmented. The pelvic fins are also heavily pigmented, and a dense band of melanophores extends across the body from the spiny dorsal fin to just above the anterior anal fin.

Eupomacentrus fasciolatus

Adult meristics

D: XII–XIV, 15–17; A: II, 12–13; P: 21–22; V: I, 5; C: 15, vertebrae: 26

Eggs

E. fasciolatus eggs are demersal, attached, and brooded.

Larvae

E. fasciolatus larvae are quite small at hatching: 2 mm SL or slightly less. They have pigmented eyes, functional jaws, no fin anlagen, and little or no yolk. The gut is very short, giving a myomere formula of 3 + 23. They are less heavily pigmented than *A. abdominalis*. An internal melanophore lies at the posterior margin of the otic capsule, the gut is pigmented anteriorly and dorsally, and a pair of external melanophores lies along the ventral center of the abdominal region. The ventral midline series extends caudad from about myomere 14 (Figure 72). The characteristic head pigment consists of a pair of internal melanophores on the anterior midbrain and a single external melanophore overlying the posterior center of the midbrain (Figure 73).

Identified *E. fasciolatus* larvae larger than ca. 3 mm SL were not taken in the nearshore plankton tows. Those smaller than ca. 3 mm SL vary little from the above description, and the juveniles are easily identified by meristics (Table 5).

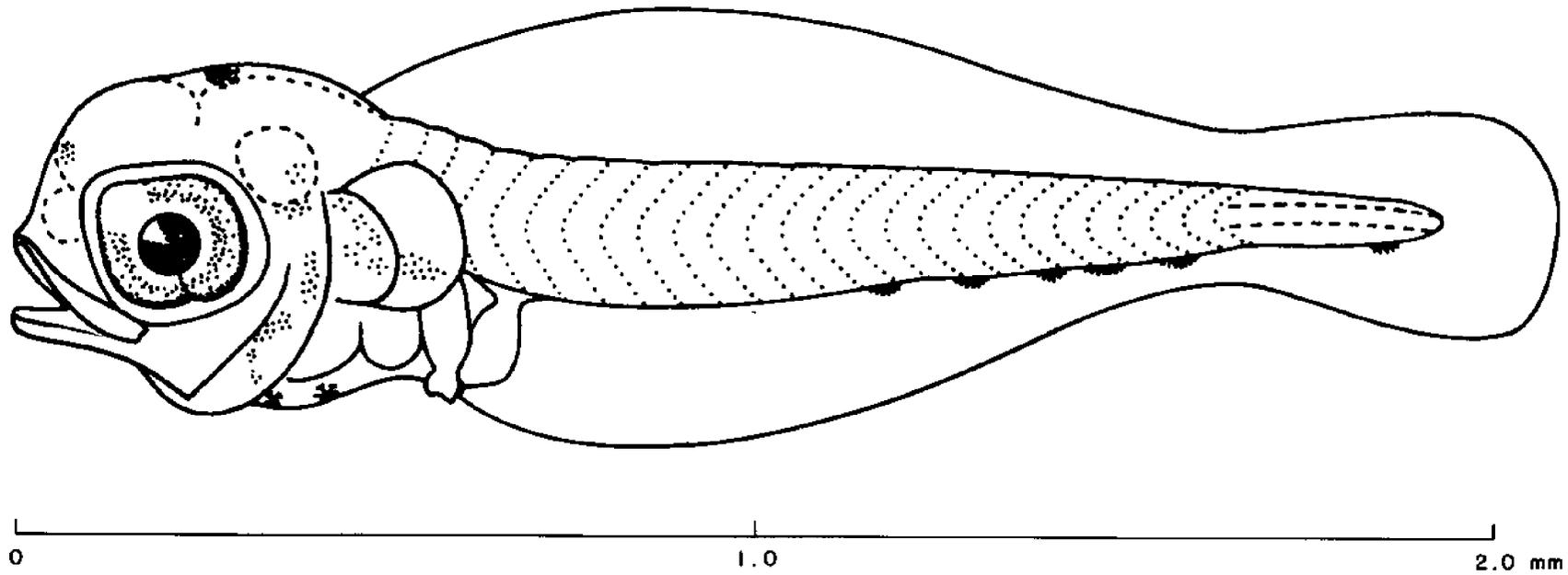


Figure 72. *Eupomacentrus fasciolatus*, day 3, 1.9 mm SL

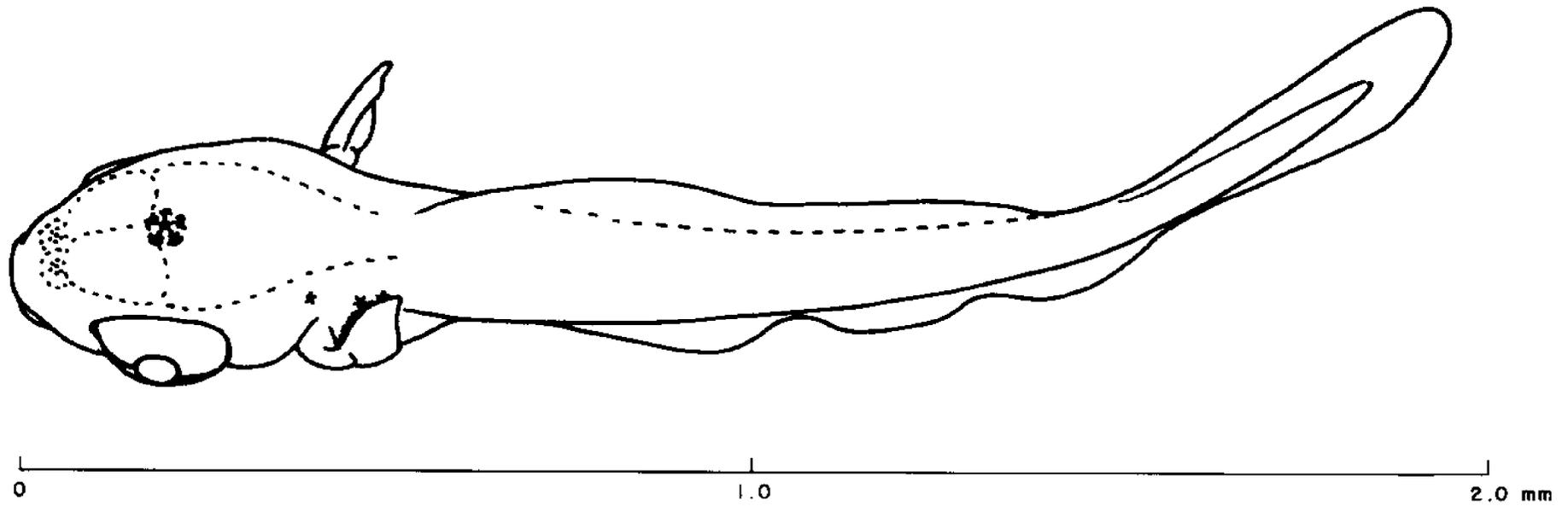


Figure 73. *Eupomacentrus fasciolatus*, day 3, 1.9 mm SL, dorsal view

TABLE 5. FIN RAY COUNTS OF HAWAIIAN POMACENTRID SPECIES

Species	Reference*	D	A	P
<i>Abudefduf abdominalis</i>	1	XIII, 13-15	II, 13-15	17-19
<i>A. sordidus</i>	1	XIII, 15-16	II, 14-15	18-19
<i>Chromis acares</i>	2	XII-XIII, 11	II, 10-11	16-18
<i>C. agilis</i>	2	XII, 12-14	II, 12-14	17-18
<i>C. hanui</i>	2	XII, 13	II, 13-14	17-18
<i>C. leucurus</i>	2	XII, 14	II, 13	16
<i>C. ovalis</i>	2	XIV, 11-13	II, 12-13	20-22
<i>C. struhsakeri</i>	2	XIV-XV, 13-14	II, 13-14	19-20
<i>C. vanderbilti</i>	2	XII, 11	II, 11	16-18
<i>C. verater</i>	2	XIV, 12-14	II, 12-14	19-20
<i>Dascyllus albisella</i>	1	XII, 15-16	II, 15-16	19-21
<i>Eupomacentrus fasciolatus</i>	1	XII-XIV, 15-17	II, 12-14	20-22
<i>Plectroglyphidodon johnstonianus</i>	1	XII, 18-19	II, 15-18	18-20
<i>P. imparipennis</i>	1	XII, 14-16	II, 11-12	18-21
<i>P. phoenixensis</i>	1	XII, 16-18	II, 13-15	20-21
<i>P. sindonis</i>	1	XII, 19-20	II, 15-16	20-22

Note: Some names are changed from the original reference, according to Allen (1975)

*1 = Gosline and Brock (1960); 2 = Randall and Swerdloff (1973)

Identification

Pomacentrid larvae have 26 myomeres, a short gut, a somewhat rounded head, and pigmentation which is usually located dorsally on the head and gut, ventrally on the gut, and along part or all of the ventral midline of the tail.

Apogonid larvae may be confused with pomacentrids at times; their differences are discussed in the "Apogonid" section. Nomeid larvae are also similar in some respects to pomacentrids; these are most easily distinguished by the higher myomere counts (31 to 41) of the nomeids.

Within the family Pomacentridae, metamorphic and juvenile stages are usually identifiable meristically (Table 5), while larval identification is based primarily on differences in pigmentation.

Literature

Ahlstrom (1965), Delsman (1930), Fujita (1957), Gosline and Brock (1960), Helfrich (1958), Randall and Swerdloff (1973), Swerdloff (1970)

LABRIDAE

Labrids constitute an important component of the Hawaiian reef fish community. However, their larval taxonomy is poorly known, and only a few "kinds" are recognized at present.

Labrids are either moderately slender or deep-bodied, have a gut extending less than one-half the length of the body, have 25 or 26 myomeres, have a long dorsal fin, and are lightly pigmented. Labrid L-3 is one of the more common labrid larvae and is typical of the slender forms.

Labrid L-3

Meristics

D: IX, 11; A: III, 12; P: 13; V: I, 5; C: 14; vertebrae: 25

Eggs

Four kinds of eggs from Hawaiian waters have been tentatively attributed to labrids (Watson and Leis, 1974): three unidentified types and *Thalassoma duperreyi*. All are planktonic and spherical, with a single small oil droplet opposite the developing embryo. None have been associated with Labrid L-3.

Larvae

The smallest L-3 larvae normally taken in nearshore plankton tows (ca. 7 mm SL) are rather advanced: dorsal, anal, and caudal fin rays are present, incipient dorsal spines are visible, and pectoral fin rays are becoming ossified. Pelvic fin buds are very small. The eyes are somewhat oval but will soon become round. The gut extends a little less than one-half the length of the body, giving a myomere formula of 11 + 14 or 12 + 13. The gas bladder is conspicuous, but usually smaller than that illustrated in Figure 74.

The posterior band of myoseptal and fin pigment is characteristic. This band consists of a few melanophores on the fin membrane along the last three or four dorsal and anal fin rays and along the myosepta at this level. Melanophores overlie the gas bladder dorsally.

In larger larvae, similar fin pigment develops along the first three or four dorsal and anal soft fin rays and along the third and fourth dorsal spines. The top of the head is pigmented in the midbrain region. In living larvae, xanthophores lie

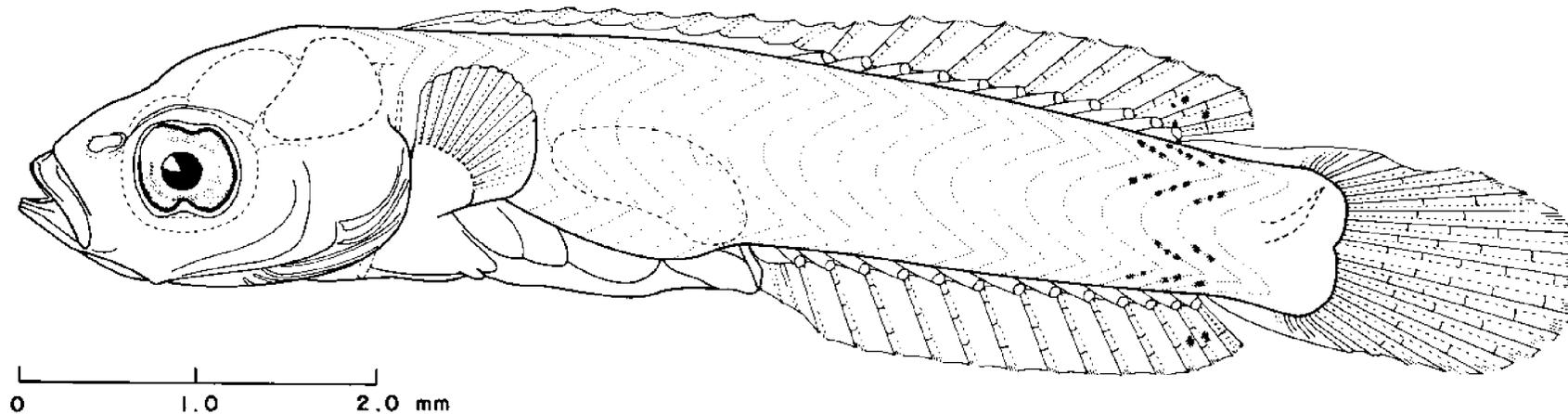


Figure 74. Labrid L-3, 7.2 mm SL

dorso- and ventrolaterally at the level of the fin melanophores, along the myosepta of the posterior pigment band, on the upper and lower jaws, at the isthmus, along the cleithra, and scattered over the gut region.

Identification

Labrid larvae are recognized by their sparse pigmentation, small mouths, long dorsal and truncated caudal fin, and 25 to 26 myomeres. Distinction between "kinds" within the family is based primarily on fin ray counts and body shape. These criteria usually do not allow identification to the specific level, but identification to the generic level is often possible.

Scarid larvae are easily confused with labrids. Metamorphic stage specimens are often distinguishable by dorsal and anal soft fin ray counts: most scarids have 9 or 10 (rarely 11), while labrids typically have 11 to 13 (usually 12 to 13) in at least one fin (Table 6).

Smaller larvae cannot be distinguished adequately, but are not commonly encountered nearshore.

Literature

Kuntz and Radcliffe (1917), Mito (1962d), Nellen (1973), Sparta (1933a), Watson and Leis (1974)

TABLE 6. FIN RAY COUNTS OF HAWAIIAN LABRID GENERA

Genus	Reference*	D	A	P
<i>Anampses</i>	1	IX, 12	III, 12	13
<i>Bodianus</i>	2,3	XII, 10-11	III, 12	17
<i>Cheilio</i>	4	IX, 12-13	III, 11-12	12
<i>Cheilinus</i>	5	IX, 10-11	III, 8-9	12-13
<i>Cirrhilabrus</i>	4	XI, 8-9	III, 8-9	15
<i>Coris</i>	3	IX, 11-12	III, 12	12-13
<i>Cymolutes</i>	4	VIII-IX, 13-15	III, 13	12
<i>Epibulus</i>	4	IX, 10	III, 8	12
<i>Gomphosus</i>	4	VIII, 12-13	III, 10-11	16
<i>Halichoeres</i>	3	IX, 12	III, 11-12	13
<i>Hemipteronotus</i>	3	IX†, 12-13	III, 12-13	12-13
<i>Labroides</i>	6	IX, 11	III, 10	13
<i>Macropharyngodon</i>	4	IX, 11	III, 11	12
<i>Novaculichthys</i>	3	IX, 12	III, 12	12-13
<i>Pseudocheilinus</i>	4, 5	IX, 10-11	III, 9	13-17
<i>Pseudojuloides</i>	4	IX, 11	III, 12	13
<i>Stethojulis</i>	7	IX, 11	III, 11	14-15
<i>Thalassoma</i>	3,4	VIII, 12-13	III, 11-12	15-17
<i>Wetmorella</i>	4	IX, 10	III, 8	12

*1 = Randall (1972); 2 = Gomon and Randall (1975); 3 = Jordan and Evermann (1903); 4 = Schultz et al. (1960); 5 = counts made by project personnel; 6 = Randall (1958); 7 = Randall and Kay (1974)

†First two spines may be separated from the rest in certain species giving rise to a count of II + VII

SCOMBROLABRACIDAE

Scombrolabrax heterolepis

Adult meristics

D: XII, 14–15; A: II, 16–18; P: 17–19; V: I, 5; C: 17; vertebrae: 31–32

Eggs

S. heterolepis eggs have not been described in the literature.

Larvae

S. heterolepis larvae are quite robust, with a large head, short gut, and small gas bladder. The myomere formula is 10 + 21–22. Larvae of ca. 4 mm SL (Figure 75) have the caudal fin anlage and incipient caudal fin rays and are just beginning to develop dorsal and anal finanlagen. The notochord is straight.

Four preopercular spines are present, with the spine at the angle a little longer than the others. Pigmentation is limited to the tip of the lower jaw, an internal melanophore posteriorly on each side of the midbrain, and melanophores anteriorly and dorsally over the gut and gas bladder.

Additional small preopercular spines are acquired in the upper row, along with pterotic and opercular spines, by ca. 5 mm SL. The notochord is flexed and pelvic fin buds are present. The body is deeper and broader. Pigmentation develops on the jaws and over the midbrain region. Larger larvae become heavily pigmented over the head, dorsolaterally over the gut, and midlaterally along the body.

Identification

S. heterolepis larvae resemble scombrids, some of the gempylids, and myctophids of the genus *Lampanyctus*. Scombrids may be distinguished by their higher myomere counts (except *Scomber australasicus*) and by their development

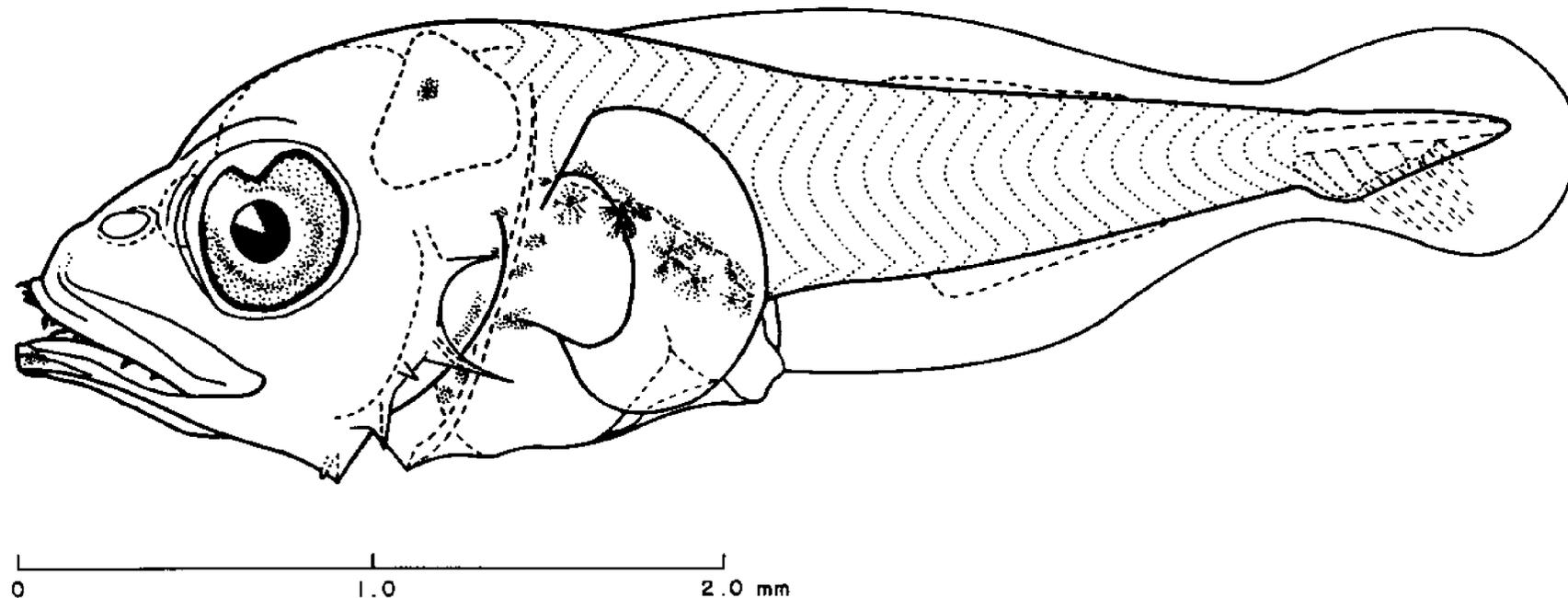


Figure 75. *Scombrolabrax heterolepis*, 4.2 mm SL.

of dorsal spines prior to, or synchronously with, dorsal fin rays. *S. australasicus* is easily distinguished by its lack of preopercular spines and by its pigmentation along the ventral midline.

Scombrolabrax may be distinguished from gempylids by its lower and shorter spiny dorsal fin, longer preopercular spines, and lack of long pelvic spines. The dorsal fin rays precede the dorsal spines in development. The larvae, particularly the larger ones, are stockier-bodied than the gempylids. Fin ray and myomere counts are used to distinguish larger specimens.

Distinction among *S. heterolepis*, gempylids, and *Lampanyctus* is discussed in the "Myctophidae" section.

GEMPYLIDAE

Gempylid larvae are rather diverse in appearance. They are somewhat deep-bodied and have moderately elongate snouts; obvious gas bladders; early developing, and ultimately quite long, pelvic spines; a few short to moderately long preopercular spines; a long or short gut; myomeres in the thirties or fifties; and a long, high, spinous dorsal fin at larger sizes. *Gempylus serpens* is the most common larval gempylid encountered in Hawaiian waters and, together with *Nealotus tripes*, represents the gempylid family in this atlas.

Gempylus serpens (Hauliuli - puhi)

Adult meristics

D: XXVI–XXXII + I–II, 10–13 + 5–8 finlets; A: II + I, 9–12 + 5–7 finlets; P: 12–15; V: I, 4; C: 17; vertebrae: 53

Eggs

G. serpens eggs have not been described in the literature. Spherical, pelagic eggs were attributed to another gempylid, *Thyrisites atun*, in Gilchrist (1916) and de Jager (1955).

Larvae

G. serpens larvae have a somewhat longer gut than most other gempylids: the myomere formula is 22 + 31 at ca. 5 mm SL. The snout is elongate and rather "squared-off." At ca. 5 mm SL (Figure 76) three spines are present on the preopercle. The two near the preopercular angle are of approximately equal length and remain so throughout larval development. In larger larvae two additional smaller spines are present on the lower limb of the preopercle. The larvae of ca. 5 mm SL have pelvic and six dorsal spines. Dorsal, anal, and caudal fin anlagen are developing, but no incipient rays are discernible. The gas bladder is visible anteriorly.

Pigment of this larval size includes melanophores at the tips of both jaws, a few over the midbrain region, one internally at the lower margin of the otic capsule, and a series dorsally over the gas bladder and gut. A series of melanophores (usually one per myomere) lies on the ventral midline between the anus and the origin of the anal fin anlage; another series lies dorsolaterally on each side between about the level of midgut and the origin of the anal fin anlage. A few melanophores may lie along the epaxial myosepta in this region. The midlateral

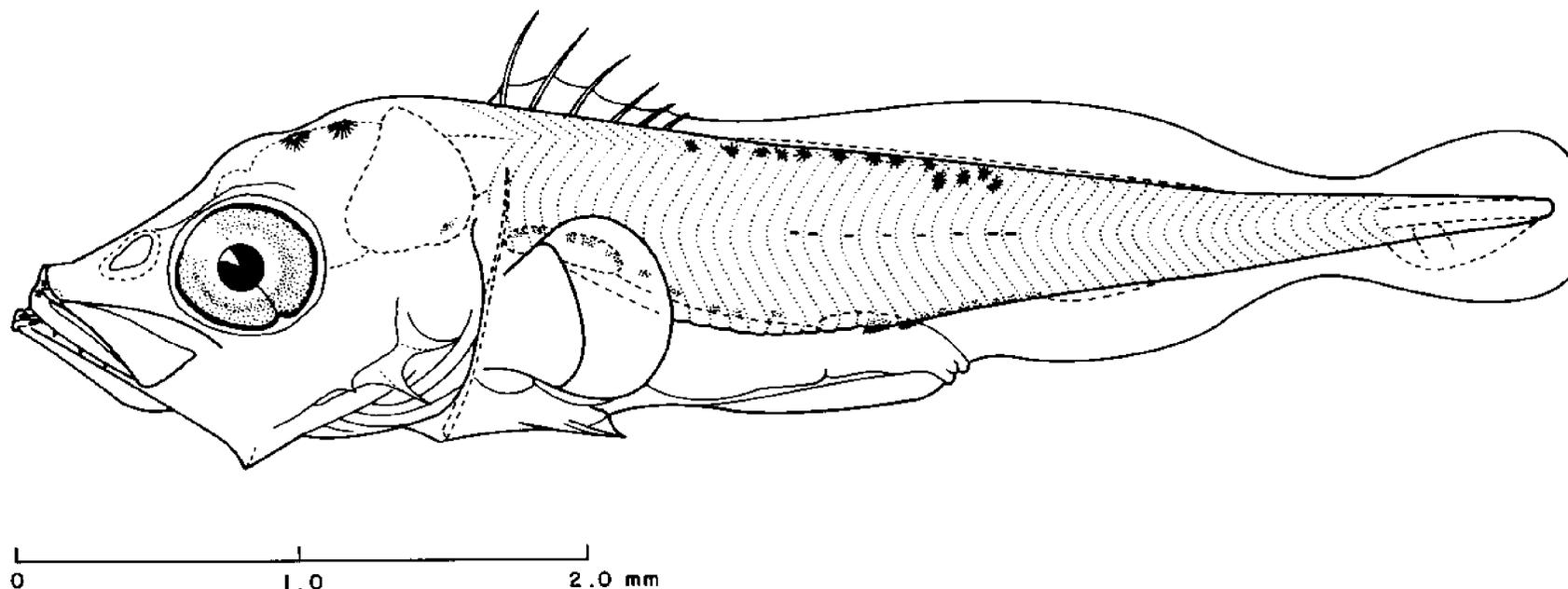


Figure 76. *Gempylus serpens*, 5.3 mm SL

melanophore series in the hindgut-to-anal fin anlage region is characteristic of *G. serpens* (Figure 76).

Changes with growth include the lengthening of the pelvic and dorsal fin spines, full development of all fins (ca. 10 to 11 mm SL), and development of supraocular, pterotic, and two more preopercular spines. The larger larvae are deeper-bodied and more heavily pigmented, particularly on the head and gut, dorsally on the body, and on the spinous dorsal fin (Voss, 1954).

Nealotus tripes

Adult meristics

D: XX–XXI + I, 16–19 + 2 finlets; A: II + I, 15–17 + 2 finlets; P: 12–14; V: I, 1–2; C: 17; vertebrae: 37–38

Eggs

N. tripes eggs have not been described in the literature.

Larvae

N. tripes is moderately deep-bodied. The gut is short in small larvae (the myomere formula is 10 + 28 at ca. 4 mm SL) but lengthens to over one-half the body length by ca. 8 to 9 mm SL. The snout is moderately elongate in small larvae and lengthens as development proceeds. Two preopercular spines are discernible on larvae of ca. 4 mm SL, with the spine of the preopercular angle longest. Supraocular, pterotic, and one or two small spines on the lower limb of the preopercle are present in larger larvae. Pelvic spines and two or three small dorsal spines are present at ca. 4 mm SL. The anlage of the spiny dorsal fin is developing, but all others are absent (Figure 77). In larger larvae the pelvic spines are longer and the spiny dorsal fin is quite long and high. By ca. 8 to 9 mm SL the fins are fully formed.

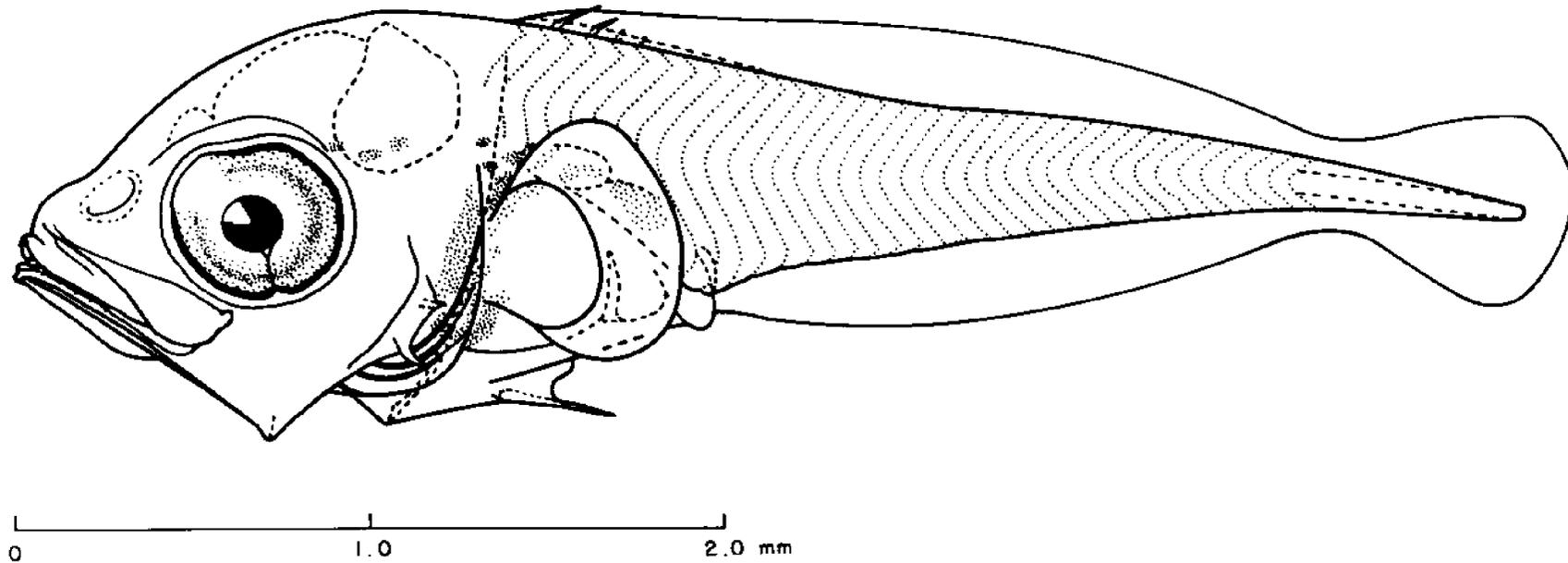


Figure 77. *Nealotus tripes*, 4.2 mm SL

Pigmentation in smaller *N. tripes* larvae is restricted to internal melanophores ventrolaterally on the posterior midbrain, anteriorly and dorsally over the gut, and on the gas bladder (Figure 77). In larger larvae additional melanophores are present over the midbrain and branchial regions, dorsally along the body, and on the spinous dorsal fin (Strasburg, 1964).

Identification

Small gempylid larvae (except *G. serpens*) are recognized by their scombrid-like appearance, with early developing dorsal and pelvic spines and preopercular spines which are usually few in number and small to moderate in size. Metamorphic stage larvae are identified by meristics (Table 7) and by their long, high, spinous dorsal fin and long pelvic spines.

G. serpens larvae are usually easily identified by the long gut, high myomere count, and midlateral pigmentation. However, confusion between *G. serpens* and the trichiurid, *Diplospinus multistriatus*, may occur. *D. multistriatus* may be distinguished from *G. serpens* by its lack of midlateral pigmentation and by preopercular spination: the spine at the angle is much longer than the others in *D. multistriatus*, but about equal to the others in *G. serpens*. Additional characteristics which distinguish *D. multistriatus* from all gempylids include its higher myomere and fin ray counts (Table 7). *D. multistriatus* is discussed as *Gempylus A* in Voss (1954).

Other gempylid larvae resemble one another, scombrids, scombrolabracids, and myctophids of the genus *Lampanyctus*. The distinction between gempylids and *Lampanyctus* is discussed in the "Myctophidae" section, and that between gempylids and *Scombrolabrax* in the "Scombrolabracidae" section.

TABLE 7. MERISTICS OF SELECTED GEMPYLID, SCOMBROLABRACID, AND TRICHIURID FISHES

Species	Reference*	Vertebrae	D	A
<i>Gempylus serpens</i>	1, 2, 3, 4	53	XXVI-XXXII + I-II, 10-13:5-8	II + I, 9-12:5-7
<i>Lepidocybium flaveobrunneum</i>	4	32	VIII-XII + 16-19:4-6	II + I, 11-13:4-5
<i>Nealotus tripes</i>	5	37-38	XX-XXI + I, 16-19:2	II + I, 15-17:2
<i>Promethichthys prometheus</i>	2		XII-XIII + 18-21:2	I-II, 15-17:2
<i>Ruvettus pretiosus</i>	2, 4	32	XIII-XV + 16-19:2	II, 16-18:2
<i>Scombrolabrax heterolepis</i>	1, 6	31-32	XII, 14-15	I + II, 16-18
<i>Diplospinus multistriatus</i>	5	59-61	XXX-XXXIV, 36-42	II + I, 29-32

Note: Numbers following colon (:) in columns "D" and "A" indicate number of finlets

*1 = counts made by project personnel; 2 = Jordan and Evermann (1903); 3 = Miller and Jorgenson (1973); 4 = Smith (1965); 5 = Strasburg (1964); 6 = Grey (1960)

The scombrids are differentiated by their higher myomere counts: most have 39 or more (*Scomber australasicus* has 31, but does not closely resemble the gempylids), while most gempylids have 32 to 38. Most scombrids also have more—and usually longer—preopercular spines, lack the long pelvic spines, and have a much lower and shorter spinous dorsal fin.

Most gempylids are distinguished from one another by fin ray and myomere counts, by pigmentation, and in at least some cases by preopercular spination (Voss, 1954). At present, three identifiable species from nearshore Hawaiian waters, *G. serpens*, *N. tripes*, and *Lepidocybium flaveobrunneum*, are easily distinguished meristically (Table 7).

Literature

de Jager (1955), Fourmanoir (1970), Gilchrist (1916: cited in Breder, Jr., and Rosen, 1966), Grey (1960), Jordan and Evermann (1903), Smith (1965), Strasburg (1964), Voss (1954)

SCOMBRIDAE

Scombrid larvae are profusely described and illustrated in the literature; e.g., Matsumoto (1959, 1967), Matsumoto et al. (1972), Mori et al. (1971), Richards and Potthoff (1974). Consequently, they will be treated only briefly here.

Scombrid larvae are slightly elongate to moderately deep-bodied, with a short gut (except *Acanthocybium*), a large head and mouth, usually heavy preopercular spination (except *Scomber*), usually early development of pelvic buds and dorsal spines, and often 39 to 43 myomeres (except *Acanthocybium*, *Sarda*, and *Scomber*). *Thunnus albacares* and *Auxis* spp. are the most common scombrid larvae in the nearshore surface waters of Hawaii.

Auxis spp. (keokeo)

Adult meristics

D: X-XII + 10-13 + 6-9 finlets; A: 12-14 + 6-8 finlets; P: 22-24; vertebrae: 39

Eggs

Mito (1961b) attributes a pelagic, spherical, 1.04-mm diameter egg with a single oil droplet to *Auxis* spp.

Larvae

Most *Auxis* spp. larvae taken in nearshore surface plankton tows have not developed to the stage of complete notochord flexion (ca. 6 to 7 mm SL). These small larvae have large heads with large mouths. The gut is short, giving a myomere formula of 8 + 31 or 9 + 30. Six to ten (depending on larval size) preopercular spines are present in two rows; the spine at the angle of the lower row is longest.

At ca. 3.5 mm SL (Figure 78) only the caudal fin anlage is present. Pigmentation includes an external melanophore overlying the posterior center of the midbrain, an internal melanophore on each side at the posterior margin of the midbrain, and another melanophore laterally on each side of the anterior hindbrain. A melanophore lies at the tip of the lower jaw, although it may be absent in some specimens. The gut is pigmented anteriorly and dorsally, and a single melanophore is present ventrally on the hindgut just above the anus. A series of

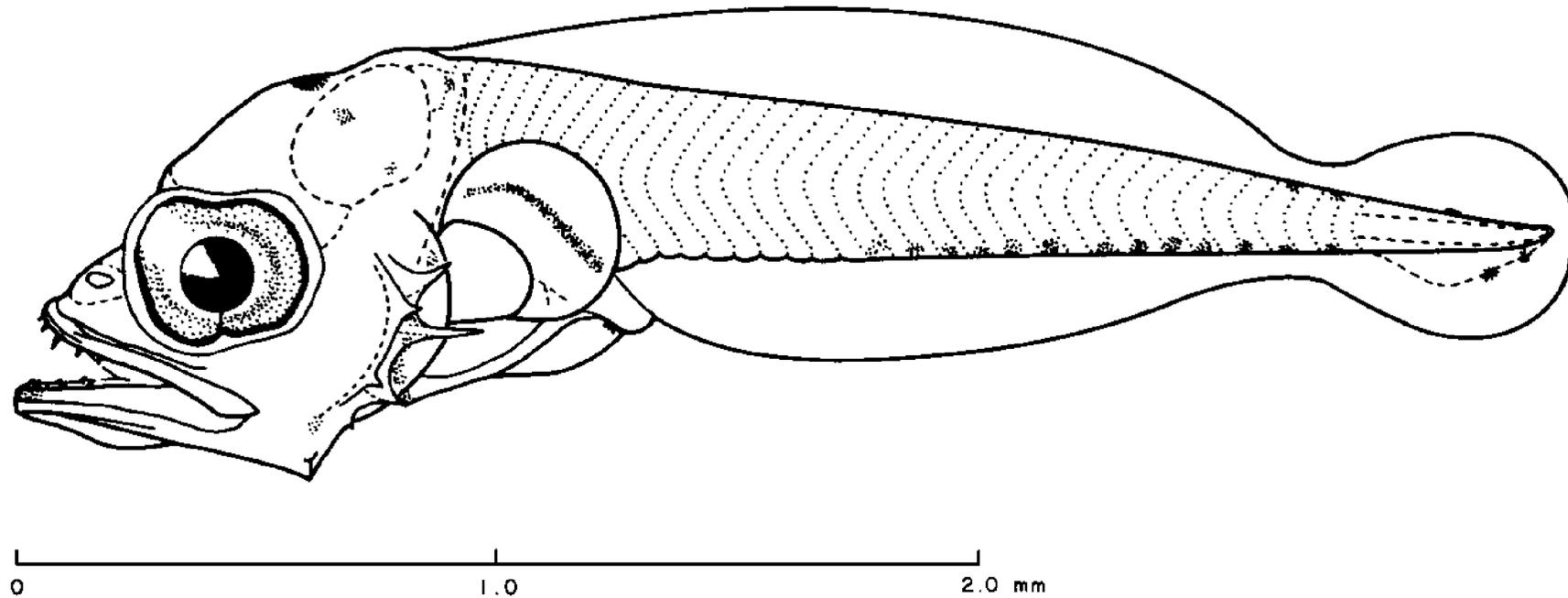


Figure 78. *Auxis* sp., 3.6 mm SL

melanophores (at most one per myomere) extends along the ventral midline, from myomere 18 to 20 to the peduncle. One or two melanophores are present on the caudal fin anlage. Others—rarely more than three—extend along the dorsal midline caudad from about myomere 35 (Figure 78). Melanophores may be present or absent at the symphysis of the cleithra but are always present in larger larvae.

Incipient caudal fin rays begin to become visible at ca. 4 mm SL, and pelvic fin buds first appear at ca. 5 mm SL. The number of preopercular spines in the lower row increases from four to six, and pterotic spines develop. The midbrain becomes more heavily pigmented externally. Further development is described and illustrated in Matsumoto (1959).

***Thunnus albacares* (ahi)**

Adult meristics

D: XII–XIV + 12–16 + 8–10 finlets; A: II, 12–15 + 7–10 finlets;
P: 33–36; C: 17; vertebrae: 39

Eggs

Mori et al. (1971) described artificially fertilized, transparent eggs, averaging 0.98 mm in diameter, from *T. albacares*.

Larvae

T. albacares larvae are thoroughly described and illustrated in the literature. For example, Mori et al. (1971) illustrated a series from the yolk sac stage through 7.8 mm SL, while Matsumoto et al. (1972) illustrated a series from 3.8 to 13.4 mm SL. A 5.7-mm SL specimen is illustrated in Figure 79 to show the characteristic features of smaller *T. albacares* larvae.

This larva has a large head and mouth, long preopercular spines, and a short gut. The myomere formula is 9 + 30. Pelvic fins; dorsal, anal, and caudal fin anlagen; and incipient caudal fin rays are present. The anterior dorsal spines and pterotic spines first appear at ca. 6 mm SL; the notochord is flexed and incipient dorsal and anal fin rays present by ca. 7 mm SL.

Melanophores are absent at the forebrain and symphysis of the cleithra, a characteristic of the genus *Thunnus*. A single melanophore is present at the tip of the lower jaw, but not on the upper (it will appear in larvae larger than

ca. 6 mm SL). External melanophores overlie the midbrain region and internal ones lie along the posterior margin of the midbrain. The gut is pigmented anteriorly, dorsally, and dorsolaterally. A few melanophores lie along the cleithra at the level of the pectoral fin. Dorsal, lateral, and ventral midline melanophores are absent, but a single melanophore may occur on the caudal fin anlage. In larger larvae the first dorsal fin is heavily pigmented.

Identification

Distinction between scombrids and *Lampanyctus* spp., gempylids, and *Scambrolabrax* is discussed in the "Myctophidae," "Gempylidae," and "Scombrabolabracidae" sections, respectively.

Among the scombrids, *Acanthocybium solandri* is immediately recognized by its elongate body and jaws, long gut, and high (63) myomere count. *A. solandri* larvae are described and illustrated in Matsumoto (1967).

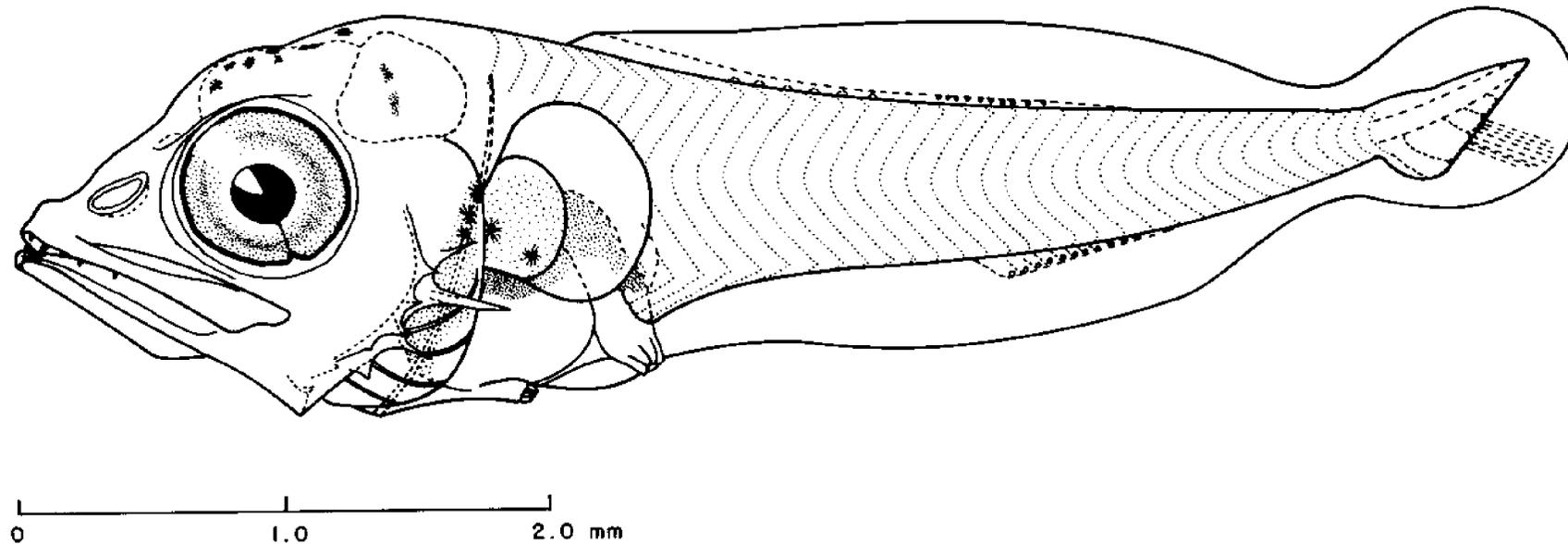


Figure 79. *Thunnus albacares*, 5.7 mm SL

Scomber australasicus is likewise easily recognized by its typical scombrid appearance, unusually low (31) myomere count, and lack of preopercular spines. Its pigmentation is similar to that of *Auxis* spp. *S. japonicus* is described and illustrated in Uchida et al. (1958).

Katsuwonus pelamis larvae may be recognized by having a melanophore at the anterior margin of the forebrain at ca. 6 mm SL and larger, lacking melanophores at the symphysis of the cleithra at all sizes and on the dorsal midline below ca. 9 mm SL, and having one to three melanophores on the ventral midline near the caudal fin. *K. pelamis* has 41 myomeres. *K. pelamis* larvae are described and illustrated in Matsumoto (1958).

Euthynnus affinis larvae larger than ca. 3.5 mm SL have one or more melanophores on the forebrain, several at the symphysis of the cleithra, a series along the ventral midline, and none midlaterally or middorsally. They have 39 myomeres. *Euthynnus* spp. larvae are described and illustrated in Matsumoto (1959).

Thunnus spp. larvae are recognized by their lack of melanophores at the symphysis of the cleithra and on the forebrain and by the number of myomeres (39). The two *Thunnus* species most commonly recognized from nearshore surface plankton tows, *T. albacares* and *T. obesus*, may be distinguished by the absence of midventral melanophores in *T. albacares* and presence of usually one or two midventrally on the peduncle in *T. obesus*. Differentiation of the various *Thunnus* species is discussed in Matsumoto et al. (1972) and in Richards and Potthoff (1974); *T. albacares* is illustrated in Matsumoto et al. (1972), and *T. obesus* (as *Parathunnus sibi*) in Matsumoto (1962).

Sarda sp. is illustrated in Jones and Kumaran (1964d).

Literature

Chen and Tan (1973), Jones and Kumaran (1964d), Matsui (1967), Matsumoto (1958, 1959, 1962, 1967), Matsumoto et al. (1972), Mito (1961b), Mori et al. (1971), Richards and Klawe (1972), Richards and Potthoff (1974), Uchida et al. (1958)

NOMEIDAE

Nomeid larvae are quite diverse. They are slightly deep to deep-bodied and lightly to heavily pigmented, having early-developing or late-developing long or short pelvic fins, and have 31 to 41 myomeres. All have weak preopercular spination, a gut extending one-half the length of the body or less, and usually moderately long dorsal and anal fins.

Cubiceps pauciradiatus, a relatively slender nomeid and the most common in Hawaiian inshore waters, represents the family in this atlas.

Cubiceps pauciradiatus

Adult meristics

D: X–XII + I, 16–18; A: I–II, 14–17; P: 16–20; V: I, 5; C: 17; vertebrae: 31.

Eggs

C. pauciradiatus eggs are described in Ahlstrom et al. (1976).

Larvae

C. pauciradiatus larvae are rather plain. They are more slender and have later-developing and smaller pelvic fins than the other nomeid genera. The gut extends nearly one-half the length of the body, giving a myomere formula of 14 + 17. The gas bladder is quite conspicuous anteriorly. The preopercular spines are small.

At ca. 4.5 mm SL (Figure 80), dorsal, anal, and caudal fin anlagen and usually six caudal fin rays are present. The notochord is beginning to flex. Pigmentation includes external melanophores above the midbrain and forebrain, on the snout, at the tips of both jaws, and near the upper end of the maxillary. An internal melanophore lies on each side at the posterior margin of the midbrain and at the anterior margin of the midbrain. A single melanophore lies at the anterior center of the gut, about on a level with the bottom of the pectoral fin base. A series overlies the gas bladder and gut dorsally. One or two melanophores each lie on the dorsal, lateral, and ventral midlines to form a band in the vicinity of myomeres 18 to 22.

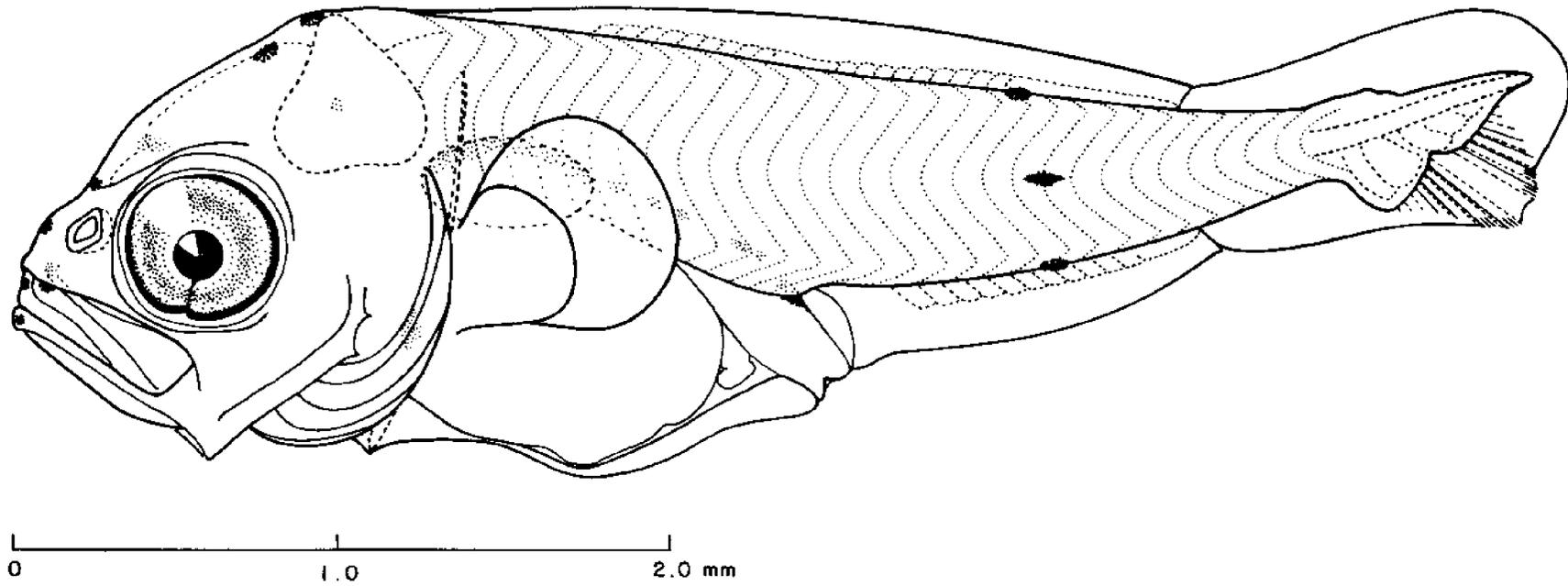


Figure 80. *Cubiceps pauciradiatus*, 4.6 mm SL

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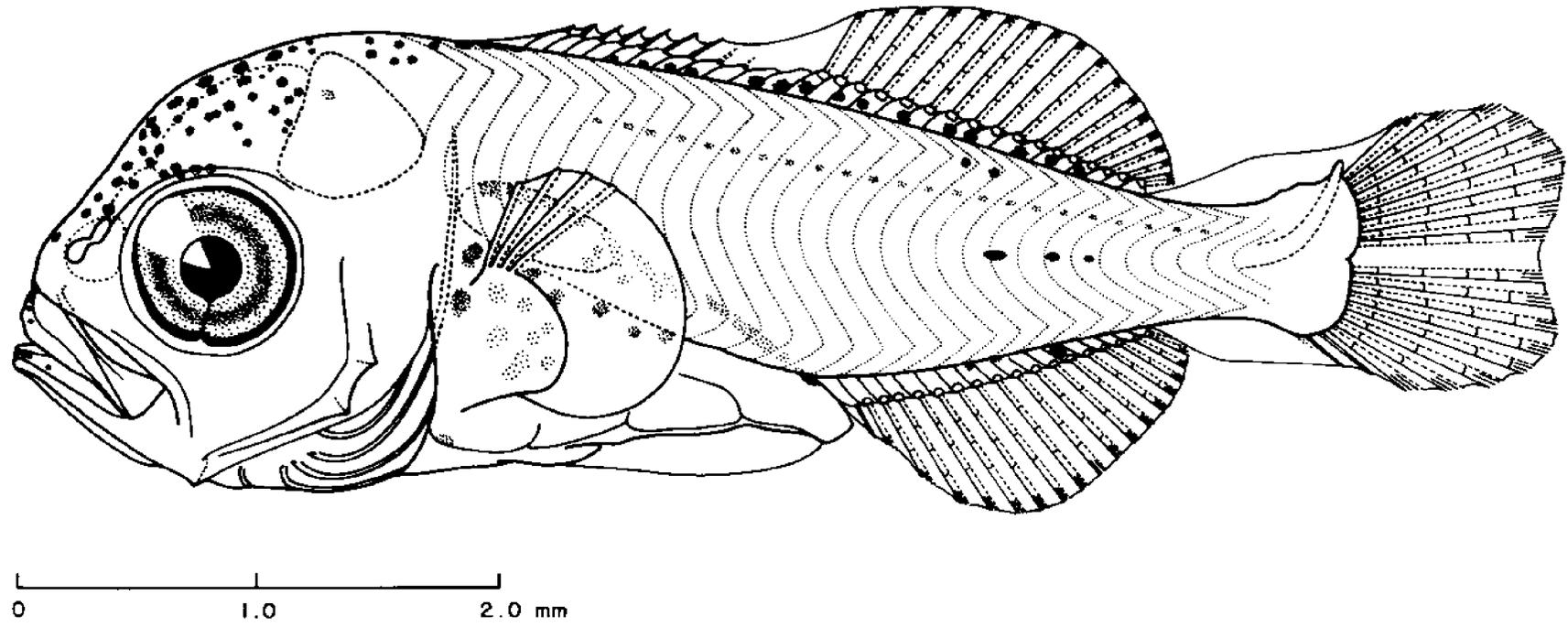


Figure 81. *Cubiceps pauciradiatus*, 5.5 mm SL

By ca. 5.5 mm SL (Figure 81) the notochord is flexed and the caudal fin emarginate. All dorsal and anal fin rays, and most dorsal spines, are present. The upper pectoral fin rays are becoming ossified, and pelvic fin buds have developed. The body is somewhat deeper. Melanophores are scattered over the dorsal surface of the head and laterally over the gut. A few more are present along both jaws. Others are paired along the base of most dorsal elements. The midlateral melanophores remain, with myoseptal melanophores above them and single melanophores along the anal fin ray bases below. A series of melanophores overlies the notochord, extending forward to the level of the gas bladder or just beyond. As development proceeds, the pigmentation increases, so that metamorphic stage individuals are nearly uniformly pigmented.

Identification

C. pauciradiatus larvae superficially resemble those of the carangid, *Trachurops crumenophthalmus*. Their differences are discussed in the "Carangidae" section.

Within the family Nomeidae, the genus *Cubiceps* may be distinguished from *Psenes* and *Nomeus*. *Psenes arafurensis* and *P. cyanophrys* larvae are deep-bodied, with 31 myomeres and large pelvic fins which develop far in advance of the other fins. *Nomeus grovonii* is moderately deep-bodied, with large pelvic fins, and 41 myomeres. *Cubiceps* are more slender, have smaller pelvic fins, and are more uniformly pigmented at larger sizes.

Within the genus *Cubiceps*, *C. caeruleus* may be distinguished from *C. pauciradiatus*. The former is slightly deeper-bodied, lacks midlateral and mid-dorsal pigments, has a midventral melanophore series along most of the tail (at least in preflexion larvae), and has more myomeres (33 in *C. caeruleus*; 31 in *C. pauciradiatus*).

Literature

Ahlstrom et al. (1976), Fourmanoir (1971b), Legaspi (1956)

GOBIIDAE

Gobiidae larvae are ubiquitous in nearshore Hawaiian waters. They are rather nondescript, with a blunt snout, a large gas bladder located midway or posteriorly over the gut which extends a little less than one-half the length of the body, 25 to 26 myomeres, and light pigmentation. Larger larvae and metamorphic stage specimens have separate dorsal and fused pelvic fins.

Larval gobiids closely resemble one another; consequently, their identification is difficult. Species attributions are mainly restricted to some of the large larvae and later stages. Among these, *Psilogobius mainlandi* is best known.

Psilogobius mainlandi

Adult meristics

D: VI + I, 10; A: I, 9; P: 16; V: I, 5; C: 15; vertebrae: 26

Eggs

P. mainlandi eggs have not been previously described in the literature, but may be oval, demersal, attached, and brooded by the adult male, as has been reported for other gobiids, e.g., Dotu and Mito (1955), Shiogaki and Dotsu (1972).

Larvae

No larvae smaller than 4 mm SL (Figures 82 and 83) have been attributed to *P. mainlandi*. At 4 mm SL the caudal fin rays and most dorsal and anal fin rays are ossified, pelvic fin buds are present, and incipient dorsal spines and upper pectoral fin rays are visible. The gas bladder is quite large. External melanophores are located at the isthmus and pelvic fin base. Two or three lie on the ventral midline posterior to the anal fin, and still others lie in two rows along the base of the anal fin in a staggered pattern. The gas bladder is pigmented dorsally.

Ossified pelvic fin rays are discernible by ca. 5 mm SL, and all fins are fully developed (except the lower two or three pectoral fin rays) by ca. 5.5 mm SL. Specimens of this size have a typical gobiid appearance (Figure 84), but do not yet resemble adult *P. mainlandi*. Larvae of ca. 5 mm SL may or may not have a melanophore on the hindgut just above the anus. Those larger than ca. 6 mm SL have one at each nostril, a pair dorsally and ventrally on the hindgut just above the anus, and occasionally a few over the midbrain and branchial regions.

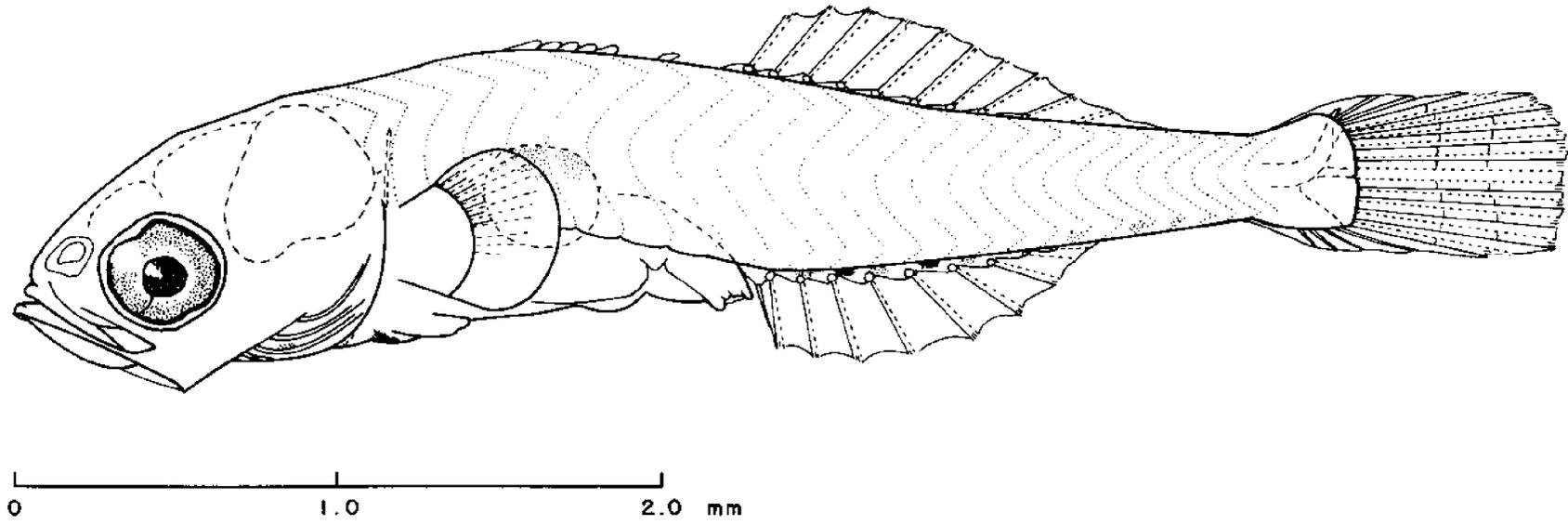


Figure 82. *Psilogobius mainlandi*, 4.1 mm SL

82

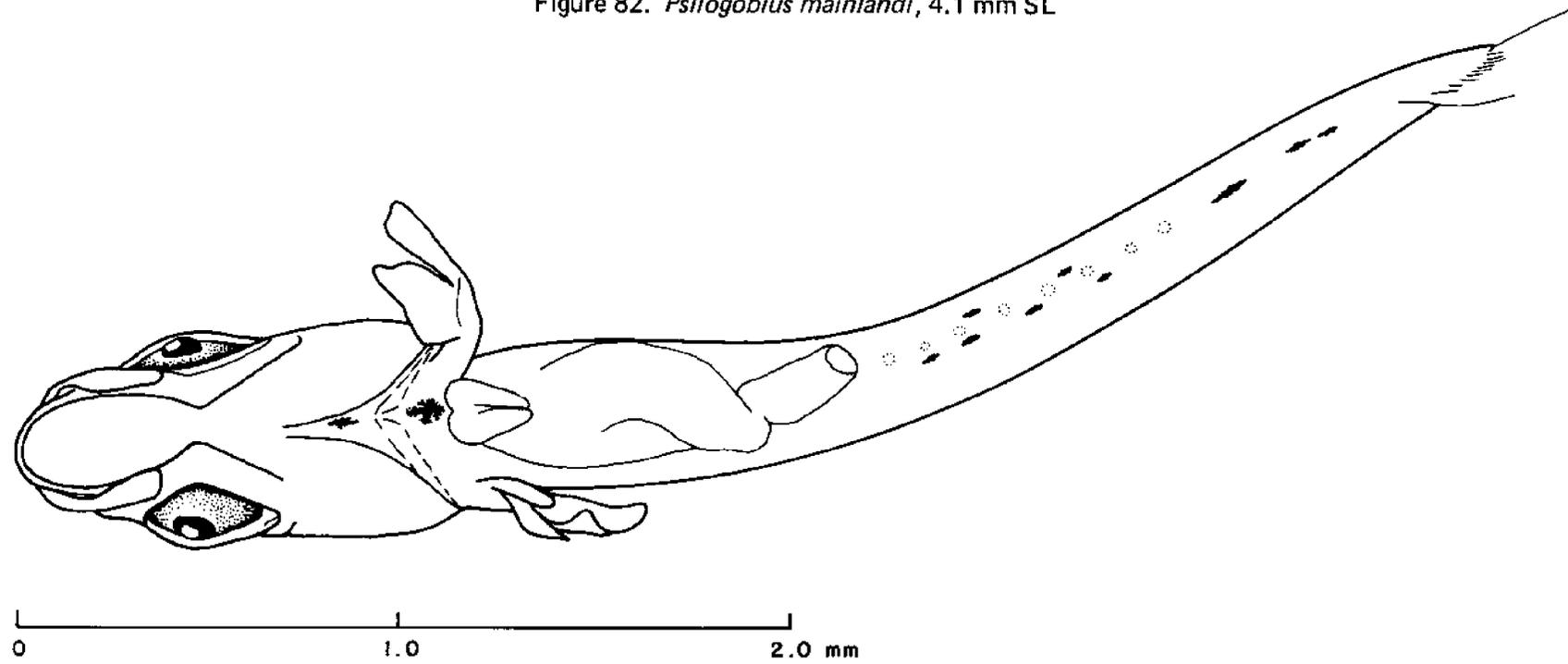


Figure 83. *Psilogobius mainlandi*, 4.1 mm SL, ventral view

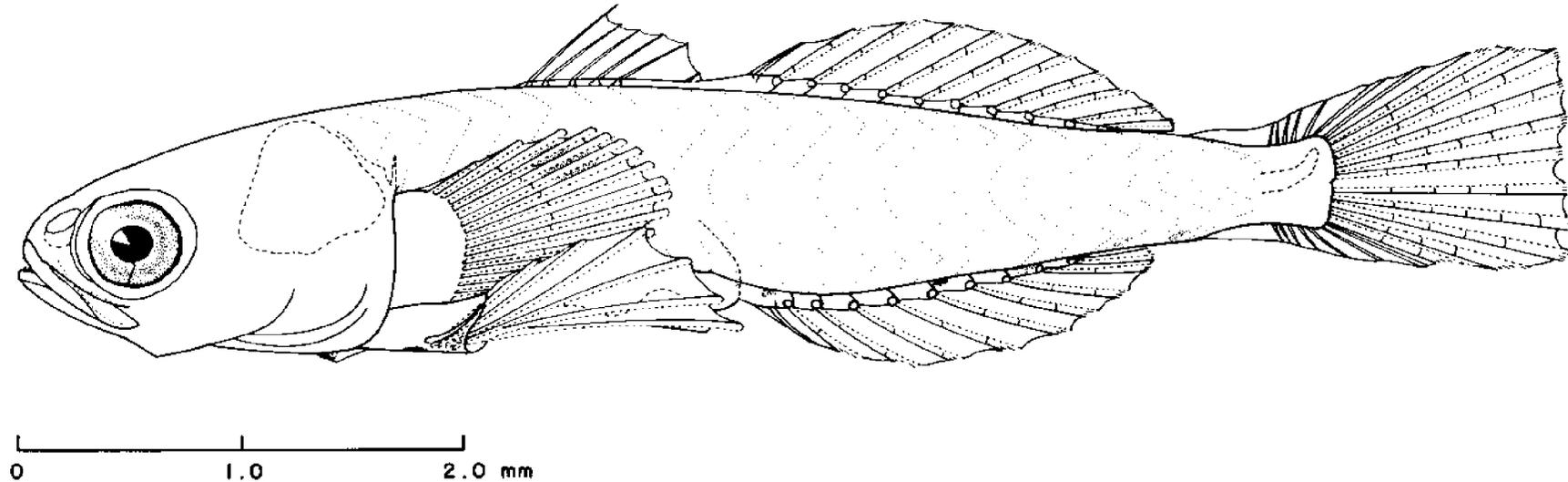


Figure 84. *Psilogobius mainlandi*, 5.8 mm SL

Identification

Gobiid larvae may be recognized by the large gas bladder, gut length, 25 to 26 myomeres, light pigmentation, and fins in larger specimens. They may be confused with apogonids at the smaller sizes; distinction between the two is discussed in the "Apogonidae" section.

Within the family Gobiidae, 19 types, including the two marine eleotrids, are recognized in Hawaii (Gosline and Brock, 1960). Those for which species attributions are possible are nearly all larger larvae, metamorphic stages, and juveniles. Brief descriptions of a few of these follow.

Asterropteryx semipunctatus. Adult meristics are D: VI + I, 11; A: I, 10; P: 17–20. *A. semipunctatus* typically has an expanded melanophore at the isthmus, one at the pelvic fin base, one dorsally on the hindgut just above the anus, and three or four evenly spaced along the postanal ventral midline. The melanophore on the isthmus may be absent in individuals smaller than ca. 4 mm SL.

Bathygobius fuscus (ohune). Adult meristics are D: VI + I, 9; A: I, 9; P: 19–20. *B. fuscus* is somewhat shorter and broader than most other gobiid larvae. Single melanophores are present at the articular, otic capsule, isthmus, and pelvic fin base; others appear on the dorsal surface of the gas bladder, the dorsal hindgut just above the anus, in two rows along the anal fin (usually 3 to 4 pairs), in a single midventral row posterior to the anal fin (usually 1 to 3), and in an internal diagonal band through the body from just behind the anal fin to dorsal fin ray 7 or 8.

Eviota epiphanes. Adult meristics are D: VI + I, 9; A: I, 8; P: 16. This species has dorsal pigmentation on the gas bladder, a dorsal melanophore on the hindgut just above the anus, and one to four posterior dorsal midline melanophores overlying the midventral series. Branched pelvic fin rays are distinctive when they become ossified.

Gnatholepis knighti (=anjerensis). Adult meristics are D: VI + I, 11–12; A: I, 11–12; P: 18. Melanophores are present only on the dorsal surface of the gas bladder; metamorphosing specimens have a bar below the eye extending across

the cheek. Live specimens have erythrophores at the articular, isthmus, pelvic base, and dorsal hindgut just above the anus; along the anal fin (usually 3 to 4); on the ventral midline posterior to the anal fin (usually 1 to 2); and in a diagonal band internally through the body from just behind the anal fin to dorsal fin ray 11 or 12.

Kellogella oligolepis. Adult meristics are D: VI + I, 11; A: I, 6; P: 15. This species is known from preflexion larvae only. Melanophores are present on the dorsal surface of the gas bladder and the dorsal surface of the gut. None to two are present ventrally on the midgut and none to two are on the dorsal midline between myomeres 16 and 18. Live specimens have erythrophores along the lower jaw, ventrally and ventrolaterally along the gut, ventrolaterally from the level of the otic capsule to between myomeres 18 and 20, and dorsally and dorsolaterally from the level of the anus to between myomeres 18 and 20.

Oxyurichthys lonchotus. Adult meristics are D: VI + I, 12; A: I, 13; P: 19. This species is more elongate than most other gobiid larvae. Single melanophores are at the isthmus and the pelvic fin base, others are on the dorsal surface of the gas bladder, and one pair is at each anal fin ray base. Living specimens have erythrophores at each anal fin ray base and two bands internally through the body.

Among the unidentified gobiids, types 8, 9, and 12 are commonly encountered.

Gobiid type 8. None have fully developed fins. Melanophores are present dorsally on the gas bladder and on the hindgut just above the anus; one (usually expanded) is present on the ventral midline halfway between the anus and peduncle.

Gobiid type 9. Adult meristics are D: $\geq V + \geq 10$; A: 9. This type is usually small and almost certainly includes more than one gobiid species, and perhaps *Asterropteryx semipunctatus* as well. Melanophores are present dorsally on the gas bladder and present or absent on the hindgut just above the anus. In addition, there are usually 2 to 5 along the ventral midline in an irregularly spaced single row.

Gobiid type 12. Adult meristics are D: ≥ 11 ; A: ≥ 10 . Single melanophores are present at the articular and present or absent on the isthmus. They are also present at the pelvic fin base and ventrally at the center of the gut and on the hindgut just above the anus. Others are present dorsally on the gas bladder and over the hindgut. Two or three elongate pairs are evenly spaced along the ventral midline between the anus and myomere 20. One or two pairs are present along

the dorsal midline on adjacent myomeres between myomeres 15 and 20 and an internal band is present through the body (may be absent in small specimens) between posterior dorsal and anal midline pairs.

Literature

Delsman (1926c), Dotu and Mito (1955), Gosline and Brock (1960), Shiogaki and Dotsu (1972)

TRIPTERYGIIDAE

Tripterygion atriceps

Adult meristics

D: III + XIII–XIV + 9–10; A: I, 19–20; P: 14–16; V: I, 2; C: 13; vertebrae: 36

Eggs

T. atriceps eggs have not been previously described in the literature. However, round, attached demersal eggs brooded by the adult male have been described for other species of this genus by Ruck (1973) and others.

Larvae

T. atriceps larvae are slender, with a short gut, a somewhat elongate snout, 36 myomeres, and a characteristic pattern of melanophores posteriorly along the dorsal and ventral midlines. They look like blennies, particularly at the smaller sizes.

Larvae of ca. 3 mm SL (Figure 85) are beyond the yolk sac stage, but have not yet developed fin anlagen. The myomere formula is 10 + 26. A small gas bladder, visible anteriorly, is present throughout larval development but is apparently lost during metamorphosis. Pigmentation is light: the gas bladder is pigmented dorsally, a large melanophore lies on the hindgut just above the anus, and three or four lie along the ventral midline in the vicinity of myomeres 24 to 30, with one or two others on the dorsal midline opposite the last one or two of the midventral series.

By ca. 6 mm SL (Figure 86) the notochord is flexed and the principle caudal fin rays are ossified, the dorsal and anal fin anlagen are developing, and the pelvic fin buds are present. The pectoral fins remain small and undifferentiated. The gas bladder is usually small and is positioned three or four myomeres more posteriorly than in ca. 3 to 4 mm SL larvae. The pigment pattern changes little: all the earlier pigment is retained, an internal melanophore may overlie the notochord just posterior to the hindbrain, and a Y-shaped melanophore lies at each soft anal fin ray base (Figures 86 and 87). A melanophore may be present at the articular.

In larvae larger than ca. 8 mm SL, an external melanophore overlies the posterior center of each midbrain hemisphere and an internal melanophore lies on

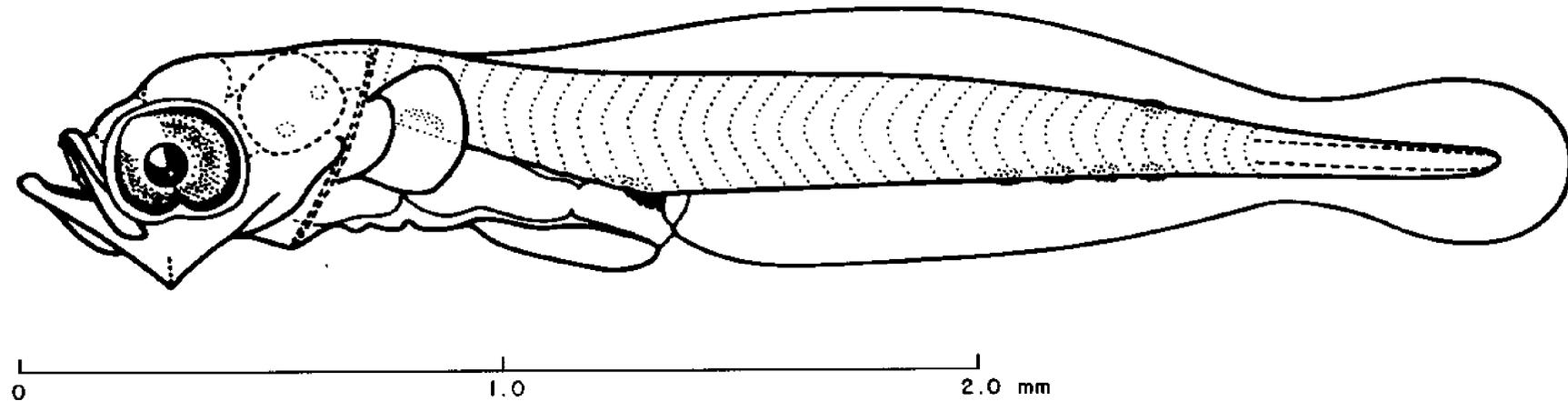


Figure 85. *Tripterygion atriceps*, 3.2 mm SL

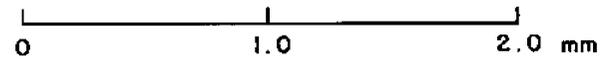
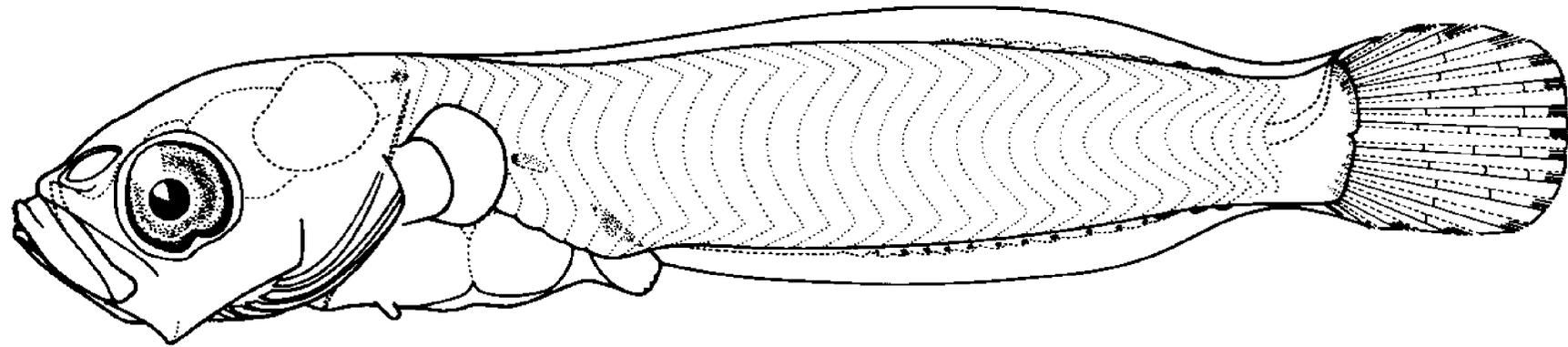


Figure 86. *Tripterygion atriceps*, 5.8 mm SL

86

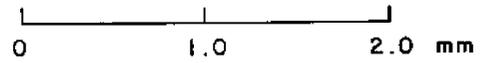
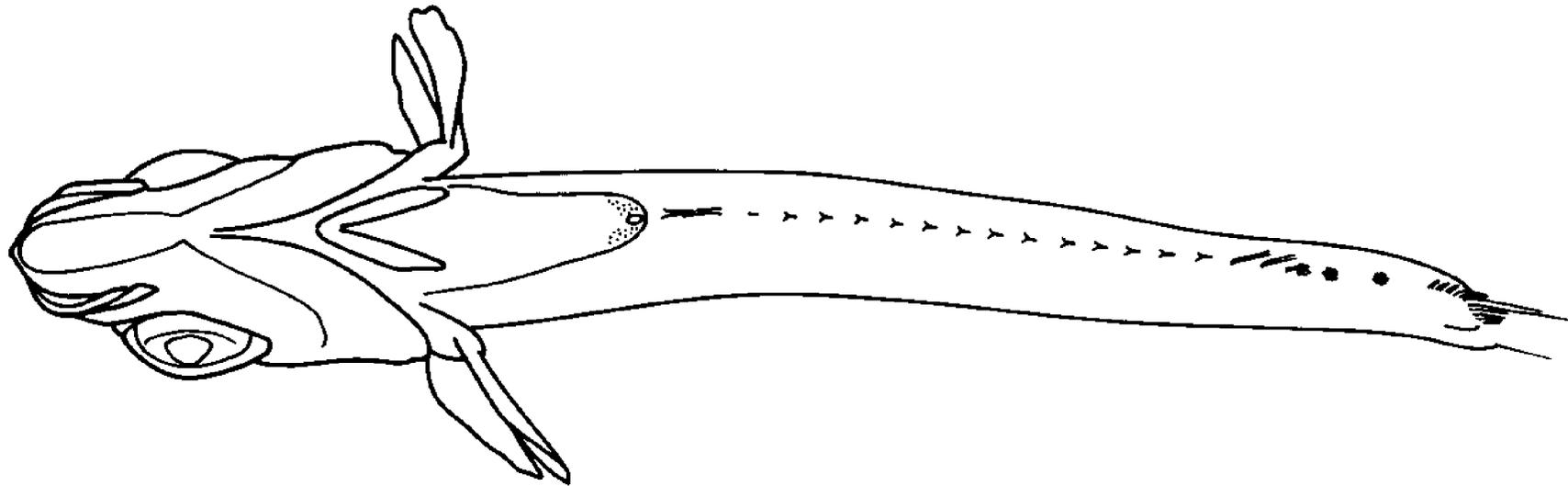


Figure 87. *Tripterygion atriceps*, 8.5 mm SL, ventral view

the dorsal center of the hindbrain. There are no other pigmentation changes before metamorphosis (ca. 10 to 11 mm SL). Larval development is discussed further in Watson ("Larval development of the scaled blenny, *Tripterygion atriceps*," in preparation).

Identification

T. atriceps larvae are immediately recognized by their blenniid appearance and distinctive dorsal and ventral midline pigmentation. The pigmentation pattern resembles larvae of the myctophid, *Lampadena urophaos*, but they are easily distinguished by the longer, convoluted gut of the latter.

Literature

Ruck (1973), Shioyaki and Dotsu (1973), Watson ("Larval development of the scaled blenny, *Tripterygion atriceps*," in preparation)

BLENNIIDAE

The blenniid larvae most commonly encountered in Hawaiian waters are of three similar, but easily distinguished, tribes: Salariini, Omobranchini, and Blenniini. All three types are rather long and slender, with a short gut, no apparent gas bladder, long dorsal and anal fins, jugular pelvic fins, and myomeres numbering in the thirties. Blenniini and Omobranchini have shorter guts, more rounded heads, and longer preopercular spines than do the salariines. Salariines, on the other hand, usually have much longer pectoral fin rays in the late larval and prejuvenile stages and characteristic large hooked canine teeth in the lower or both jaws. The types are distributed differently with respect to distance away from shore (and possibly vertically as well: see Watson, 1974). *Enchelyurus brunneolus* typifies the Blenniini-Omobranchini type larvae, while *Istiblennius zebra* represents the Salariini.

Enchelyurus brunneolus

Adult meristics

D: X, 20–21; A: II, 2Q; P: 14–15; V: I, 2; C: 13; vertebrae: 35

87

Eggs

E. brunneolus larvae hatch at ca. 2.5 mm SL, with very little yolk, pigmented eyes, and functional jaws. Three or four very small preopercular spines are present.

Yolk sac larvae

E. brunneolus larvae hatch at ca. 2.5 mm SL, with very little yolk, pigmented eyes, and functional jaws. Three or four very small preopercular spines are present.

Larvae

In ca. 3 mm SL larvae (Figure 88), four small preopercular spines of approximately equal length and one or two small supraocular spines may be present. Two small teeth are present anteriorly in the upper jaw. The gut is quite short, giving a myomere formula of 6 + 29. The caudal fin anlage is just beginning to develop. Melanophores overlie the midbrain region externally and the dorsal and dorsolateral surface of the gut internally. A single melanophore may lie ventrally on the gut, just anterior to the anus. A characteristic row of five to seven

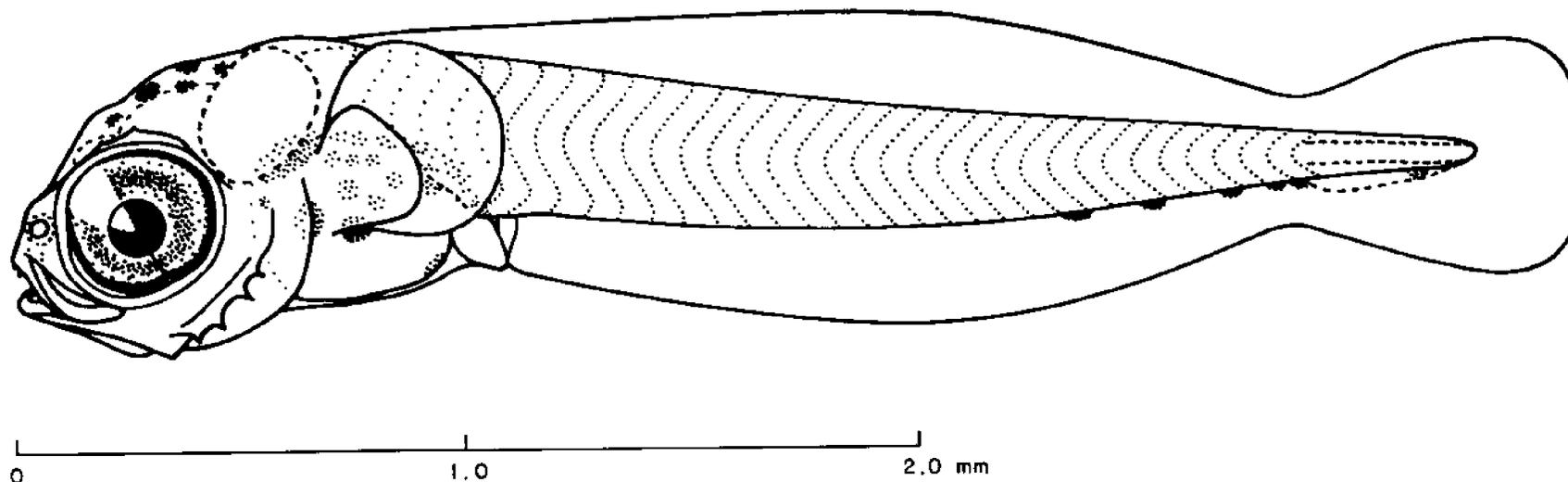


Figure 88. *Enchelyurus brunneolus*, 3.2 mm SL

88

melanophores lies posteriorly along the postanal ventral midline, usually extending no further cephalad than myomere 25.

By ca. 3.5 mm SL the spine at the angle of the preopercle is clearly longer than the others; the larvae are otherwise little changed.

Larvae of ca. 6 mm SL (Figure 89) have pelvic fin buds and fully developed pectoral and caudal fins. All dorsal and soft anal fin rays are partly ossified, incipient anal rays are discernible, and the spiny dorsal is forming. The myomere formula is $9 + 26$. The ventral midline pigment is reduced by ca. 6 mm SL: only a single melanophore remains just posterior to the base of the last anal fin ray. A pair of elongate melanophores lies along the distal margin of the peduncle, and a series of widely spaced melanophores overlies the notochord posteriorly. The gut usually becomes more heavily pigmented laterally, and the branchial region becomes heavily pigmented as well. The pigmentation of the midbrain region changes little (Figure 89).

The spine at the preopercular angle shortens as development proceeds beyond ca. 7 mm SL; by ca. 12 mm SL it is very short and soon disappears entirely. The adult form is nearly attained by ca. 12 mm SL; at about this size *E. brunneolus* settle out of the plankton.

Istiblennius zebra (panoa)

Adult meristics

D: XIII, 21; A: II, 22; P: 14; V: I, 2; C: 13; vertebrae: 38

Eggs

I. zebra has round, demersal, attached eggs which are brooded by the adult male.

Larvae

Small larvae, ca. 2.5 to 3.5 mm SL (Figure 90), are often taken in nearshore plankton tows. The smallest of these are slender and round-headed, with a fairly short gut and a characteristic group of five expanded melanophores along the distal margin of the pectoral fin. A few melanophores are present ventrolaterally on the gut, and a series of five or six each lie above the gut and posteriorly on the ventral midline.

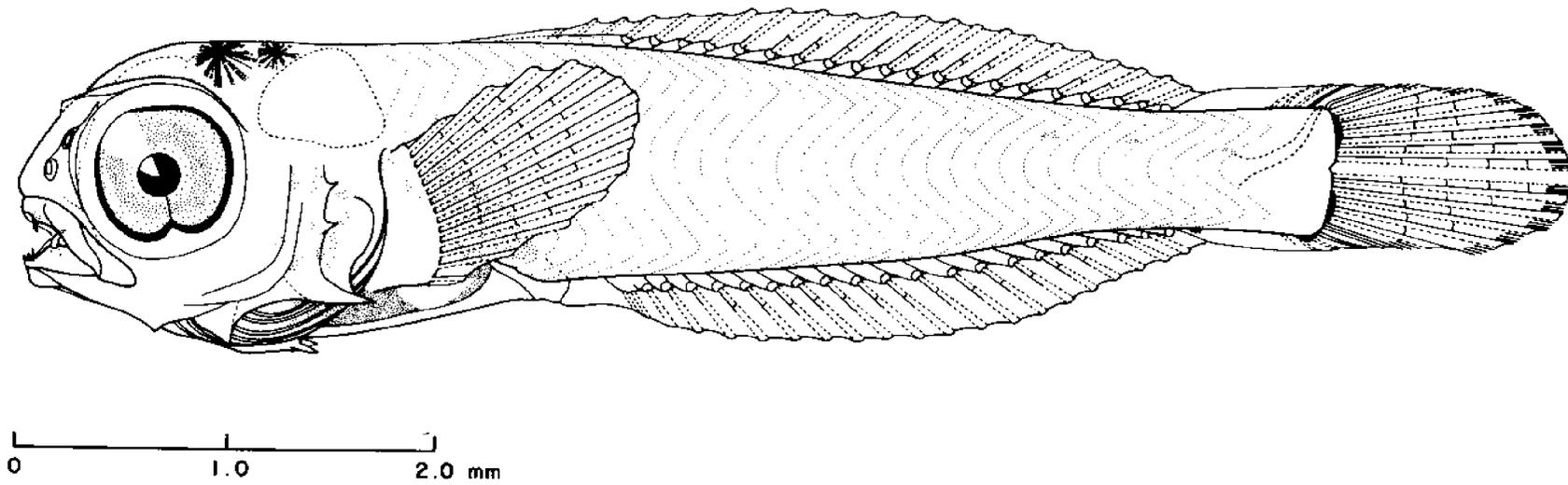


Figure 89. *Enchelyurus brunneolus*, 6.1 mm SL

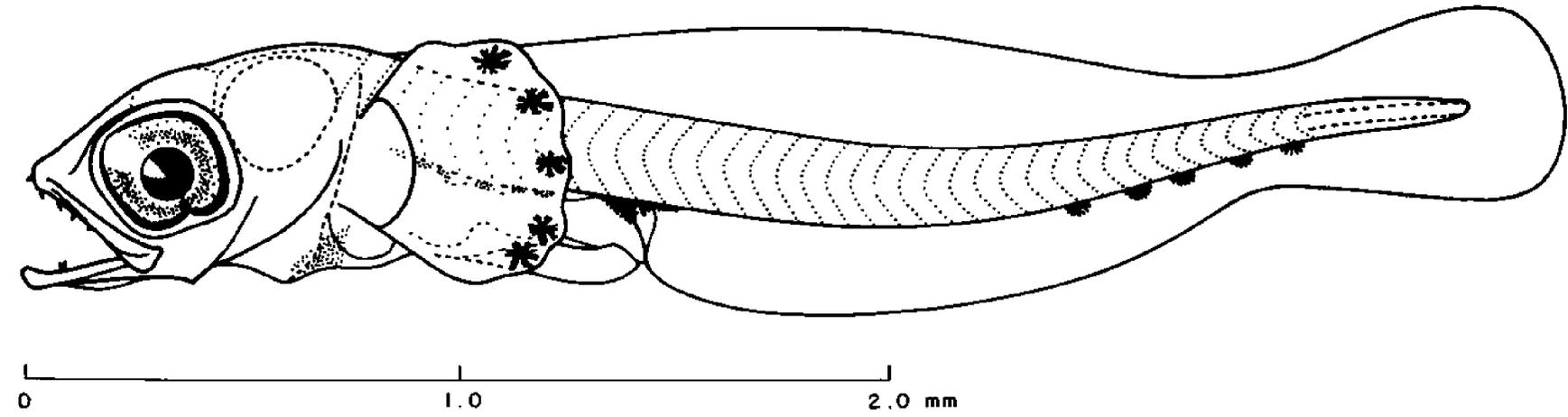


Figure 90. *Istiblennius zebra*, day 4, 3.3 mm SL

Larvae of ca. 3.5 mm SL remain slender, with a myomere formula of 10 + 28. Between 3 and 3.5 mm SL (Figure 90) the jaws elongate and teeth develop. Pigmentation changes little: the series along the ventral midline of the tail extends no further forward than myomere 26 or 27; the characteristic five expanded melanophores lie along the distal pectoral fin margin; a series of melanophores overlies the gut dorsally; and additional melanophores lie internally in the region of the lower part of the cleithra (Figure 90).

Larvae larger than ca. 3.5 mm SL are rarely encountered inshore, although prejuveniles larger than ca. 20 mm SL are not uncommon. *I. zebra* of intermediate sizes (Figure 91) are usually taken offshore. These offshore *I. zebra* are long and slender, with very long pectoral fins and little pigment. The large, hooked canine teeth in the lower jaw are characteristic of salariine larvae and prejuveniles (Figure 92).

All fins are fully developed by ca. 11 mm SL (Figure 91). Small supraocular and preopercular spines are present. The myomere formula remains 10 + 28. A few melanophores lie on top of the head in the midbrain region and a single melanophore lies on the articular. None to a few melanophores may occur under the operculum. Widely scattered melanophores surround the gut dorsally and

laterally. A melanophore lies near the proximal end of the second or third innermost epural and hypural caudal fin rays. The typical pectoral fin pigment consists of an expanded melanophore at the distal end of each pectoral fin ray, except the uppermost two or three. A few scattered melanophores may lie on the membrane in the distal half of the fin as well (Figure 91).

Identification

Blennioid larvae are rather elongate, with short guts, myomeres numbering in the thirties, jugular pelvic fins and long dorsal and anal fins at larger sizes, early development of pectoral fin rays, long pectoral fins in the larger Salariaiini, moderate preopercular spines in the Blenniini, and large preopercular spines in the Omobranchini. The salariine larval teeth are distinctive.

Differences in pigmentation and preopercular spination allow identification of the various kinds of small blennioids, although not all can be identified to the specific level. Metamorphic stage and prejuvenile specimens are easily identified by fin ray and nuchal cirri counts (Table 8).

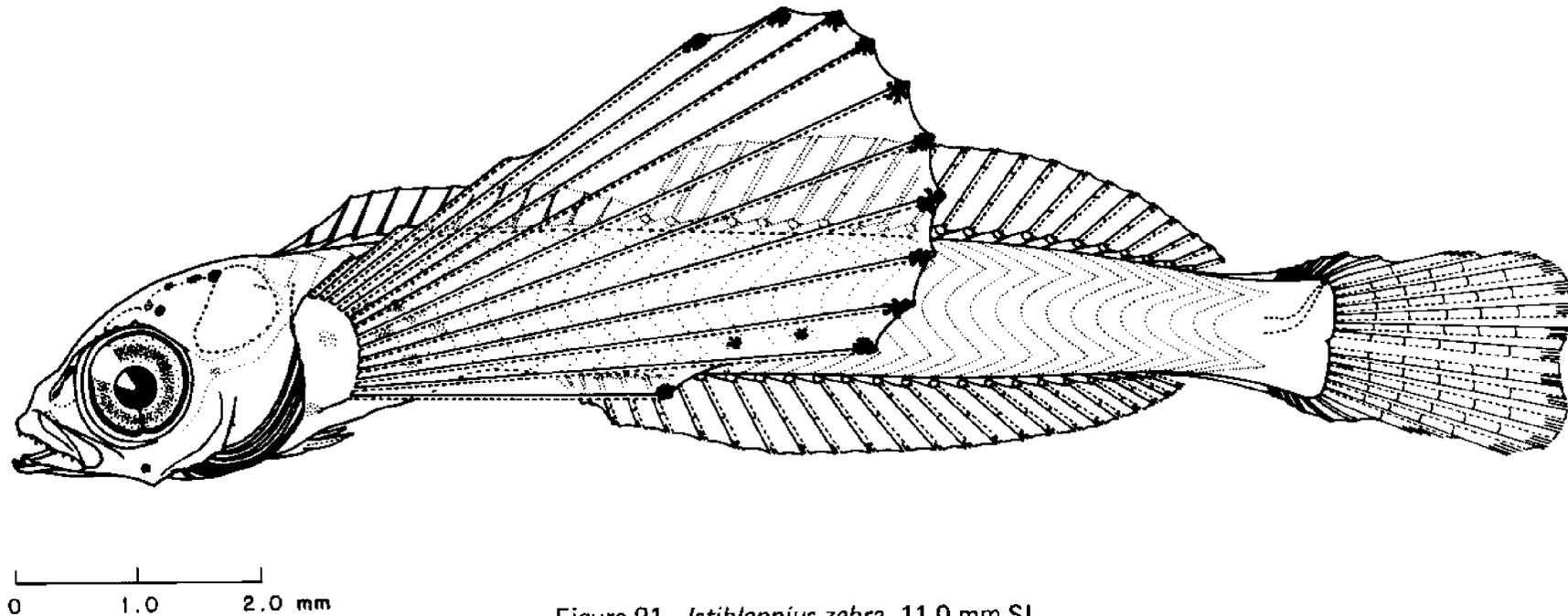


Figure 91. *Istiblennius zebra*, 11.0 mm SL

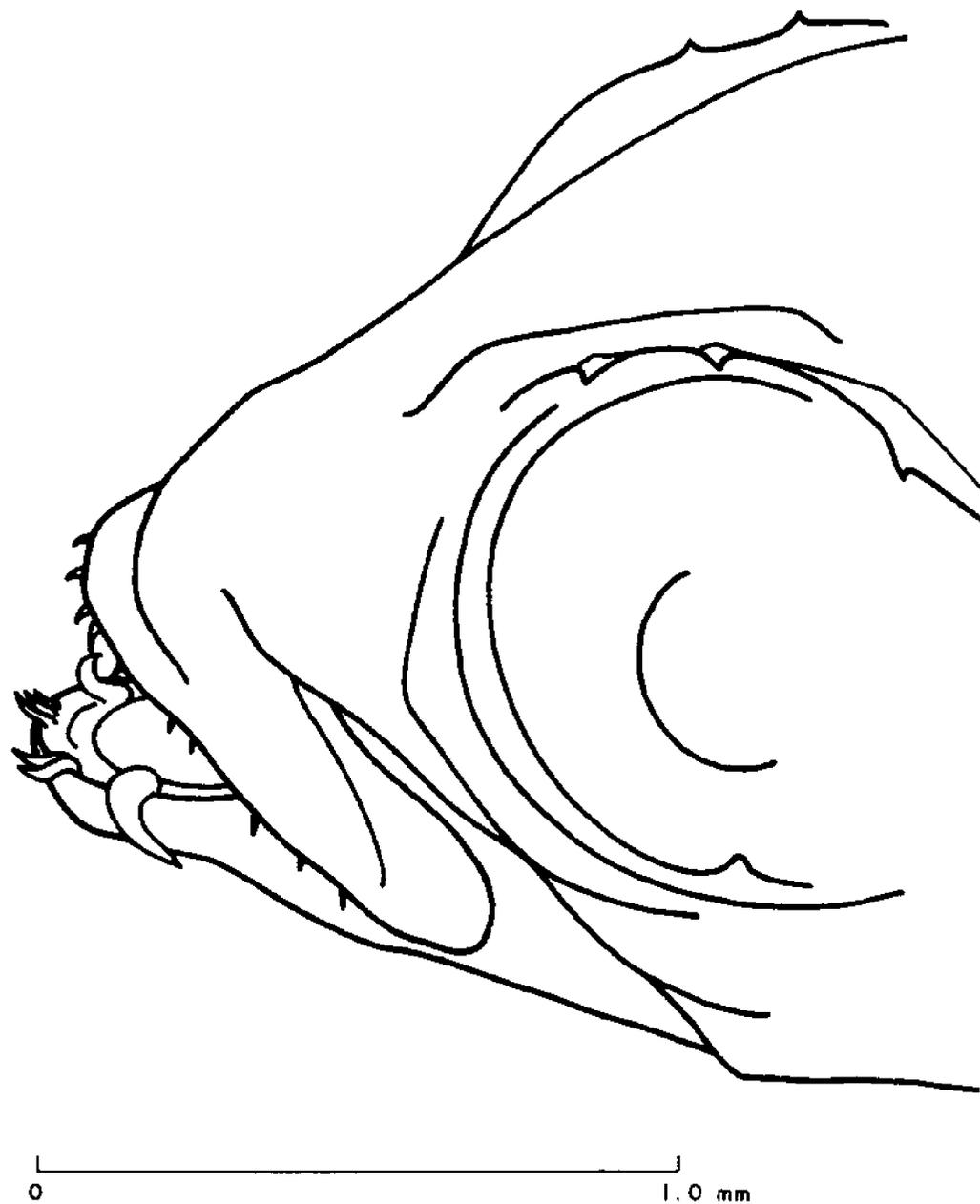


Figure 92. *Istiblennius zebra*, 11.0 mm SL, view of jaw

TABLE 8. SELECTED MERISTICS OF HAWAIIAN BLENNIID SPECIES

Species	Reference*	D	A	Nuchal Cirri
<i>Blennius</i> sp.	1	XII, 14-15	II, 16-17	0
<i>Cirripectus lineopunctatus</i>	1	XII, 15	II, 16	24-28
<i>C. obscurus</i>	1	XII, 16-17	II, 16-17	39-42
<i>C. variolosus</i>	1	XII, 13-14	II, 15	36-38
<i>Ecsenius bicolor</i> (=hawaiiensis)	2	XII, 16-18	II, 18-20	0
<i>Enchelyurus brunneolus</i>	1	X, 20-21	II, 20	0
<i>Entomacrodus marmoratus</i>	1	XIII, 14-15	II, 15-16	2-4
<i>Exallias brevis</i>	1	XII, 12-13	II, 13-14	32-36
<i>Istiblennius gibbifrons</i>	1	XIII, 16-19	II, 17-20	0
<i>I. zebra</i>	1	XIII, 20-22	II, 20-22	0
<i>Omobranchus rotundiceps obliquus</i>	1	XI-XIII, 18-21	II, 20-23	0
<i>Plagiotremeus</i> (=Runula) <i>ewaensis</i>	3	34-35	32-33	0
<i>Plagiotremeus ewaensis</i>	4	40	30	0
<i>P. gasfinei</i>	1	VIII, 35-36	II, 29-30	0

*1 = counts made by project personnel; 2 = Chapman and Schultz (1952); 3 = Strasburg (1956); 4 = Brock (1948)

Plagiotremeus spp. (tribe Nemophini) larvae differ from other blenniids in being heavily pigmented from the smallest sizes. They lack preopercular spines and do not have extraordinarily large pectoral fins. Their canine teeth develop early and are very strong.

Omobranchus rotundiceps obliquus larvae are illustrated as *O. elongatus* in Watson (1974).

Literature

Brock (1948), Chapman and Schultz (1952), Dotsu and Oota (1973), Fives (1970), Fourmanoir (1971b), Hildebrand and Cable (1938), Mito (1954: this species was referred to as *Istiblennius* by Smith-Vaniz and Springer, 1971), Strasburg (1956), Watson (1974)

SCHINDLERIIDAE

Schindleria pietschmanni

Adult meristics

D: 17–18; A: 16–17; P: 15–16; V: absent; C: 13; vertebrae: 35–37

Eggs

Oblong *Schindleria* sp. eggs (1.3 x 0.5 mm) lacking oil droplets and with a "cap" on one end are described and illustrated in Watson and Leis (1974). Whether these eggs are planktonic or demersal is not known.

Larvae

S. pietschmanni larvae are small and slender, with a spherical gas bladder, a gut extending about one-half the length of the body, usually 36 myomeres, and little pigment.

The smallest larvae, ca. 3.5 mm SL (Figure 93), lack the narrow, elongate peduncle of larger schindleriids and have not developed dorsal and anal finanlagen although the notochord is flexed and 10 ossified caudal rays are present. The gut extends from one-half to just over one-half the length of the body, giving a myomere formula of 18 + 18 or 19 + 17. The gas bladder lies at about the midpoint of the gut. A pair of melanophores occurs dorsally on the gut just anterior to the gas bladder, another pair lies just above the anus, and three single melanophores are about evenly spaced along the ventral midline of the tail.

By ca. 4.5 mm SL (Figure 94) both dorsal and anal fins are developing and 13 ossified caudal fin rays are present. The peduncle is becoming elongate and narrow. The pigmentation on the gut is retained, an additional melanophore lies on the posterior surface of the gas bladder, and the midventral pigment is reduced to a single posterior melanophore. All pigment except that on the gas bladder is lost as development proceeds. Beyond ca. 4.5 mm SL the typical adult *Schindleria* features are clearly visible.

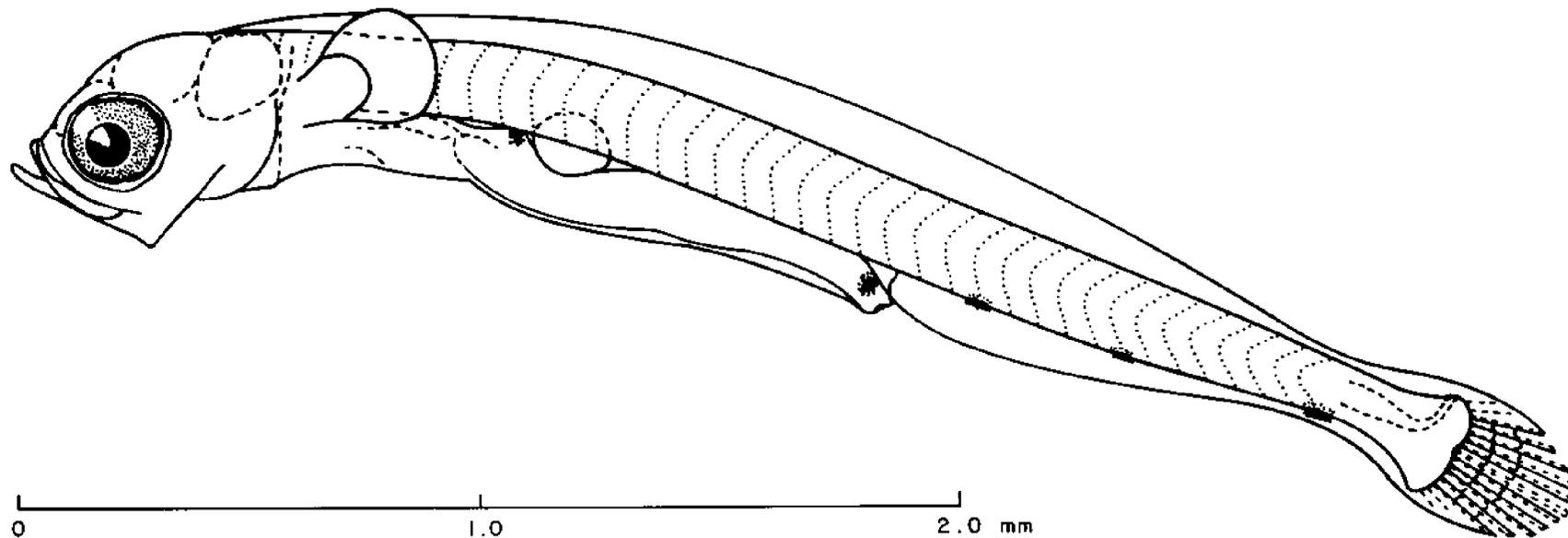


Figure 93. *Schindleria pietschmanni*, 3.5 mm SL

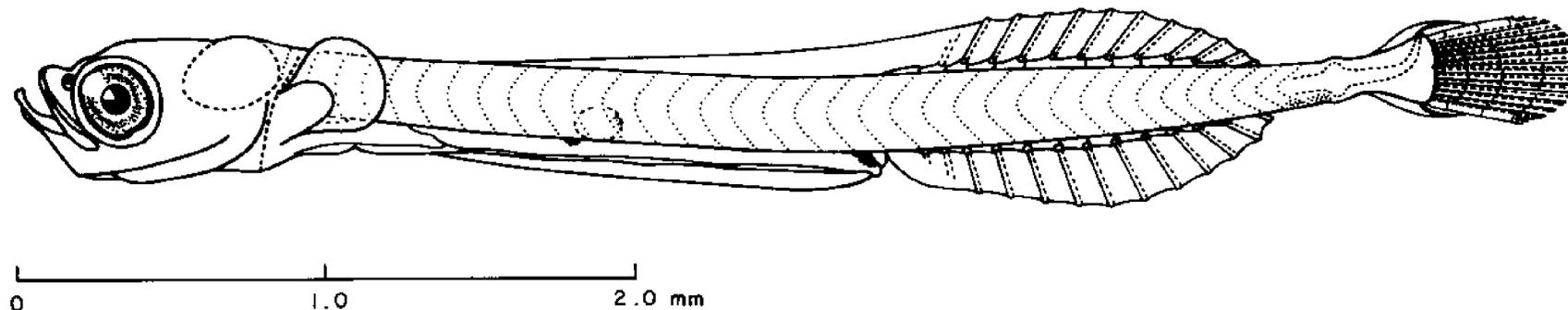


Figure 94. *Schindleria pietschmanni*, 4.7 mm SL

Identification

S. pietschmanni larger than ca. 4.5 mm SL are immediately recognizable as typical schindleriids. Smaller larvae may be identified by myomere counts, gut length, the spherical gas bladder, and pigmentation.

S. pietschmanni and *S. praematurus* (at least those longer than ca. 4.2 mm SL) are easily distinguished by gut length: in the former the gut is just over one-half the body length (never as long as 60 percent), while in the latter it is just over two-thirds of the body length (never shorter than 60 percent). Counts of total and preanal vertebrae likewise differentiate the species (Table 9).

Literature

Brunn (1940), Jones and Kumaran (1964c), Sardou (1974), Watson and Leis (1974)

93

TABLE 9. SCHINDLERIA MERISTICS

Species	Reference*	D	A	Total Vertebrae	Preanal Vertebrae
<i>Schindleria pietschmanni</i>	1	17-18	16-17	35-37	16-18
<i>S. pietschmanni</i>	2	15-17	13-16	35-43	18-28
<i>S. praematurus</i>	1	18-22	11-14	35-39	21-24
<i>S. praematurus</i>	2	16-22	10-13	33-36	19-23

Note: Two references were consulted and since counts did not always overlap, both are included.

*1 = Jones and Kumaran (1964c); 2 = Sardou (1974)

SCORPAENIDAE

The family Scorpaenidae is well-represented in Hawaiian waters, but its larval taxonomy is poorly known. Most scorpaenid larvae (eight types are presently recognized) are identifiable to the familial level only. These have 24 to 26 myomeres; a moderately short gut; (usually) large and heavily pigmented pectoral fins; large preopercular, supraocular, and paired parietal spines except at the smallest sizes; and a dermal sac enclosing most of the body in the early stages.

Adult meristics

Some fin counts for the Hawaiian genera are summarized in Table 10; other fin counts for all genera are V: I, 5; C: 11; vertebrae: 24–26

Eggs

Scorpaenid eggs are often massed within a planktonic, spherical to elliptical gelatinous matrix. Two types from Hawaiian waters are described in Watson and Leis (1974): the first with ca. 200 to 400 closely packed oval eggs of 0.80 to 0.85 x 0.60 x 0.65 mm, and the second with ca. 100 to 150 loosely packed round eggs of 0.73 to 0.75 mm diameter. Species attributions have not been made.

Larvae

A small specimen of scorpaenid S-3 represents the family. This 3.6-mm SL larva (Figure 95) retains the dermal sac and lacks dorsal, anal, and caudal anlagen. Preopercular and supraocular spines are absent, but the parietal spines are beginning to develop. The gut is short (myomere formula 7 + 18), but becomes elongate rapidly: at ca. 4 mm SL the myomere formula is 8 + 17 and by ca. 4.5 mm SL it is 9 + 16. Fin anlagen and preopercular and supraocular spines have not developed by ca. 4.5 mm SL.

A pair of melanophores lies internally on the midbrain of the 3.6-mm larva, the gas bladder is pigmented dorsally, and numerous melanophores cover the distal half of the pectoral fin. A single melanophore lies on the hindgut above the anus (Figure 95).

Identification

Young scorpaenids may be recognized by myomere counts, the dermal sac, and their heavily pigmented pectoral fins. They usually lack pigment on the myomeres.

TABLE 10. FIN RAY COUNTS OF HAWAIIAN SCORPAENID GENERA

Species	No. Examined	D	A	P
<i>Pterois</i>				
<i>P. sphex</i>	13	XIII, 10½	III, 6½	15–16
<i>Dendrochirus</i>				
<i>D. barberi</i>	23	XIII, 8½–10½	III, 5½	17–18
<i>Scorpanenodes</i>				
<i>S. kellogi</i>	15	XIII, 7½–8½	III, 5½	18–20
<i>S. hirustus</i>	12	XIII, 8½–9½	III, 5½	17–18
<i>S. paruipinnis</i>	16	XII–XIII, 9½	III, 5–5½	17–19
<i>S. littoralis</i>	10	XIII, 9½	III, 5½–6½	17–19
<i>S. corallinus</i>	4	XIII, 8½	III, 5½	17–18
<i>Plectrogenium</i>				
<i>P. nanum</i>	14	XII, 6½–7½	III, 5½	22–24
<i>Taenianotus</i>				
<i>T. triacanthus</i>	12	XII, 8½–10½	III, 5½–6½	14–15
<i>Iracundus</i>				
<i>I. sigaifer</i>	13	XII, 9½–10½	III, 5½	17–18
<i>Setarches</i>				
<i>S. guentheri</i>	32	XII, 9½–10½	III, 5½–6½	20–22
<i>Ectreposebastes</i>				
<i>E. imus</i>	19	XII, 10½–11½	III, 6½–7½	19–20
<i>Phenacoscorpius</i>				
<i>P. megalops</i>	2	XII, 9½	III, 5½	17
<i>Pontinus</i>				
<i>P. macrocephalus</i>	15	XII, 9½–10½	III, 5½	16–17
<i>Scorpaenopsis</i>				
<i>S. diabolus</i>	24	XII, 8½–10½	III, 5½–6½	18
<i>S. cacopsis</i>	11	XII, 8½–9½	III, 5½	17–19
<i>S. brevifrons</i>	12	XII, 9½	III, 5½	18–20
<i>S. fowleri</i>	4	XII, 9½	III, 5½	16
<i>S. altirostris</i>	4	XII, 9½	III, 5½	17–18
<i>Rhinopias</i>				
<i>R. xenops</i>	4	XII, 9½	III, 5½	18
<i>Neomerinthe</i>				
<i>N. rufescens</i>	16	XII–XIII, 8½–10½	III, 5½	18–19
<i>Scorpaena</i>				
<i>S. conioarta</i>	11	XII, 9½–10½	III, 5½	15–17
<i>S. ballieui</i>	10	XII, 9½	III, 5½	16
<i>S. gahctacma</i>	14	XII, 9–10½	III, 5½	15–17
<i>S. pele</i>	19	XII, 8½–9½	III, 5½	16–17
<i>S. colorata</i>	17	XII, 9½	III, 5½	16–18

Note: All counts are from Eschmeyer and Randall, 1975.

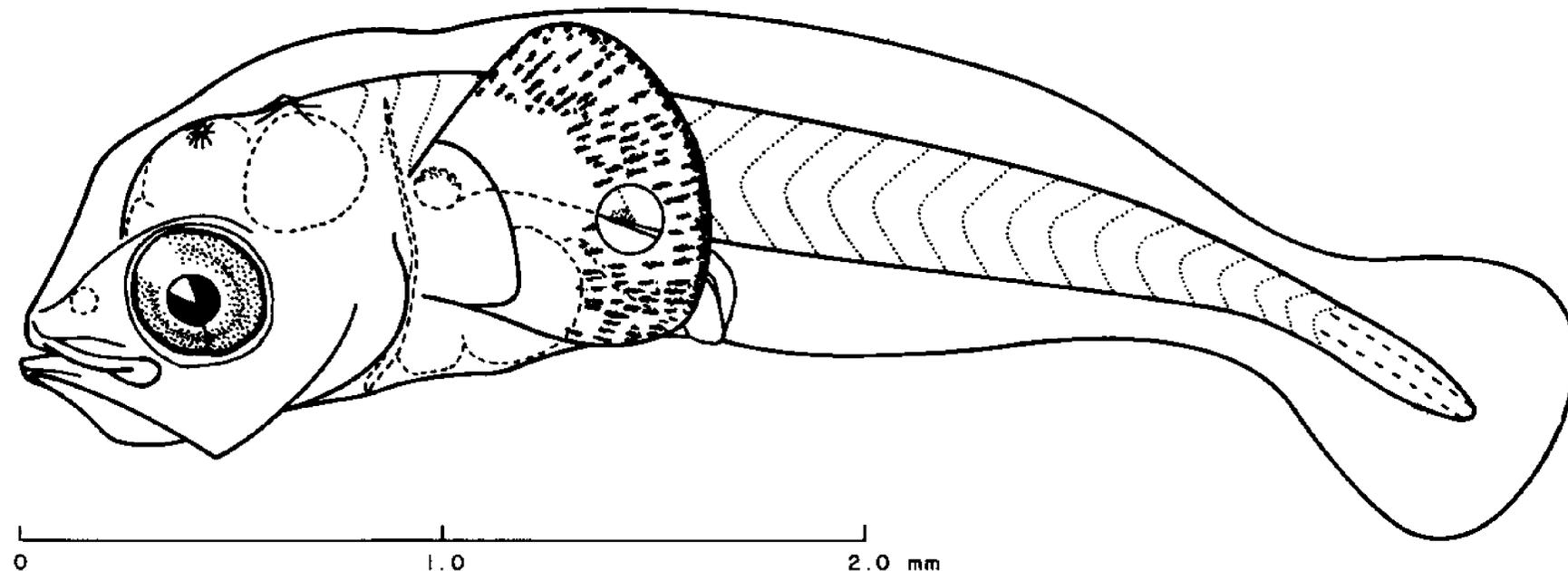


Figure 95. Scorpaenid S-3, 3.6 mm SL. (Note hole in pectoral fin showing hindgut pigment.)

Young larvae of some anthiine serranids (less than ca. 3.5 mm SL) resemble these small scorpaenids (e.g., compare Figure 55 with Figure 95). Distinguishing characteristics are given in the "Serranidae" section.

Scorpaenid larvae larger than ca. 4.5 to 5 mm SL are immediately recognized by their pair of large, horn-like parietal spines and very spiny heads in general. They resemble priacanthid, caproid, and some anthiine serranid larvae in having spiny heads, but they can be distinguished by the fact that these other families possess a single supraoccipital spine rather than the parietal pair of scorpaenids. Holocentrids likewise have a single supraoccipital spine and develop a rostral spine very early as well.

Larvae of the closely related family, Caracanthidae, possess even more elaborate head spination than the scorpaenids. The smallest caracanthids observed (ca. 8 mm SL) are readily distinguished from scorpaenids by their fin counts: D: VII, 11; A: II, 11; P: 14.

Istiophorids and dactylopterids likewise have elaborate head spination, but are easily distinguished from scorpaenids by being more heavily pigmented. Dactylopterids have blunter snouts than scorpaenids, while istiophorids have longer, pointed ones.

Within the scorpaenids, the distinction between the types is difficult and only tentative for larvae which lack fully developed fins. Since the smaller larvae constitute a fairly homogeneous group, identifying characteristics are limited to pigmentation differences.

Literature

Eschmayer and Randall (1975), Mito and Uchida (1958), Moser (1967), Orton (1955), Watson and Leis (1974)

CALLIONYMIDAE

Callionymus decoratus

Adult meristics

D: VI + 8–9; A: 8; P: 20; V: I, 5; C: 10; vertebrae: 20

Eggs

C. decoratus eggs are planktonic, spherical, and 0.55 mm in diameter, with no oil droplet. This egg is illustrated as unidentified type XLII in Watson and Leis (1974).

Larvae

C. decoratus larvae are small and moderately deep-bodied, with large heads and fairly heavy pigmentation. They hatch at ca. 1.3 mm SL and develop quickly, attaining an essentially adult configuration by ca. 5 mm SL.

Larvae of ca. 2.5 mm SL (Figure 96) are beyond the yolk sac stage, but have not yet developed dorsal, anal, or caudal fin anlagen. They are moderately deep-bodied and large-headed. The gut extends less than one-half the length of the body (myomere formula 8 + 12). The gas bladder is present anteriorly, but is difficult to see. Single rows of melanophores lie along the dorsal, lateral, and ventral midlines to about myomere 14 to 16. Lateral melanophores are present, primarily along the myosepta between about myomeres 8 and 16. The tail is unpigmented posterior to the midline series. Melanophores may occur in the anal finfold between the anus and about myomere 14 to 16. The gut is pigmented dorsally, dorsolaterally, and ventrally. The gas bladder is pigmented dorsally. Internal melanophores lie just anterior to the symphysis of the cleithra. A few melanophores overlie the mid- and hindbrain region, and others occur anteriorly on the snout and lower jaw.

Larvae of ca. 3 mm SL (Figure 97) have complete pelvic, anal, caudal, and second dorsal fins. The first three or four dorsal spines are discernible. The caudal fin is beginning to elongate and become pointed. Pectoral fin rays are absent. The snout is beginning to elongate and the head to broaden. The gas bladder cannot be seen. The myomere formula remains 8 + 12, although at this size myomeres are

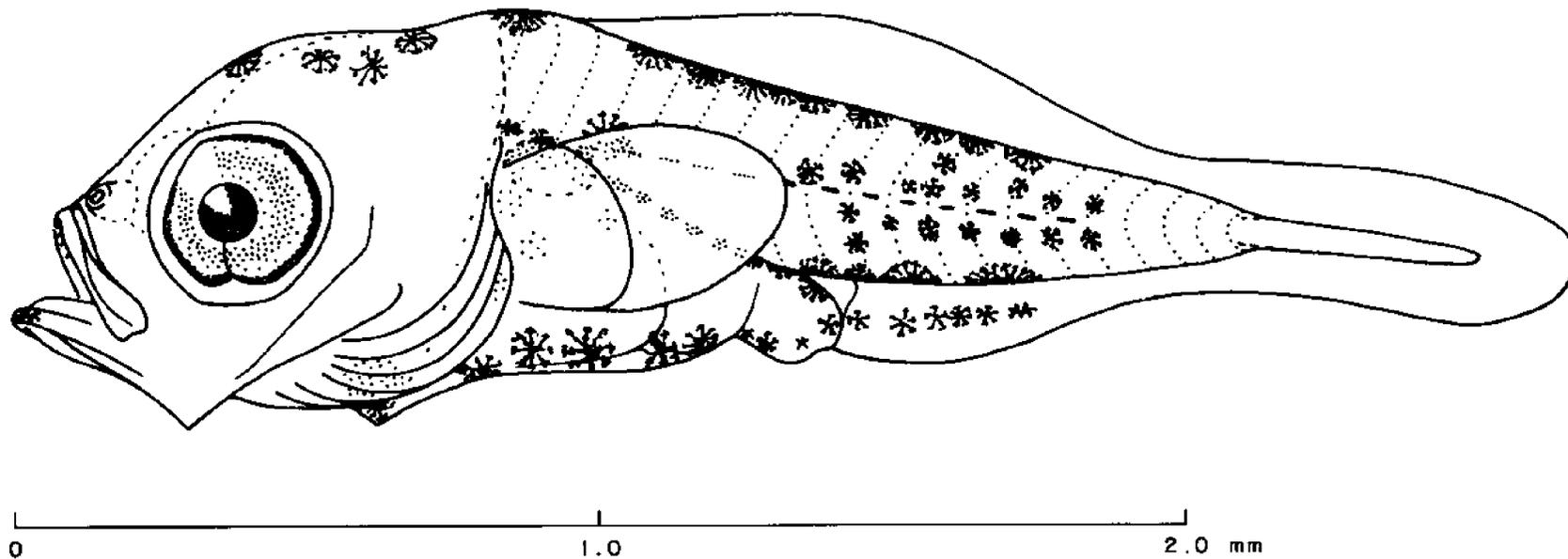


Figure 96. *Callionymus decoratus*, 2.5 mm SL

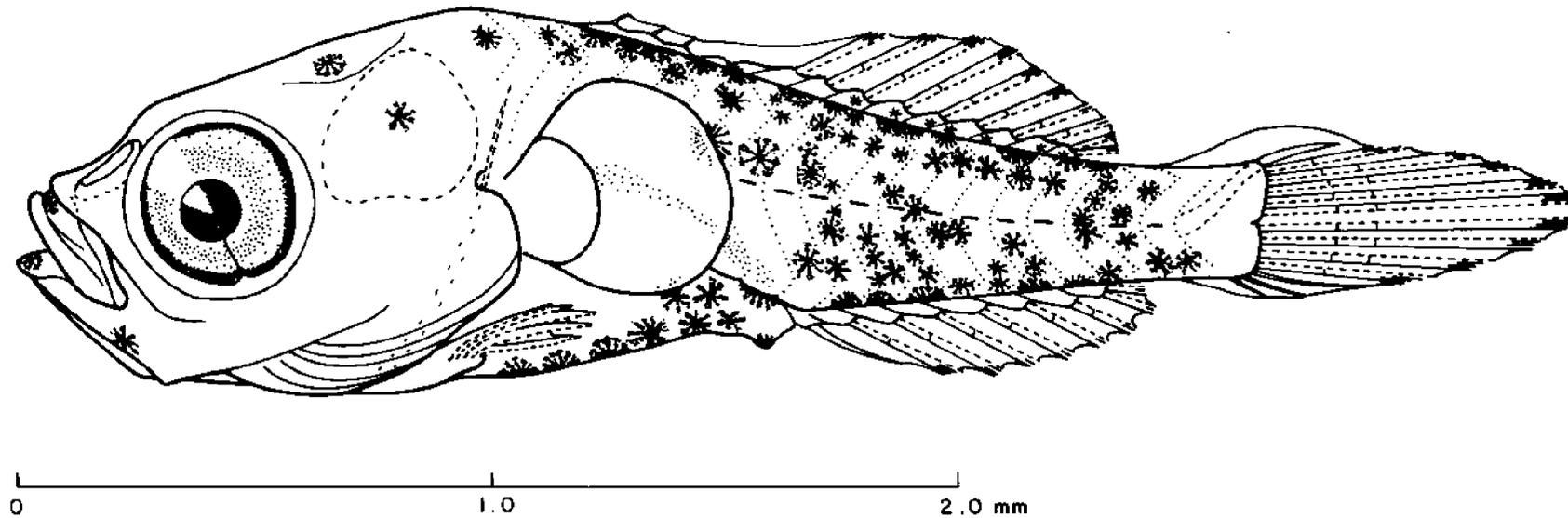


Figure 97. *Callionymus decoratus*, 2.9 mm SL

very difficult to count owing to the heavy pigmentation. The pigmentation is heavier laterally and extends caudad. Pairs of small melanophores lie at the base of most dorsal fin rays (Figure 97). The head pigment changes little, except that a row of melanophores develops ventrally along the lower jaw.

By ca. 4 mm SL (illustrated in Watson, 1974) all fins are fully developed, the snout has elongated further, and the head has flattened and become broader. The preopercular spines first appear at ca. 5 mm SL. Beyond this size range the pigmentation increases generally and a black band develops along the distal half of the first dorsal fin.

Identification

C. decoratus are easy to recognize and unlikely to be confused with other species, except callionymid larvae.

An unidentified callionymid, C-2, may be mistaken for *C. decoratus*. These are distinguished by pigmentation patterns: C-2 is more heavily pigmented on the

head and lacks the dorsal midline melanophores posterior to the first dorsal fin at sizes smaller than ca. 5 mm SL. Specimens larger than ca. 5 mm SL are distinguished by fin ray counts: C-2 has fewer dorsal spines and pectoral fin rays (D: IV + 10; P: 17).

Literature

Demir (1972), Mito (1962c), Watson (1974), Watson and Leis (1974)

TETRAODONTIDAE

Tetraodontid 1 (keke)

Adult meristics

Myomeres: 20. See Table 11 for fin ray counts.

TABLE 11. FIN RAY COUNTS OF HAWAIIAN TETRAODONTID GENERA

Genus	D	A	P
<i>Arothron</i>	10–11	10–11	16–18
<i>Lagocephalus</i>	9–13	7–12	15–17
<i>Sphoeroides</i>	9	9	14
<i>Canthigaster</i>	9–12	9–11	16–18

Eggs

Hawaiian tetraodontid eggs have not been described in the literature. However, Fujita (1966) described demersal, adhesive, spherical eggs, 0.61 to 0.70 mm in diameter, with a cluster of small oil globules, from *Lagocephalus lunaris spadiceus*. Uchida et al. (1958) ascribed demersal, strongly adhesive, spherical eggs, with numerous oil droplets, to several *Fugu* species.

Larvae

Tetraodontid larvae taken in nearshore surface plankton samples are usually small. They are enclosed in a dermal sac, are somewhat elongate, and are rounded anteriorly. The gut extends to less than one-half the length of the body, giving a myomere formula of 7 + 13 at ca. 2 mm SL (Figure 98). The gas bladder is large, but not easily seen owing to the heavy pigmentation over the gut region. The nasal capsule is visible.

Pigmentation at ca. 2 mm SL (Figure 98) includes subdermal melanophores extending dorsally and dorsolaterally from above the forebrain to about myomere 2 or 3 and another near the upper end of the preopercle. The gut region is heavily pigmented anteriorly, dorsally, and dorsolaterally. The body is unpigmented posterior to the anus.

By ca. 3.5 mm SL (Figure 99) the gut has extended a little, giving a myomere formula of 9 + 11 (the anterior myomeres are nearly impossible to count at this size). The upper pectoral fin rays are becoming ossified, but unpaired fin anlagen are absent. The snout is becoming rather squared-off. The dorsal pigment is denser and extends caudad to about the level of the anus. The number of melanophores near the upper end of the preopercle is increased. The pigment on the gut and ventrally on the hypomeres remains dense and extends two or three myomeres caudad along the ventral margin. Midlateral melanophores extend from about the level of the anus to two or three myomeres caudad. Melanophores lie on the hypomeres in the vicinity of the anus.

Larger larvae have a typical tetraodontid appearance and are easy to recognize.

Identification

It should be pointed out that Tetraodontidae, as used here, actually refers to the superfamily Tetraodontoidae, which includes both Tetraodontidae and Canthigasteridae.

The presence of a dermal sac may lead to confusion among tetraodontid larvae, some of the other Tetraodontiformes, and Lophiiformes. Among those commonly encountered, tetraodontids may be distinguished from *Melanocetus johnsoni* by their higher anal fin ray counts (A: ≥ 7 vs. A: 4, respectively). *M. johnsoni* is generally less heavily pigmented on the myomeres at the smallest sizes and has a shorter gut. Female *M. johnsoni* larvae have a small illicium which the tetraodontiformes lack. The gill opening in the older tetraodontiformes is at the level of, and anterior to, the pectoral fin base. In *Melanocetus*, on the other hand, it is below the pectoral fin base.

Diodontids and ostraciontids may be distinguished from tetraodontids by being much deeper-bodied and more heavily pigmented, more-or-less uniformly so as compared with the tetraodontids. In addition, diodontids have much higher fin ray counts (D: ≥ 12 ; A: ≥ 12 ; P: ≥ 18), while ostraciontids have lower fin ray counts (D: ≤ 10 ; A: ≤ 10 ; P: < 12). Development of ostraciontid and diodontid larvae is discussed and illustrated in Leis (1978b).

Literature

Fujita (1966), Leis (1978b), Uchida et al. (1958), Welsh and Breder (1922)

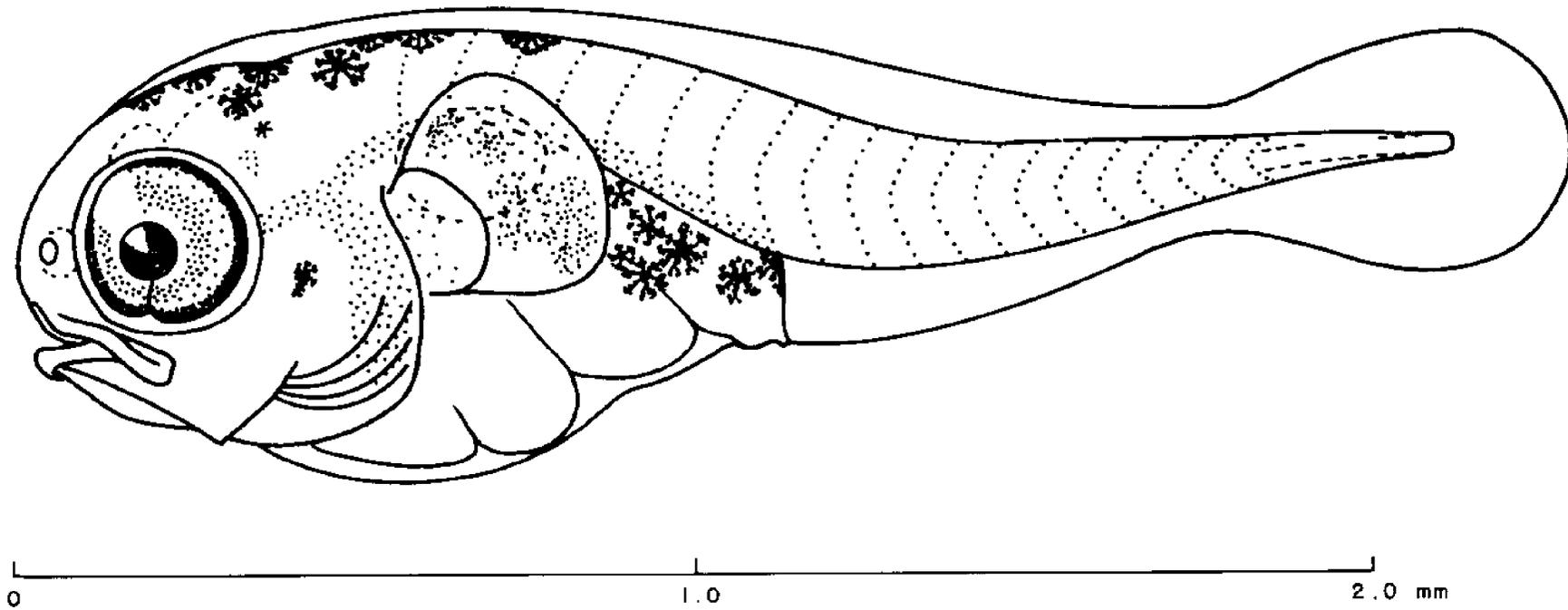


Figure 98. Tetraodontid 1, 2.1 mm SL

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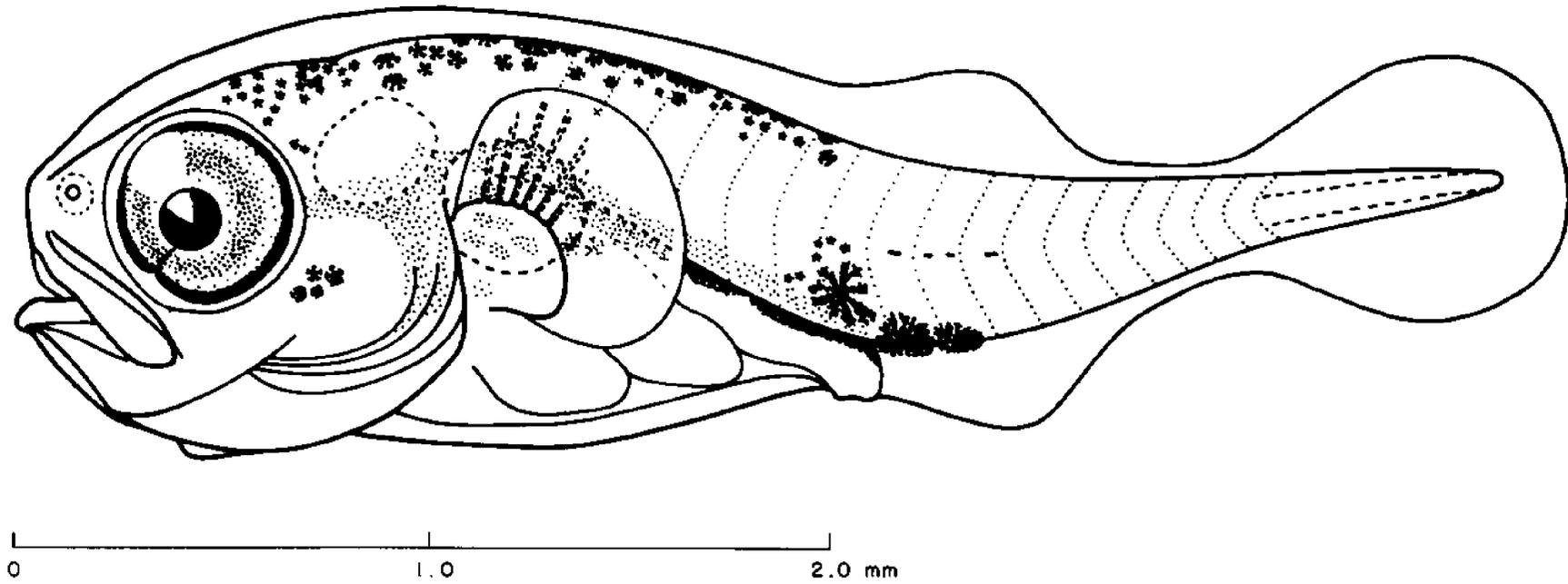


Figure 99. Tetraodontid 1, 3.6 mm SL

MOLIDAE

Ranzania laevis (makua)

Adult meristics

D: 17; A: 19; P: 13; V: absent; C: 20–21 (not a true caudal fin); vertebrae: 8 + 10

Eggs

R. laevis eggs are planktonic, spherical, and 1.42 to 1.65 mm in diameter, with 20 to 30 small oil droplets scattered on the surface of the yolk sac.

Larvae

Only an illustration of *R. laevis* is included (Figure 100); development of eggs and larvae are described in Leis (1977).

Literature

Leis (1977), Schmidt (1921a, 1921b), Sherman (1961)

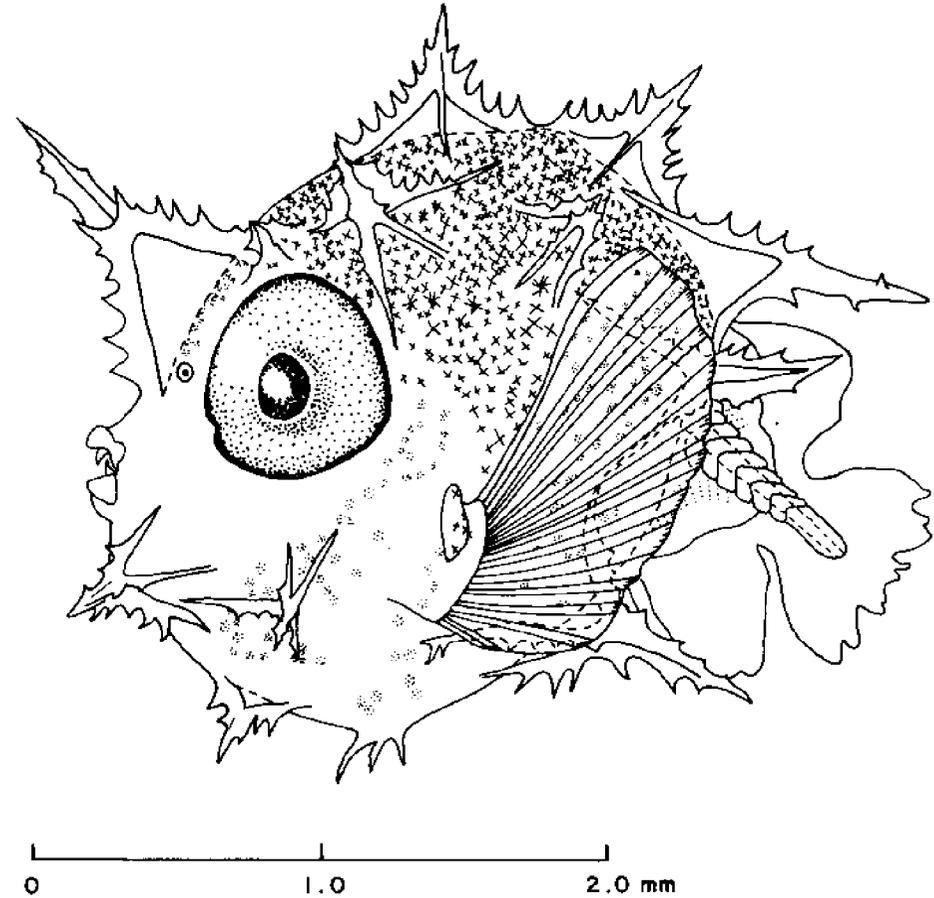


Figure 100. *Ranzania laevis*, 3.1 mm SL

MELANOCETIDAE

Melanocetus johnsoni

Adult meristics

D: 13–15; A: 4; P: 17–21; V: absent; C: 9; vertebrae: 19–20

Eggs

M. johnsoni eggs have not been described in the literature.

Larvae

M. johnsoni larvae are short and deep-bodied, becoming rather rounded at larger sizes. The body is almost completely enclosed in a dermal sac.

The smallest larvae, ca. 2 mm SL (Figure 101), are slightly elongate and lack fin anlagen. At this size pigment is restricted to the vicinity of the head and gut. Embedded melanophores cover the dorsal and dorsolateral sides of the gut, and a few lie subdermally below the pectoral fin base and over the foregut region. The branchial and midbrain regions are pigmented. Subdermal melanophores lie just above the otic vesicles and on the first two or three myomeres. The dermal sac is unpigmented.

Dorsal, anal, and caudal fin anlagen usually develop by ca. 2.5 mm SL. The notochord is flexing and six caudal fin rays are discernible at this size. The illicium ("fishing pole") is sometimes visible, inside the sac, in the interorbital region. A band of melanophores usually lies on the peduncle, and a group lies dorsally just anterior to the origin of the dorsal anlage.

The anal and caudal fins are fully developed by ca. 3 mm SL. Incipient dorsal fin rays are discernible, and the pectoral fins remain undifferentiated.

By ca. 6 mm SL the dorsal fin is ossified and the pectoral fin is nearly developed. The body remains encased in a dermal sac. The illicium is visible in the interorbital region. The dorsal and caudal fin pigment areas have expanded considerably and may join laterally at the level of the dorsal fin. Larval development is discussed in greater detail in Bertelsen (1951).

Identification

Small *M. johnsoni* larvae resemble small tetraodontiform larvae (e.g., Diodontidae, Ostraciontidae, Tetraodontidae) in that they are enclosed in a dermal sac. Distinguishing characteristics are given in the "Tetraodontidae" section.

M. johnsoni can be distinguished from other ceratioids by its lack of pelvic fins, its small pectoral fins, and its fin ray counts. These and other distinguishing characteristics are discussed in Bertelsen (1951).

Literature

Bertelsen (1951)

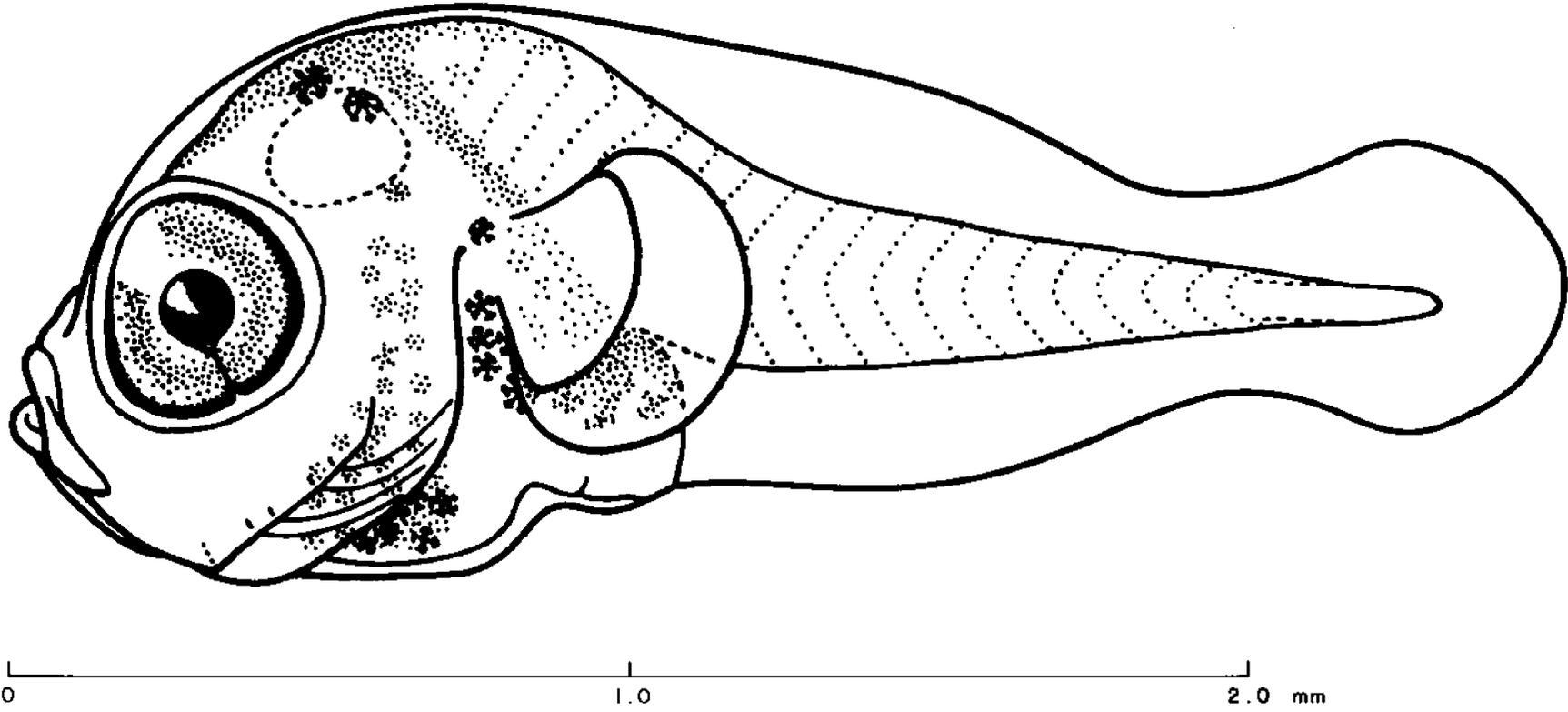
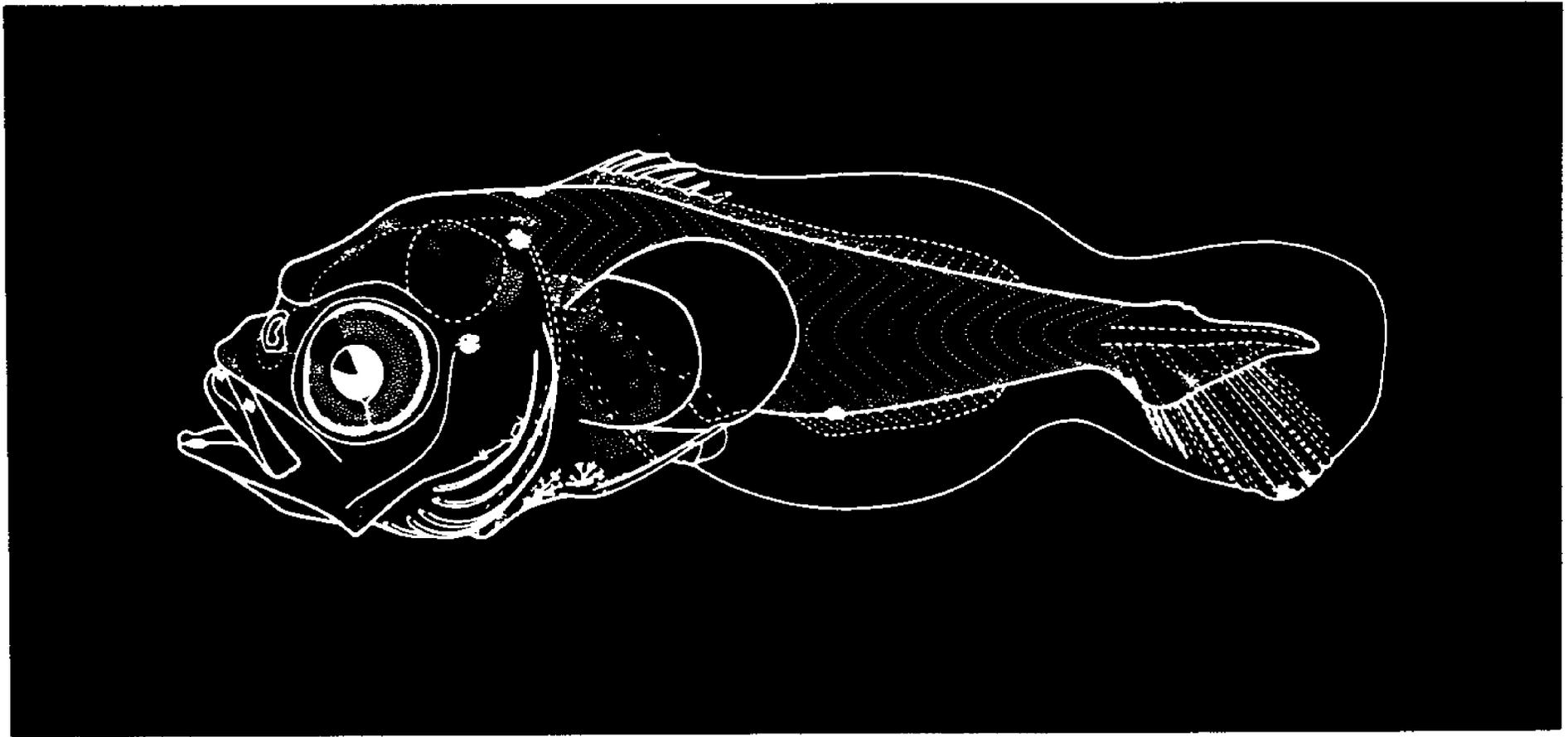


Figure 101. *Melanocetus johnsoni*, 2.3 mm SL

Part II. Larval Fish Distributions



INTRODUCTION

Part II of this atlas is a summary of the temporal and spatial variation of the ichthyoplankton in the nearshore waters of the three islands studied. Owing to the high diversity and low density of larval fishes, only 40 species were taken in adequate numbers to characterize their distributions. Twenty-seven of these are represented on maps. The distributions of the approximately 200 additional species taken (see Appendix) are unknown since, unless specifically mentioned in their respective family sections, they were rare in the samples taken.

METHODS

With a few exceptions, all samples were taken with a metered 500 μm mesh (1 meter diameter) net towed at about 1 m sec^{-1} (2 knots) with the rim of the net protruding about 5 cm from the surface. Replicate tows were made at each station. Tow time averaged about 10 minutes, i.e., about 600 m^3 of water was strained.

Although obviously biased in excluding both extruded larvae and larvae able to avoid such a net, all samples are considered equivalent. The net was handled in the same way by the same field technicians, and problems associated with clogging, e.g., stalling, was minimal. The net was washed after each tow if any evidence of clogging was present.

The vast majority of larvae taken ranged from 3 to 8 mm SL.

The entire sample was preserved with formalin in the field and returned to the laboratory where all larvae were removed, identified, and tabulated. Larval numbers reported were standardized to number/1,000 m^3 .

Environmental data, consisting of at least O_2 , salinity, temperature, and seiche disc transparency measurements, as well as meteorological notes, were recorded at each survey station. Of these environmental variables, only turbidity was correlated with larval abundance (Miller, 1974).

SAMPLING LOCATIONS

The primary data base of Part II is fivefold. The winter and summer data are from 34 nearshore locations around Kauai, Oahu, and Maui (Figure 102). These, along with data from a separate study of Molokini, a small islet off southwest Maui (Figure 102), are the basis of an earlier, less detailed report (Miller,

1974). The remaining three parts constitute results from more intensive studies of Kaneohe Bay, Oahu; Kahe Point, Oahu; and Maalaea Bay, Maui (Figure 102). These five sources of information, which were variously biased in the perspective of a comprehensive spatial and temporal survey of the distribution of larval fishes of Hawaii, are summarized below.

Surveys of Kauai, Oahu, and Maui

The purpose of these surveys was to yield an extensive picture of the relative abundance of larvae along various coastlines of the islands. As such, each of the three islands was sampled as quickly as possible (usually in 3 days) to minimize temporal variability, at least on a scale of days. All samples were taken during daylight hours; consequently, no estimate of shorter-term (e.g., diel) variability was possible. All samples were taken by surface tows, and, because bays were of primary interest, certain segments of the coastline (Figure 102) were sampled less intensively than others. Segments of windward Maui and Oahu were omitted entirely. Only winter and summer trips were possible; therefore only gross (i.e., 6-month) seasonal changes were detectable. Peaks of abundance occurring in spring and fall were not studied.

The 34 sampling locations are shown in Figure 102. At most of these locations, two stations were sampled, yielding a total of 56 winter and 57 summer stations. One station was located as close to shore as the boat draft (2 m) or swell permitted. The water depth at these shallow (hereafter termed inshore) stations was usually about 5 to 10 m (Table 12). The second station was usually located about 1 km offshore from the inshore station. These deep stations had an average depth of about 30 to 40 m. At a few locations, sampling tows were made at deep stations only. Although these deep stations were all within 2 km of shore, they are referred to as offshore stations. At least replicate surface tows were made at each station. The numbers reported are station means adjusted to a per 1,000 m^3 of water filtered basis unless otherwise indicated. For convenience "per 1,000 m^3 " is omitted when referring to larval density, except in figures. For example, 56 larvae/1,000 m^3 is given only as 56. These data are referred to as survey data.

Kaneohe Bay studies

Data for the Kaneohe Bay studies are from the results of this study as well as Watson and Leis (1974), Watson (1974), and Miller (1973). In the Watson and Leis study, surface samples were taken day and night biweekly for 13 months in the Sampan Channel entrance and in the southern (more confined) portion of the bay. Watson's study was on the investigation of the vertical distribution of fish

larvae in south Kaneohe Bay. Miller made horizontal neuston transects of the bay's entire length.

The above studies together with this study which sampled Kaneohe Bay intermittently over a span of 3 years provide the most complete data on seasonal and diel variability of fish larvae in any Hawaiian bay. The larval fish fauna of Kaneohe Bay, however, is quite different from that of most of the other inshore habitats of the islands. Seasonal data on many species common in the more open windward and leeward nearshore environments are missing. Although most of these species occur in Kaneohe Bay intermittently, their presence there is probably more linked to hydrographic conditions than to spawning season. It does appear, however, that certain seasonal peaks of abundance in the bay are typical of many species (Watson and Leis, 1974), and, lacking evidence to the contrary, probably resemble at least the larvae of inshore adult residents of the same family.

Where data from other locations contradict such inferred seasonalities, they are so noted in the accounts of individual species. It must be pointed out, however, that in every known case the spawning seasons are long, at least 3 to 6 months, and broad peaks are to be expected.

Kahe Point, Oahu

Kahe Point was sampled intermittently over 4 years. Unlike Kaneohe Bay, it is an open coast and the faunal composition is more representative of the nearshore larval fish fauna of the islands in general. An added import of the data at Kahe Point is that several 24-hour or longer series of samples at 2 to 6-hour intervals were taken. These data are best estimates of (1) the diurnal pattern of variability and (2) small-scale hydrographic variability of more open coasts.

A disadvantage of Kahe Point data is that the hydrography is influenced by the warm effluent of a steam-electric generating station (discharge = $18 \text{ m}^3/\text{sec}$), at least in the immediate vicinity of the shore outfall. This influence is constant, however, and should not affect the hydrographic variability caused by tides or seiches. It probably does augment any small-scale upwelling (Miller, 1979), thereby resulting in the presence of more offshore (or deeper-water) larvae.

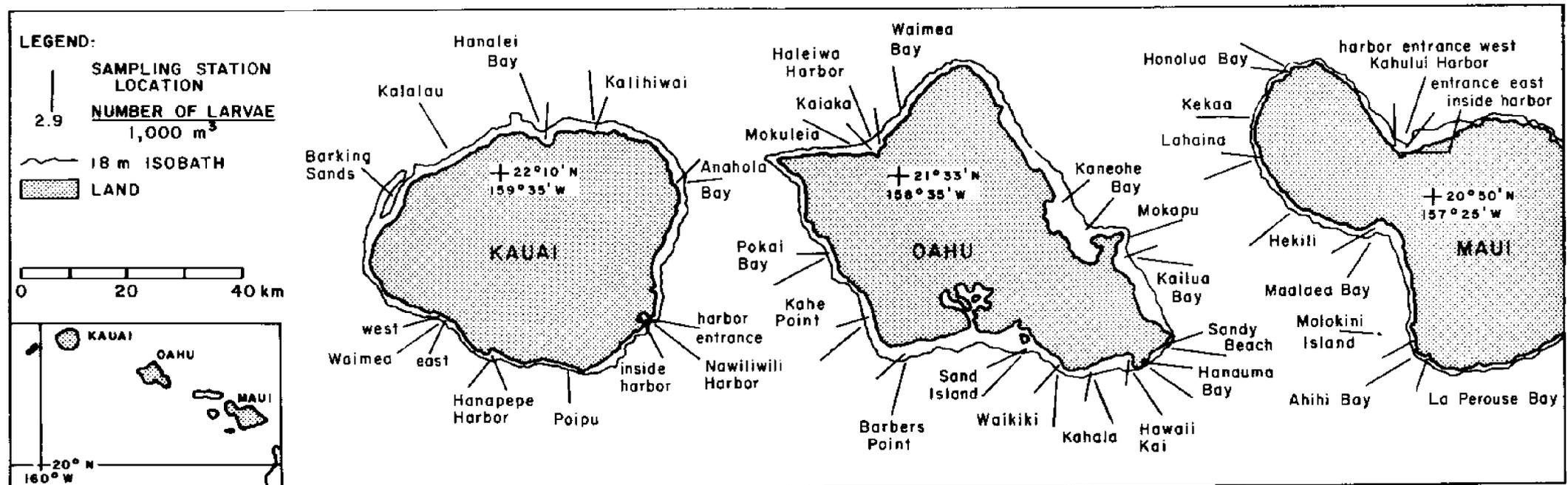


Figure 102. Sampling locations 1971-72. (See Table 12 for sampling location names and station data.)

TABLE 12. SAMPLING LOCATIONS, DATES, AND DEPTHS, 1971-74

Location	1972		Depth (m)	
	Winter	Summer	Inshore Station	Offshore Station
MAUI				
Kahului Bay	02/15	06/31		29 - 40
Inside harbor	02/15	06/31	6 - 7	
East	02/15	06/31	4 - 18	
West	02/15	06/31	5 - 9	
Honolua Bay	02/15	06/31	5 - 9	22 - 32
Kekaa	02/15	06/31		22 - 40
Lahaina	02/16	07/01	5 - 9	25 - 36
Hekili	02/16	07/01		27 - 29
Maalaea Bay	02/17	07/01	13 - 18	58 - 59*
Ahihi Bay	02/16	07/01	5 - 11	
La Perouse Bay	02/16	07/01	5 - 11	36 - 68
Molokini Island	02/17	07/02		25 - 185
KAUAI				
Anahola Bay	01/20	07/05	7 - 14	36 - 59
Kalihiwai	01/20	07/05	13 - 16	40 - 77
Hanalei Bay	01/20	07/05	6 - 14	36 - 70
Kalalau	01/21	07/06		29 - 45
Barking Sands	01/21	07/06		22 - 23
Waimea Bay	01/21	07/06		29 - 50
West	01/21	07/06	5 - 11	
East	01/21	07/06	4 - 7*	
Hanapepe Bay	01/21	07/07	7 - 11	29 - 56
Koloa Landing	01/22	07/07		27 - 58
Nawiliwili Harbor	01/22	07/07		16 - 32
Inside harbor	01/22	07/07	7 - 11	
Harbor entrance	01/22	07/07	9 - 11	
OAHU				
Waikiki	02/08	06/13	5 - 13	54 - 115
Kahala	02/08	06/13	11	20 - 36
Hawaii Kai	02/08	06/13	5 - 9	22 - 25†
Hanauma Bay	02/08	06/13	5 - 18	36 - 38
Sandy Beach	02/08	06/13	4 - 11	41 - 47†
Kailua Bay	02/08	06/13	5 - 11	40 - 56
Mokapu	02/08	06/13		27 - 32†
Kaneohe Bay	02/08	06/14	5 - 13*	65 - 104*
Waimea Bay	02/09	06/14		22 - 36
Kaiaika Bay	02/09	06/14	14 - 31	
Haleiwa Harbor	02/09	06/14	5 - 25	45 - 58
Mokuleia	03/06	06/12		29 - 43
Pokai Bay	03/06	06/12	4 - 7*	25 - 41
Kahe Point	03/06	06/12	3 - 5	27 - 128
Barbers Point	03/06	06/12	7 - 12	36 - 63
Sand Island	03/06	06/12	5 - 6†	90 - 279

* Not sampled in winter
 † Not sampled in summer

Molokini Island

In addition to the survey, the waters off Molokini Island were sampled four times over 2 years to investigate the effects of a small island and attendant current flow interruption on the distribution of fish larvae (Miller, 1974). Although Molokini Island is 4 km from the nearest major island (Maui), no additional species were taken there, and indeed the fauna closely resembled that of many nearshore stations, attesting to the strong oceanic influence at the other nearshore stations.

Maalaea Bay, Maui

An ancillary diel series of samples was taken in Maalaea Bay during the winter survey of the islands. The nocturnal composition of larval fishes differed both qualitatively and quantitatively from the daytime composition.

In March 1973, replicate daytime surface tows were made at four shallow stations spaced at intervals of about 4 km along the southern coast of the bay. These are referred to as south Maalaea Bay samples.

The sampling dates and certain station data are presented in Tables 12 and 13 for all of the studies above.

Additional sources of larvae

Throughout the 4-year investigation, specimens were periodically obtained by dip-netting at night. This yielded many larger specimens than obtained by towing, but was qualitative only. Dip-netted specimens included the premetamorphic juveniles of many reef species, e.g., Scaridae, Labridae, Chaetodontidae, Acanthuridae, and Mullidae. Dip-netting and the diel changes observed in the fauna of Kaneohe Bay (Watson and Leis, 1974), Kahe Point, and Maalaea Bay suggest that a different distribution picture would emerge from nocturnal surveys, although the larvae of most species were present during both day and night. Those exhibiting exceptionally large diel changes in abundance are discussed in accounts of individual species.

Finally, certain specimens were obtained for descriptive purposes only from collections of midwater trawl samples, usually off leeward Oahu by the National Marine Fisheries Service, Honolulu Laboratory; the Oceanic Institute, Waimanalo, Hawaii; and University of Hawaii investigators Thomas A. Clarke and Richard E. Young.

TABLE 13. DATA FROM OTHER SAMPLING STUDIES

Location	Date	Depth (m)	No. of Samples
Kaneohe Bay* Sampan Channel South Bay	03/71 to 04/72 Morning, afternoon, and night biweekly	2 - 3 25	329
Kahe Point†	09/73 10/73 03/74	5 - 40 4 - 54 5 - 18	42 42 28
Molokini Island	08/72 12/72 03/73 08/73	25 - 185 25 - 185 25 - 185 25 - 185	22 4 12 6
Maalaea Bay	02/72 Every 6 hours over a 24-hour period	14 - 16	8
Four stations at 4-km intervals from Ahihi Bay northward	03/73	4 - 9	16

*Watson and Leis (1974); frequent other samples taken during 1971-74 in both South Bay and outside Sampan Channel

†See Leis (1978) for details of other Kahe Point samples

Inferences of spawning seasons are based primarily on data from Kaneohe Bay (Watson and Leis, 1974; Watson, 1974) and Kahe Point.

Other sampling data (from Molokini Island and Maalaea Bay) are discussed only in exceptional cases. Analyses are largely limited to the 10 most abundant families. Where less abundant species or families showed strong seasonal or spatial affinities, these are noted; however, most species occurred at densities too low to permit generalizations of their seasonal or spatial patterns.

Much of the sampling by Oceanic Institute was done in Manana Bay, Oahu, between Kailua Bay and Sandy Beach (see Figure 102).

Maps of distributions and characterization of the distribution of the near-shore larval fish fauna are based mainly on the winter and summer surveys off Maui, Kauai, and Oahu. These stations included highly stressed, enclosed bays (e.g., Nawiliwili Harbor, Kauai) as well as the more pristine nearshore waters of the islands (e.g., La Perouse Bay, Maui). These data adequately reflect the different types of nearshore habitat and certainly comprise the most complete larval fish survey of any tropical nearshore environment of comparable size. Additional sampling at these locations at different times may yield somewhat different results.

Further sampling, especially along open coastlines, would no doubt yield small numbers of larvae of additional species. These would probably not significantly change the overall characterization of the nearshore fauna. However, differently biased gear would no doubt yield different results.

DUSSUMIERIIDAE

Etrumeus teres

E. teres was taken at only four stations, all inshore, during the survey. One or two specimens each were taken at Hawaii Kai, Ahihi Bay, and Kailua Bay in winter and a single individual at Honolulu Bay in summer. The poor representation in the catches was surprising, since *E. teres* eggs are common in Kaneohe Bay (Watson and Leis, 1974). However, few (200) larvae were taken there too, mostly in spring. *E. teres* apparently spawns primarily in bays. The low densities of larvae taken are probably attributed to two factors: (1) larvae are relatively large at hatching and probably adept at avoiding towed nets; and (2) larvae are subsurface inhabitants, being most abundant below the 3 m depth during the day and more-or-less dispersed at night (Watson, 1974).

Spratelloides delicatulus

S. delicatulus larvae were not taken during this survey. Specimens were taken by Leis at Kahe Point in February, July, and September, and also outside Kaneohe Bay in June, July, and August. Oceanic Institute samples (unknown date) from Manana Bay, Oahu contained a few larvae.

ENGRAULIDAE

Stolephorus purpureus

Stolephorus purpureus larvae were taken during the survey in about equally small numbers during the winter and summer. The locations of positive catches were all leeward protected bays or windward harbors: winter—Waimea, Nawiliwili Harbor, Sand Island, Maalaea Bay, and Kahului Harbor; summer—Nawiliwili Harbor, Hanapepe Harbor, Waikiki, and Kahului Harbor. With the exception of Kahului Harbor in winter, all were shallow tows. Single tow densities ranged from 1.3 to 8.3 larvae/1,000 m³.

Although few larvae were taken, all positive catches occurred in vicinities of known adult populations, corroborating the fact that *S. purpureus* is a "bay" species (Watson and Leis, 1974; Tester and Hiatt, 1952).

S. purpureus larvae are vertically distributed as a function of size: yolk sac larvae are most abundant at the surface during the night and morning and below

3 m during the afternoon, while older larvae are most abundant below 3 m at all times (Watson, 1974).

S. purpureus eggs are found throughout the year in bays (Watson and Leis, 1974); larval abundance in Kaneohe Bay was characterized by primary peaks in winter and spring.

Stolephorus buccaneeri

S. buccaneeri is encountered even less frequently than *S. purpureus*. None were taken during this survey. Several specimens were taken off Mokapu, Kahe Point, and Kaneohe Bay, all between September and November, and mostly at night. None were taken in Kaneohe Bay (Watson and Leis, 1974).

CHANIDAE

Chanos chanos

No *Chanos chanos* larvae were taken during this survey. All specimens were caught at either Kahe Point or Kaneohe Bay; these were never abundant. All specimens were taken from July to October, suggesting a fall spawning peak. Most of the Kaneohe Bay specimens were taken in the Sampan Channel. This, and their occurrence at Kahe Point, suggests an offshore distribution of larvae. The larvae appeared to be more abundant at the surface at night.

GONOSTOMATIDAE

Cyclothone sp.

Cyclothone sp. larvae accounted for about 74 percent of the gonostomatid larvae taken during the survey; about four times the amount taken in the winter were taken in the summer (Figures 103 and 104). The distributions were similar for both seasons, although the highest densities occurred in leeward inshore tows. For example, an exceptionally large catch (201) occurred at the Lahaina inshore station.

Watson and Leis (1974) took several *Cyclothone* sp. larvae from the Sampan Channel in Kaneohe Bay in February, March, and June. No diel cycle was evident. The maximum number caught in other samplings was 301 in south Maalaea Bay in March. At the same time 171 were taken off Molokini Island.

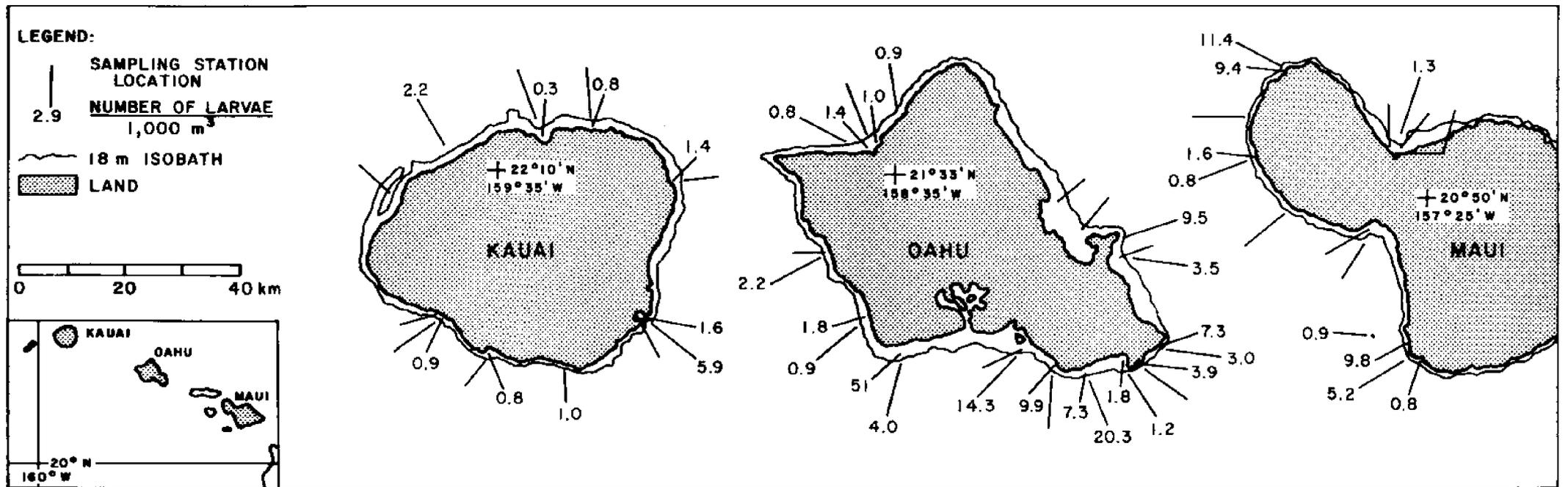


Figure 103. Winter distribution of *Cyclothone* sp. larvae

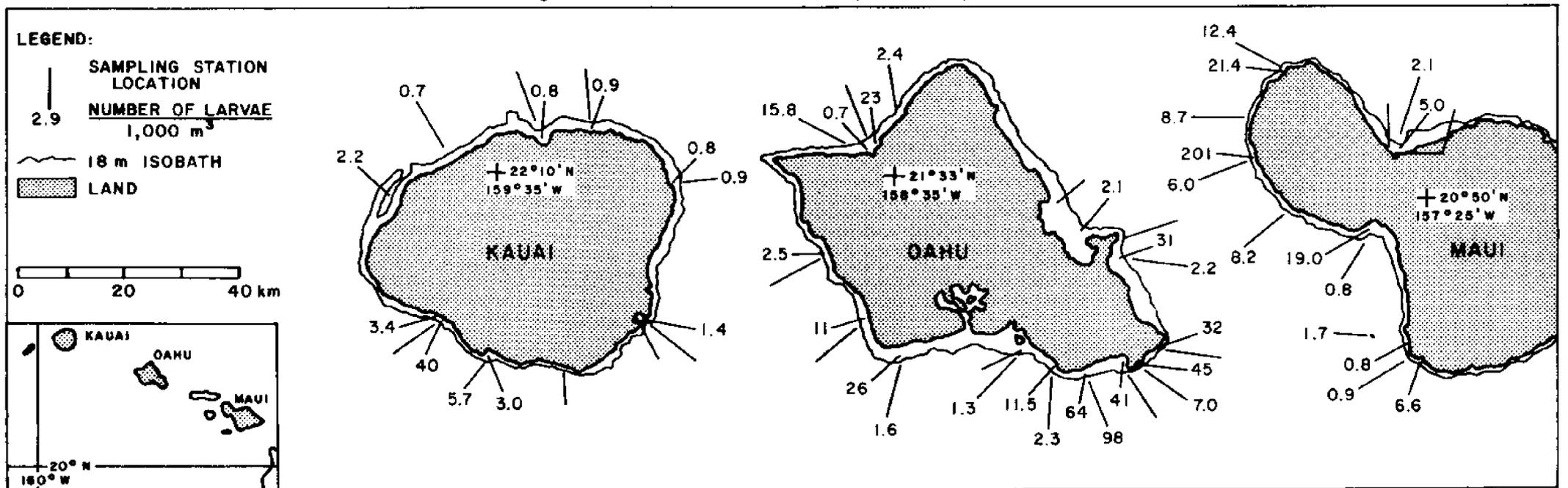


Figure 104. Summer distribution of *Cyclothone* sp. larvae

Cyclothone sp. larvae, like *Ceratoscopelus* larvae, occurred almost without exception in moderate numbers in other tows throughout the year.

Vinciguerria nimbaria

V. nimbaria larvae, like *Cyclothone* sp. larvae, were taken in most tows during both seasons (Figures 105 and 106). However, perhaps owing to considerably smaller numbers, its distribution appeared more leeward, especially in summer. Generally, more larvae were taken in inshore tows, although large catches occurred in offshore tows at Nawiliwili Harbor, Barbers Point, and Kahala. Numbers taken in winter and summer were about equal, although all of the exceptionally large catches were taken in winter.

Watson and Leis (1974) took only three larvae from the Sampan Channel in Kaneohe Bay. The largest catch of *V. nimbaria* in other tows was 33 in south Maalaea Bay in March.

SYNODONTIDAE

Trachinocephalus myops

Few *T. myops* larvae were taken during both the winter and summer surveys. Single specimens were taken inshore in winter at Waimea Bay, Sandy Beach, Maalaea Bay, and Ahihi Bay. One or two specimens were taken in offshore tows at Hanalei Bay, Kahala, and Lahaina. In winter, single specimens were taken inshore at Sandy Beach, Kahala, and Barbers Point and two from outside Hanauma Bay.

The largest catches in the other samples were from Molokini Island in March: densities ranged from 2.2 to 23.8 in single tows.

Prejuveniles were nearly always attracted to lights at night and could easily be caught by dip-netting.

CHLOROPHTHALMIDAE

Chlorophthalmus proridens

C. proridens larvae were taken in small numbers at six survey stations in winter and 10 stations in summer. Generally only one or two specimens were

present in the positive tows, but a maximum density of 13.5 was taken inshore at Lahaina in summer. All but a single winter specimen at Nawiliwili Harbor occurred at leeward stations. About equal numbers of shallow and deep stations yielded positive tows. Although not abundant, the distinctly leeward distribution of this species is probably real.

The largest single-tow density was 47 larvae/1,000 m³ at Molokini Island in March.

MYCTOPHIDAE

Ceratoscopelus warmingi

C. warmingi were the most ubiquitous larvae encountered during the survey, being taken at 38 of 57 summer stations (Figure 107) and 39 of 56 winter stations (Figure 108). The maximum density (80) was inshore at Lahaina in summer, but several specimens were taken at most other stations. Slightly fewer larvae were taken in winter. The highest densities occurred in shallow tows along leeward coasts both in summer and winter.

Watson and Leis (1974) took specimens of *C. warmingi* larvae in Kaneohe Bay year-round; however, most were taken in late winter and early spring. Densities averaged about one. *C. warmingi* larvae were taken year-round at nearly all other sampling locations at densities similar to the survey densities (Figures 107 and 108). Exceptionally large catches were recorded at Molokini Island (131) in March (Miller, 1974) and in Maalaea Bay (483). None of the day-night comparisons (Kaneohe Bay included) showed a strong diel difference.

Diaphus spp.

Diaphus spp. larvae showed distributions similar to *Ceratoscopelus* larvae, that is, mostly leeward with greater densities in shallow tows (Figures 109 and 110). *Diaphus* spp. larvae, like *Ceratoscopelus* larvae, were about equally abundant during both winter and summer. However, considerably lower densities of *Diaphus* spp. were found (maximum was 30 inshore at Honolulu Bay in summer).

Ceratoscopelus warmingi and *Diaphus* spp. larvae were about equally abundant in Kaneohe Bay (Watson and Leis, 1974), and both were more abundant from late winter through early spring. No diel pattern was detected. Unlike *C. warmingi*, *Diaphus* spp. larvae were not particularly abundant at Molokini

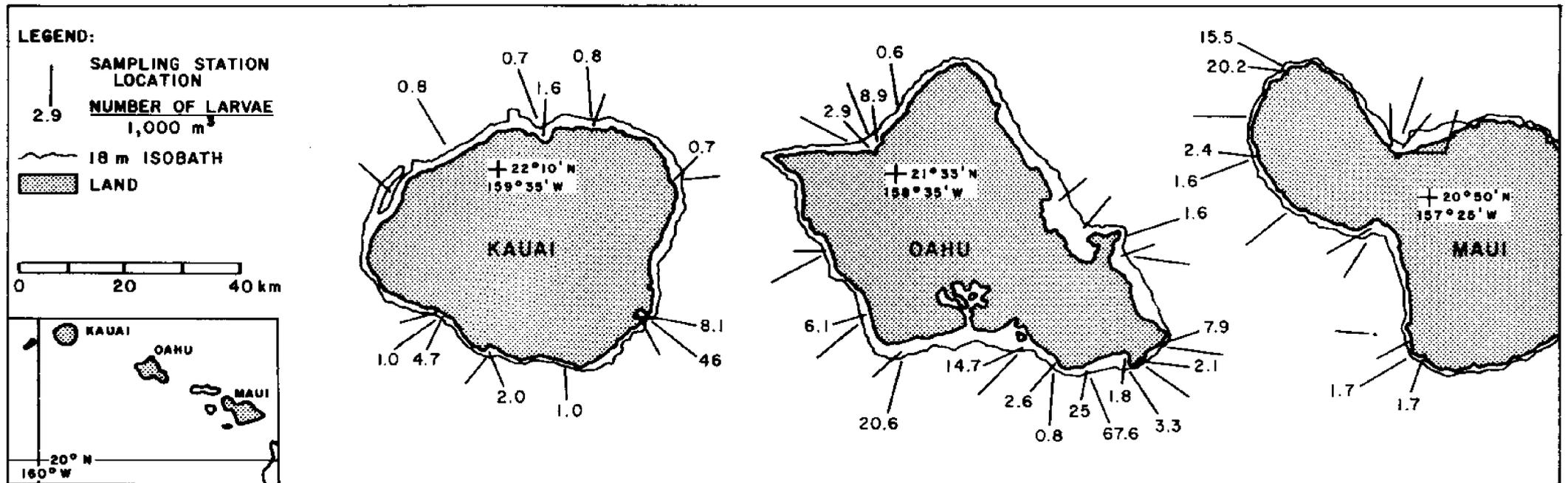


Figure 105. Winter distribution of *Vinciguerria nimbaria* larvae

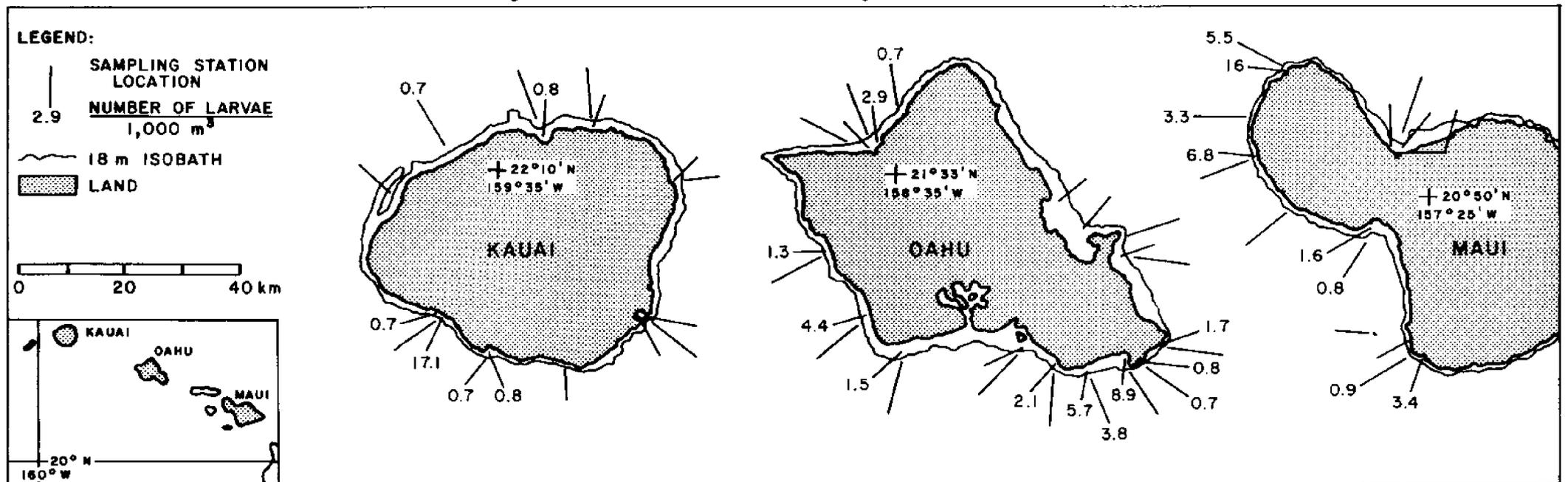


Figure 106. Summer distribution of *Vinciguerria nimbaria* larvae

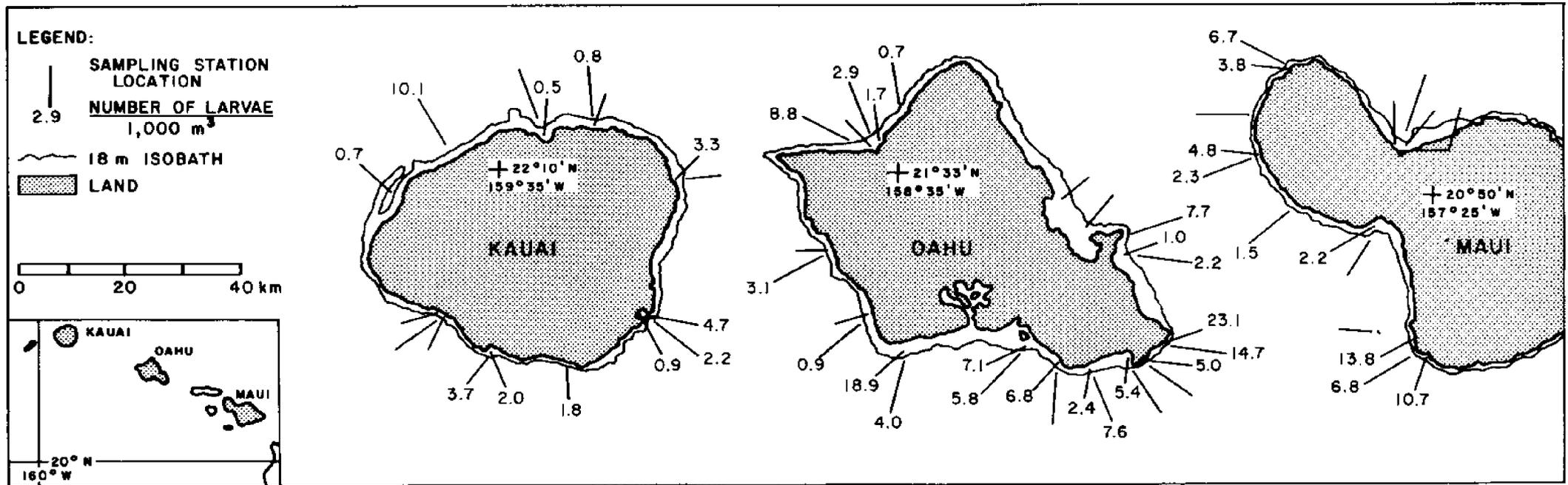


Figure 107. Winter distribution of *Ceratoscopelus warmingi* larvae

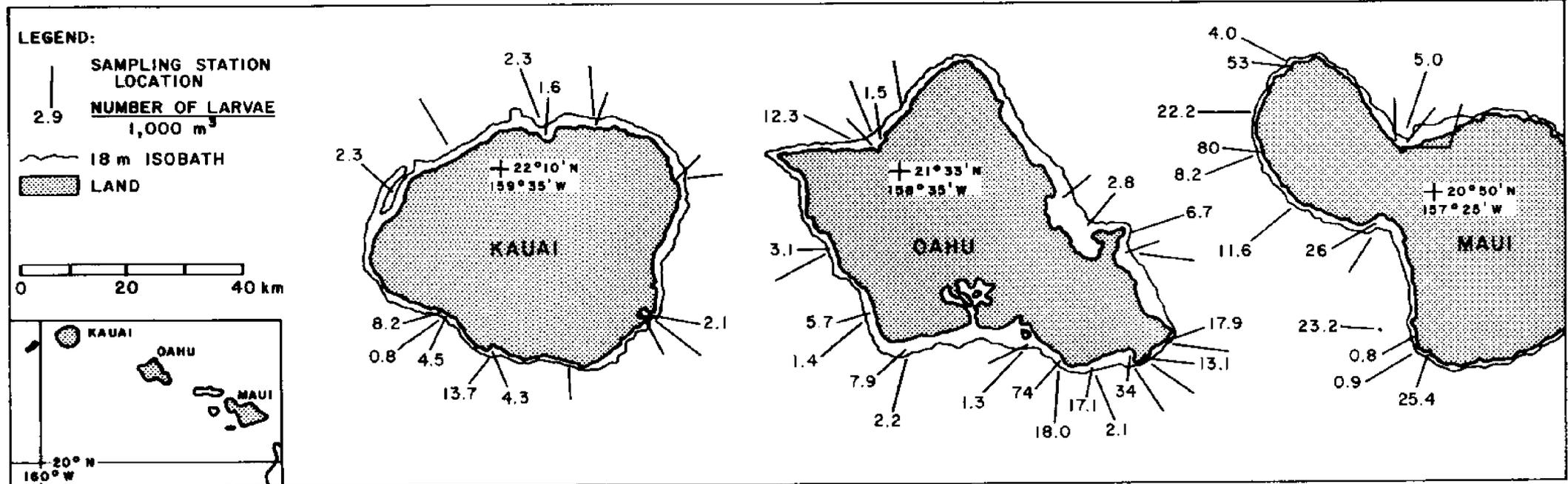


Figure 108. Summer distribution of *Ceratoscopelus warmingi* larvae

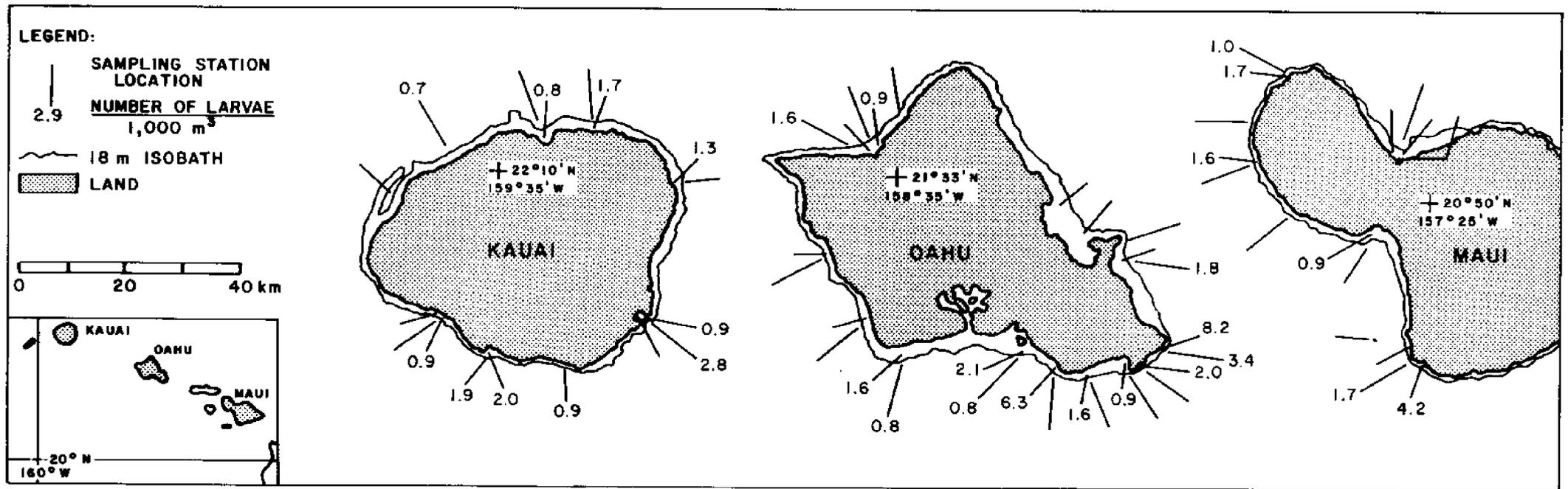


Figure 109. Winter distribution of *Diaphus* spp. larvae

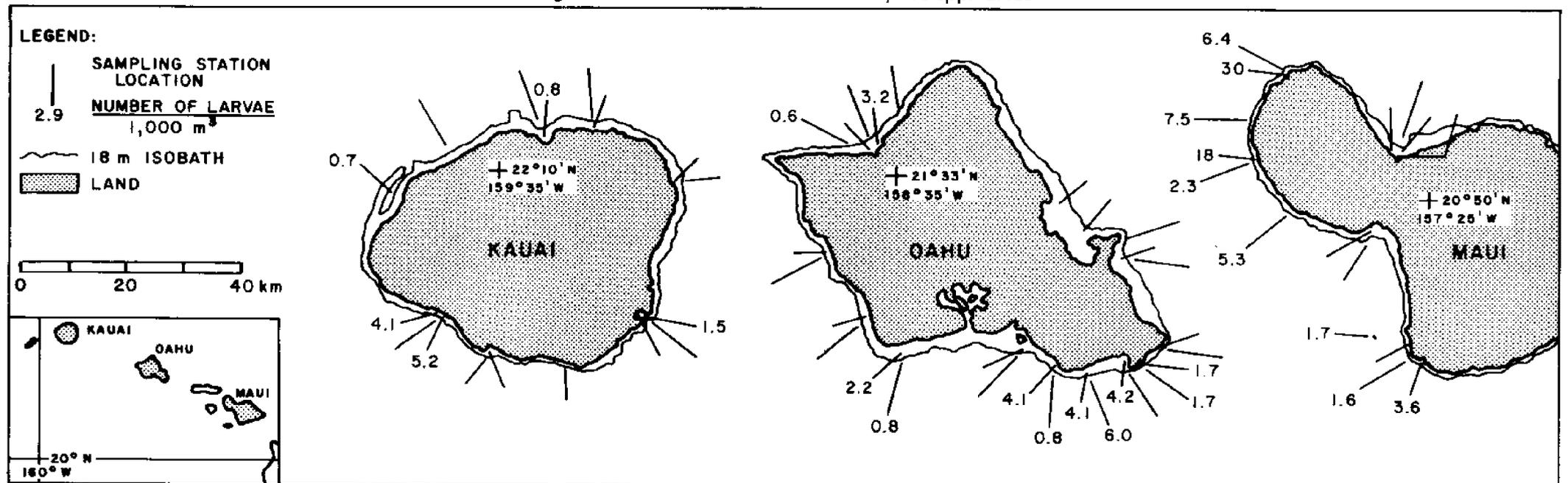


Figure 110. Summer distribution of *Diaphus* spp. larvae

Island in March, when they occurred in exceptionally high densities (maximum 83) in south Maalaea Bay.

Hygophum proximum

H. proximum larvae were taken during both summer and winter, but in considerably greater numbers in winter (Figures 111 and 112). Like *C. warmingi* and *Diaphus* spp. larvae, their distribution was mainly leeward. The maximum densities were at Sand Island (19) and Kahala (11.5). Generally, one or two specimens were taken at the other stations. Six of the eight positive summer tows and 11 of the 15 positive winter tows were inshore.

In Watson and Leis' (1974) study of Kaneohe Bay only 10 larvae were caught from February through June. There were no exceptionally large catches in any of the other sample tows.

Lampadena spp.

Lampadena spp. larvae were taken in about the same numbers as *Hygophum* (Figures 113 and 114). However, *Lampadena* spp. larvae were not as confined to leeward coasts as *Hygophum* and were even less confined to inshore tows. Considerably more larvae were caught in winter than summer (maximum 16.6 at Mokapu). Most of the *Lampadena* spp. larvae were taken off Oahu.

Lampadena spp. were the third most abundant myctophid larvae taken in Watson and Leis' (1974) survey of Kaneohe Bay; most larvae were taken in winter and early spring. *Lampadena* spp. larvae were taken in small numbers at most other stations in winter or spring. An exceptionally large catch (37) was taken in south Maalaea Bay in March.

EXOCOETIDAE

Cypselurus spp.

Two unidentified species of *Cypselurus* (sp. 1 and sp. 2) were taken during the survey. Since their summer distributions were nearly identical (Figures 115 and 116) they are described together. During the winter only six larvae—4 *Cyps*₁ and 2 *Cyps*₂—were taken at five stations off Maui and Oahu. During the summer *Cyps*₁ and *Cyps*₂ were taken at 15 and 22 stations, respectively (Figures 115 and 116), at both inshore and offshore stations. Off Kauai and Maui mostly windward

stations were positive; off Oahu they were absent mainly from the north shore. The largest catches were *Cyps*₁ at Kalihiwai (16.7) and *Cyps*₂ at Barbers Point (20.8) and Hanalei Bay (10.3).

Watson and Leis (1974) took 70 exocoetid larvae, mainly from the Sampan Channel in Kaneohe Bay at all times during the year. They were rare in samples from other locations.

ATHERINIDAE

Pranesus insularum

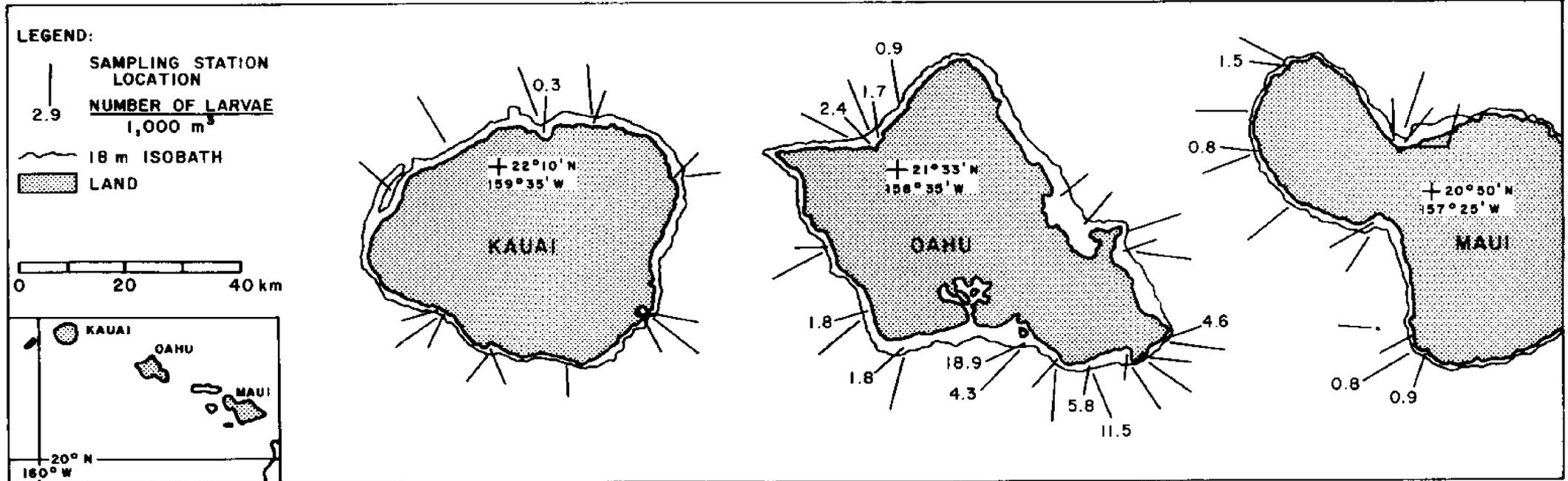
P. insularum is primarily a bay species (Gosline and Brock, 1960) and the larvae are similarly distributed. All were taken in inshore tows and most of these were near or in bays or harbors. Two positive tows occurred during the winter survey; one larva each was caught at Hanalei Bay and Ahihi Bay. In summer, 10 tows were positive; most had a single specimen (Hanapepe Harbor, Kahala, Sandy Beach, Kailua Bay, Pokai Bay, and Kahe Point). Two positive tows occurred at Kahului Harbor; one of the tows yielded the maximum number (27) encountered anywhere during the survey. Two specimens were taken in a single tow at Kahului Harbor.

In their study of Kaneohe Bay, Watson and Leis (1974) found *P. insularum* year-round with a peak of abundance in summer and fall (35 larvae/1,000 m³). In another study of Kaneohe Bay, Miller (1973) reported the occurrence of this species in neustonic daytime tows. Their numbers decreased from the southern enclosed portion of the bay toward the more open northern portion of the bay. Watson and Leis (1974) found an increase in numbers at night.

P. insularum larvae are restricted to the upper 5 m of southern Kaneohe Bay during the day and are most abundant in the upper 40 cm. At night they become somewhat dispersed, but remain more abundant near the surface (Watson, 1974).

Iso hawaiiensis

I. hawaiiensis larvae are much rarer than *P. insularum* larvae. Only two were taken during the survey, one each at Sand Island (offshore) in winter and at the east entrance of Kahului Harbor in summer. Watson and Leis (1974) encountered this species once in the Kaneohe Bay Sampan Channel. Perhaps this larva has a more offshore distribution, as evidenced by the encounter of relatively high



118

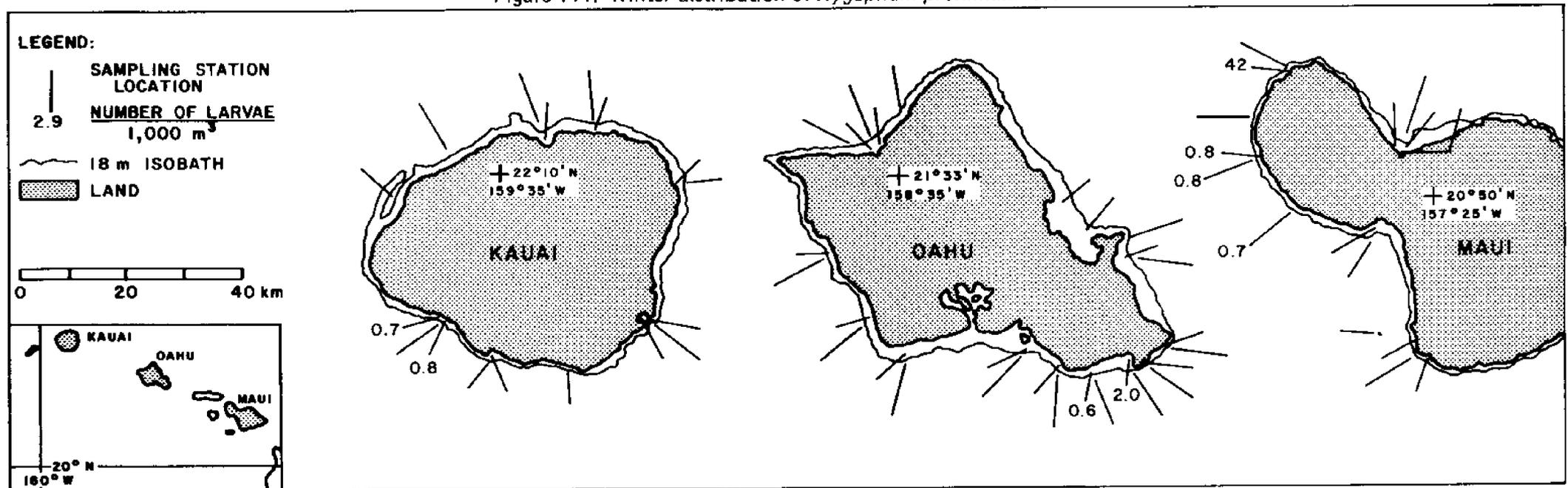


Figure 112. Summer distribution of *Hygophum proximum* larvae

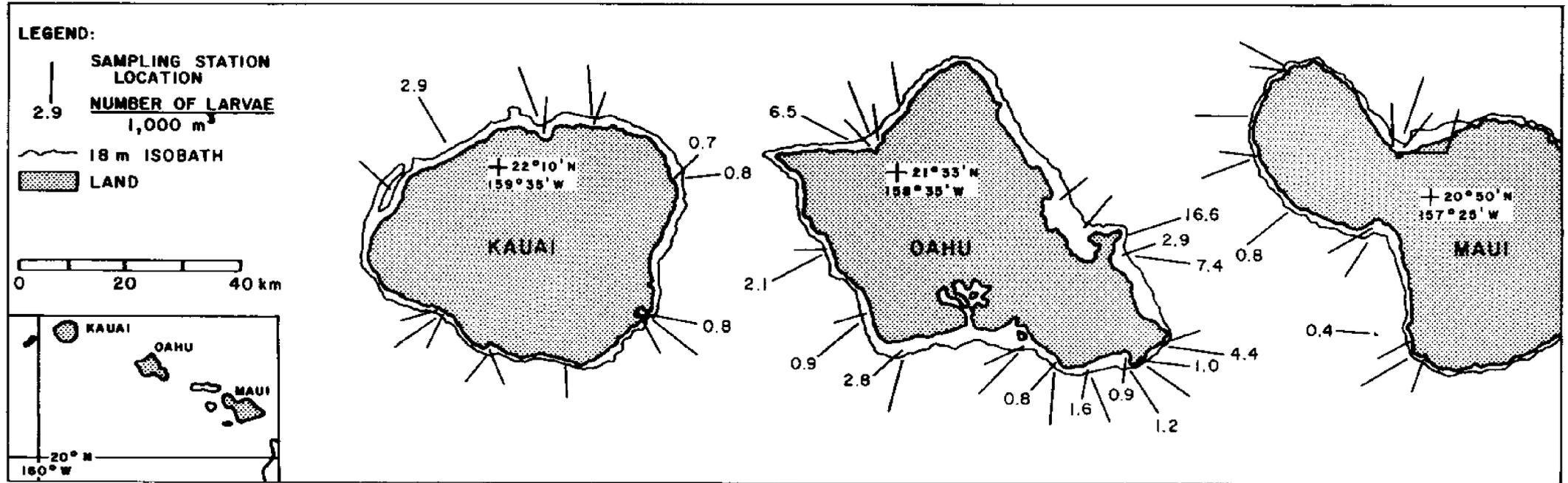


Figure 113. Winter distribution of *Lampadena* sp. larvae

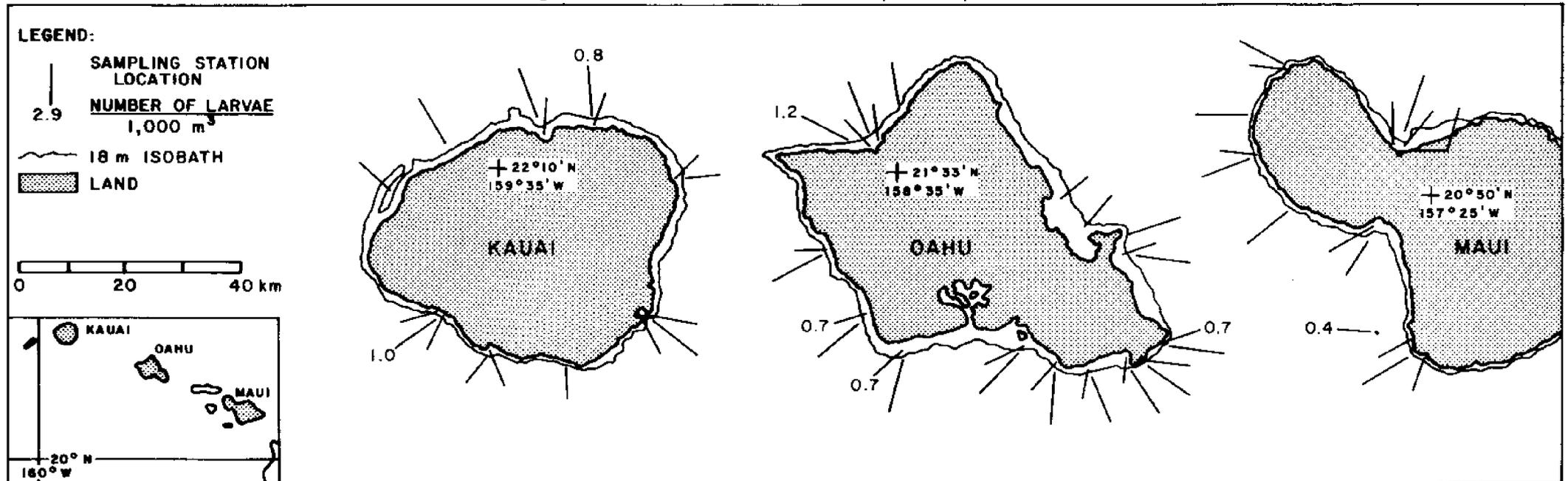


Figure 114. Summer distribution of *Lampadena* sp. larvae

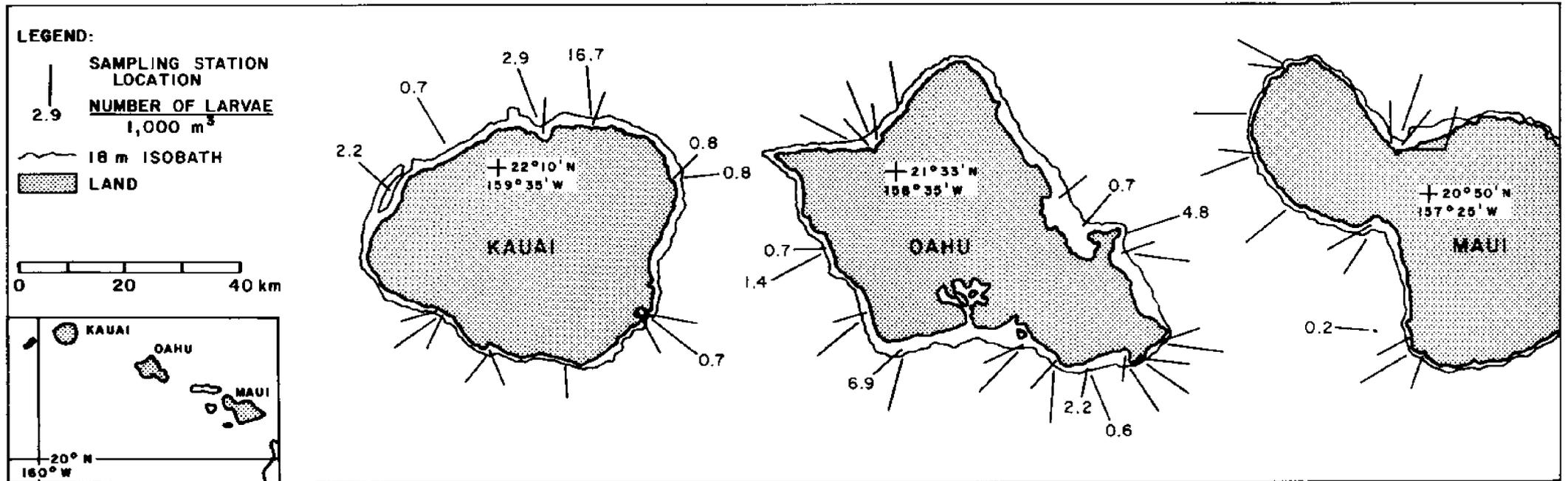


Figure 115. Summer distribution of *Cypselurus* sp. 1 larvae

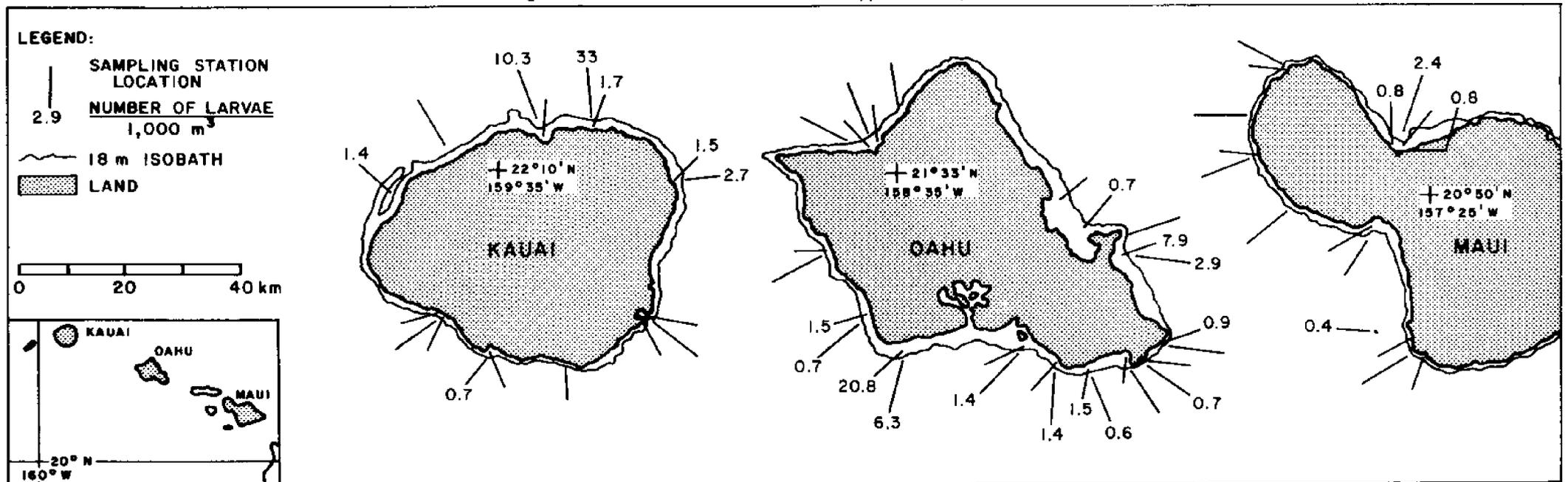


Figure 116. Summer distribution of *Cypselurus* sp. 2 larvae

numbers in Waimanalo Bay, Oahu, by workers at Oceanic Institute (W. Madden, 1973: personal communication).

KYPHOSIDAE

Kyphosid larvae were taken in small numbers during both winter and summer. In winter they occurred off all three islands (Figures 117 and 118). In summer all kyphosid larvae, except one at Barbers Point, Oahu, were taken off Kauai. Since no other species was taken in summer exclusively off Kauai, it seems unlikely that unusual hydrographic conditions were responsible. An alternative explanation may be that the summer kyphosids were a different species.

Five of the eight positive summer tows and 12 of the 17 winter tows were conducted offshore. No windward or leeward trends were indicated.

Kyphosid larvae were taken in other samples with about the same frequency and nearly all in winter—from October to March. Several larvae were taken off Kahe Point in July; these may also have been different species. Nine larvae were taken during the Kaneohe Bay survey during the January to April interval.

MULLIDAE

Considerably more mullid larvae were taken in summer than in winter (Figures 119 and 120), although three of the largest catches occurred in winter at Kalalau (38), Mokuleia (36), and Molokini Island (13.1). No obvious affinity for leeward or windward shores was indicated; however, the vast majority of larvae were taken in offshore tows. This latter pattern differs from most other species.

In Watson and Leis' (1974) study, only 18 larval mullids were taken from the Sampan Channel in Kaneohe Bay in winter and spring. Mullid larvae were infrequently encountered in other samples.

Metamorphic stage and juvenile mullids were frequently taken by dip-netting at night near shore.

SERRANIDAE

Serranid Sr-5 (Anthiinae)

Serranid larvae occurred at only seven stations during the survey. In summer, single specimens were taken off Kauai in inshore tows at east Waimea Bay and at Hanapepe Harbor and in one offshore tow at Kalalau. In winter, one serranid larva each was taken in inshore tows at Waimea Bay and Sandy Beach. Serranid larvae were taken in offshore tows at Waimea Bay (1 specimen) and Sandy Beach (2 specimens).

None were taken from Kaneohe Bay (Watson and Leis, 1974); however, some were taken at Kahe Point.

APOGONIDAE

Foa branchygramma

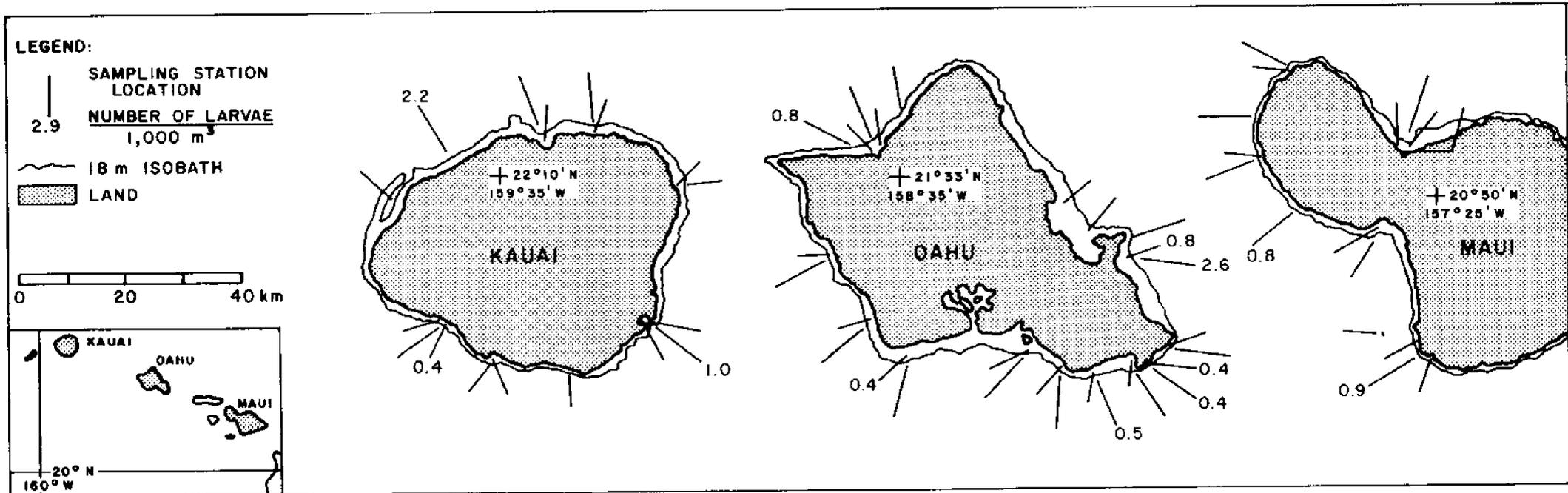
F. branchygramma was the most common apogonid larva taken during the survey; however, its numbers were never high. Most of the larvae taken during the survey occurred in summer (Figure 121). Eight larvae were taken in inshore tows in winter: one each at Hanalei Bay, Hanapepe Harbor, Kahala, Honolulu Bay, and La Perouse Bay and three at Ahihi Bay. Two larvae were taken in winter tows off Moku.

Watson and Leis (1974) found considerably greater numbers of *F. branchygramma* larvae in Kaneohe Bay throughout the year, with spring and fall peaks of 200 and 140, respectively. More larvae were present at night than during the day. The vertical distribution and migration responsible for these diel changes in Kaneohe Bay are described in Watson (1974).

No exceptionally large catches occurred at any of the other stations.

CARANGIDAE

Carangid larvae appear to be divisible into two groups according to their distribution. *Caranx mate* and *Gnathanodon speciosus* larvae are conspicuous components of the larval fish fauna of Kaneohe Bay (Watson and Leis, 1974) and probably other semi-enclosed bays of Hawaii. Neither was taken more than once or twice during the survey. The other group, represented by *Seriola* sp., and *Trachurops crumenophthalmus*, and at least six unidentified types, comprised



122

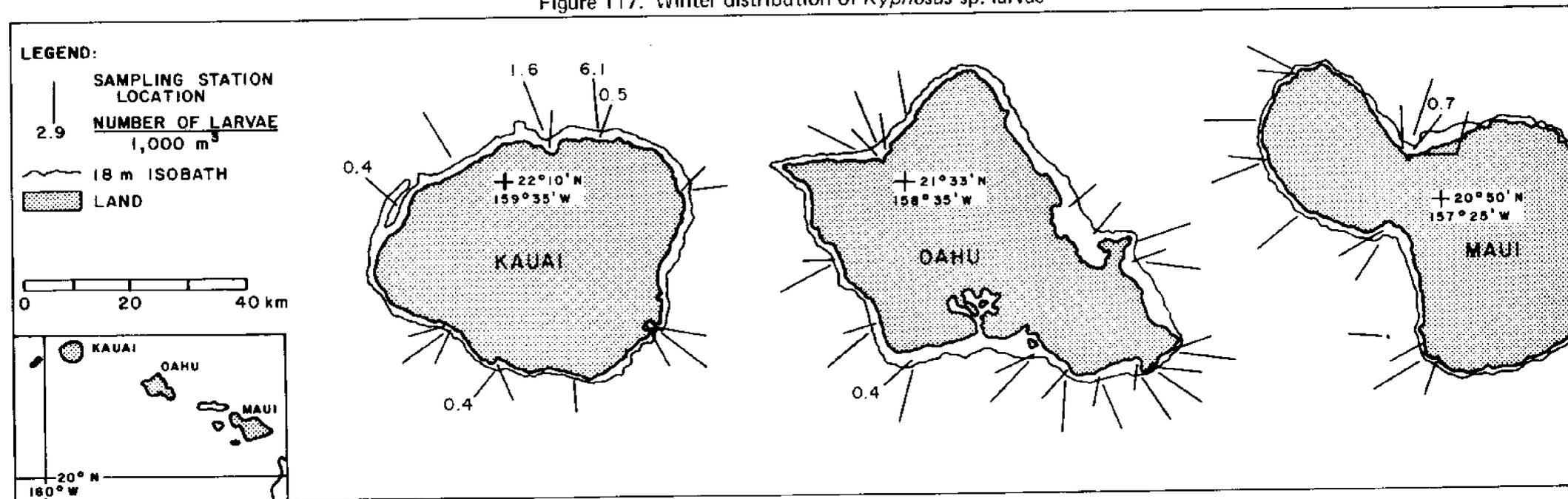


Figure 118. Summer distribution of *Kyphosus* sp. larvae

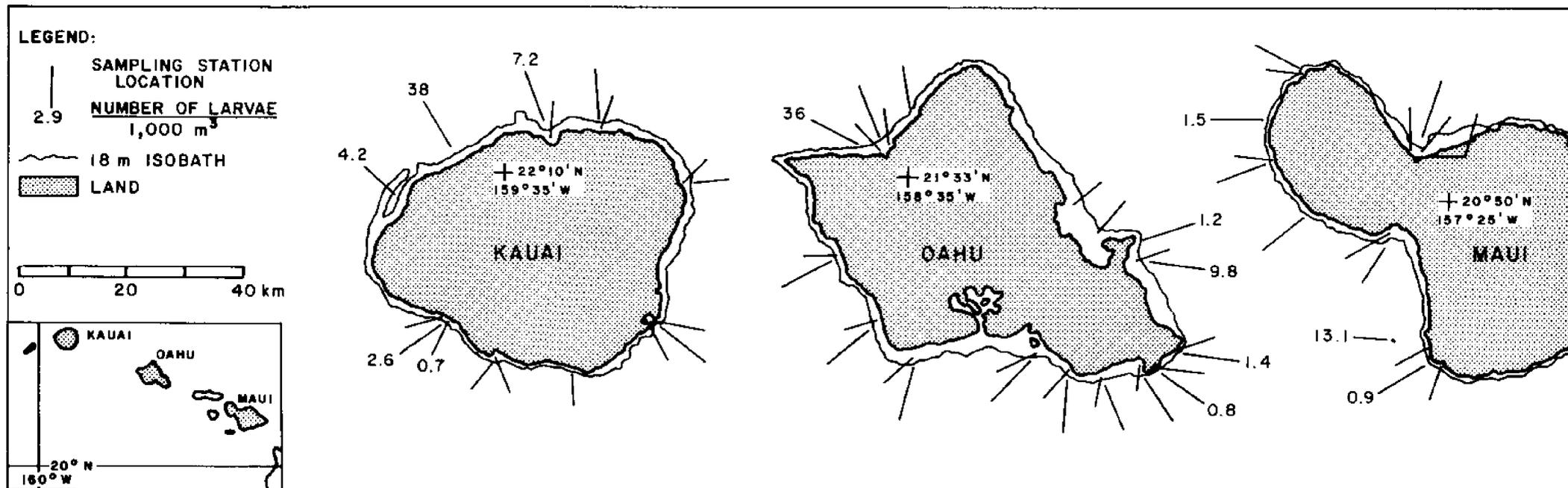


Figure 119. Winter distribution of Mullidae larvae

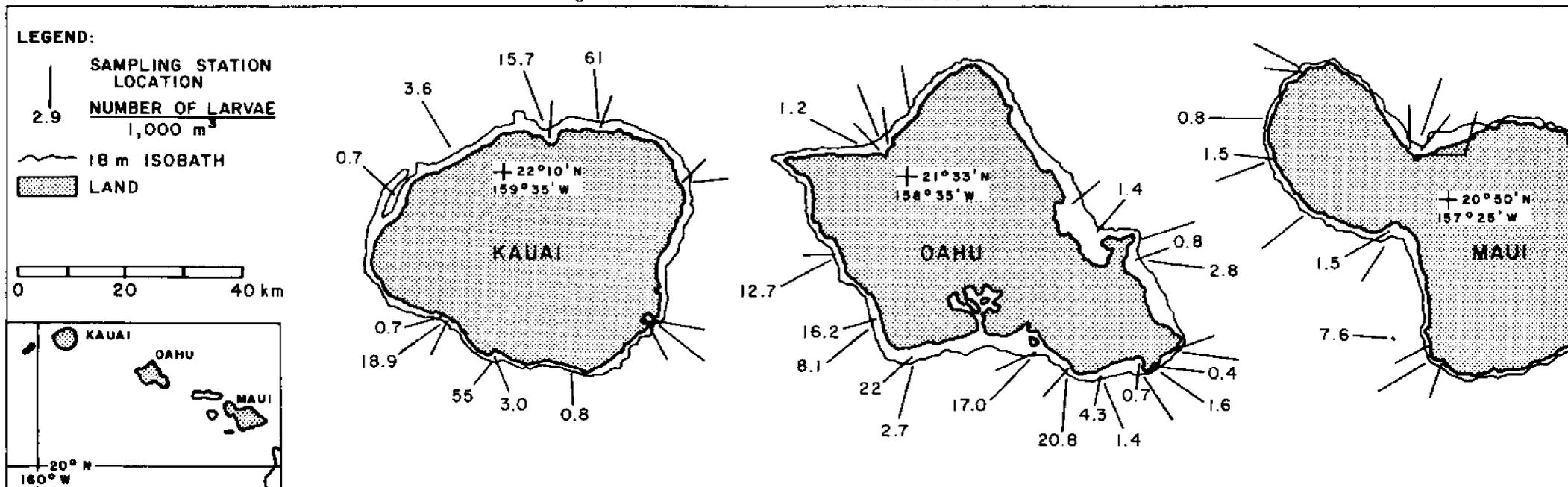


Figure 120. Summer distribution of Mullidae larvae

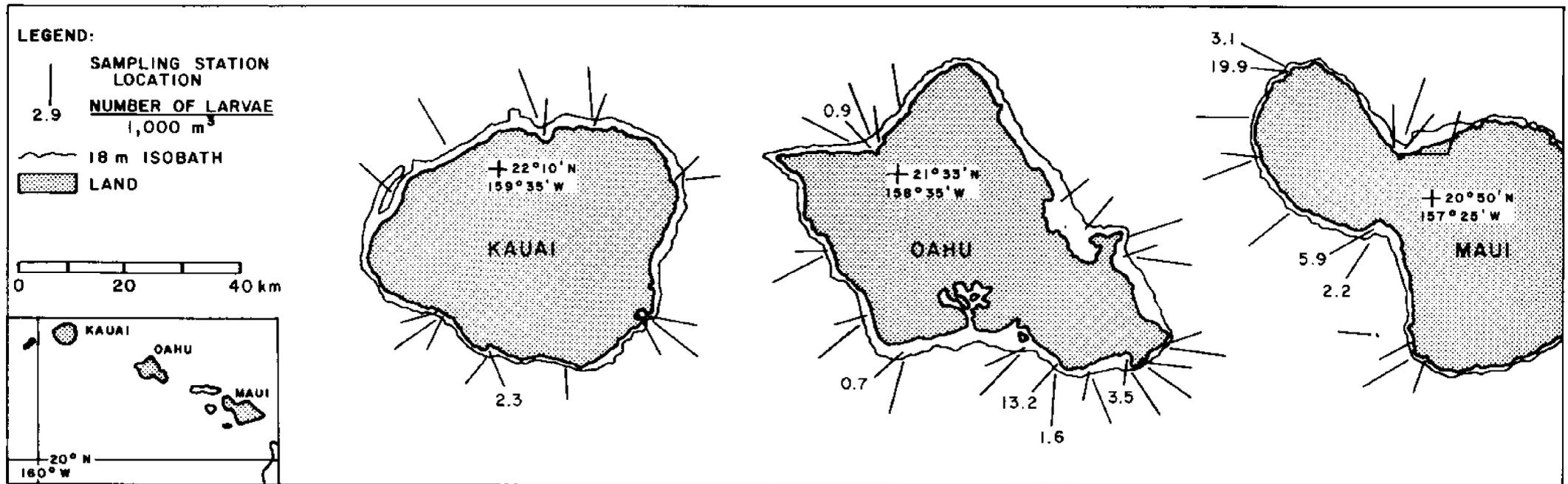


Figure 121. Summer distribution of *Foa brachygramma* larvae

124

over 80 percent of the carangid larvae taken, suggesting a more offshore distribution. The adults of both groups are known to occur both in and out of bays.

Seriola sp.

Seriola sp. larvae were much less common during the survey than *T. crumenophthalmus*. Too few specimens were taken to adequately describe the distribution, but they appeared to be more evenly distributed both windward and leeward than *T. crumenophthalmus*. *Seriola* sp. larvae occurred at more stations in summer than in winter, but the total numbers taken were similar (Figures 122 and 123). Most of the larvae were taken in offshore tows, differing from the pattern of *T. crumenophthalmus*.

Watson and Leis (1974) described *Seriola* sp. larvae as rare in Kaneohe Bay: only 21 specimens were taken from the Sampan Channel from December to May. No large catches of *Seriola* sp. larvae occurred in any other tows, although this species was rather frequently encountered in small numbers.

Trachurops crumenophthalmus

T. crumenophthalmus larvae were taken only in summer, mainly at the leeward stations. The maximum densities were 14.6 at offshore Sand Island and 13.5 at inshore Lahaina. Two or three larvae were taken from east Kalalau, La Perouse Bay, Maalaea Bay, Hawaii Kai, Barbers Point, and Hanapepe Harbor, mainly in the inshore area.

Watson and Leis (1974) took more from Kaneohe Bay.

CORYPHAENIDAE

Coryphaena hippurus

The summer distribution of *C. hippurus* was largely leeward (Figure 124); larvae were about evenly distributed among inshore and offshore stations. Larvae were nearly always encountered in low densities during the survey; the maximum single tow density (11.1) occurred at Hanalei Bay. Most of the positive tows contained one or, less frequently, two larvae; hence, their distribution decidedly tends toward uniformity.

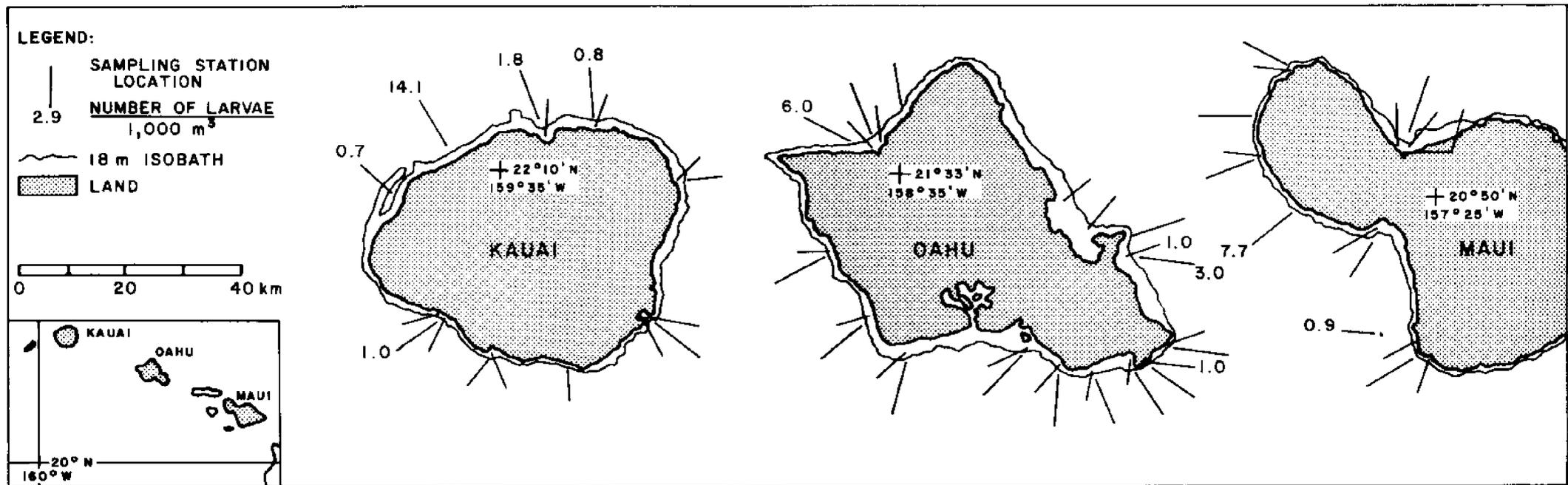


Figure 122. Winter distribution of *Seriola* sp. larvae

125

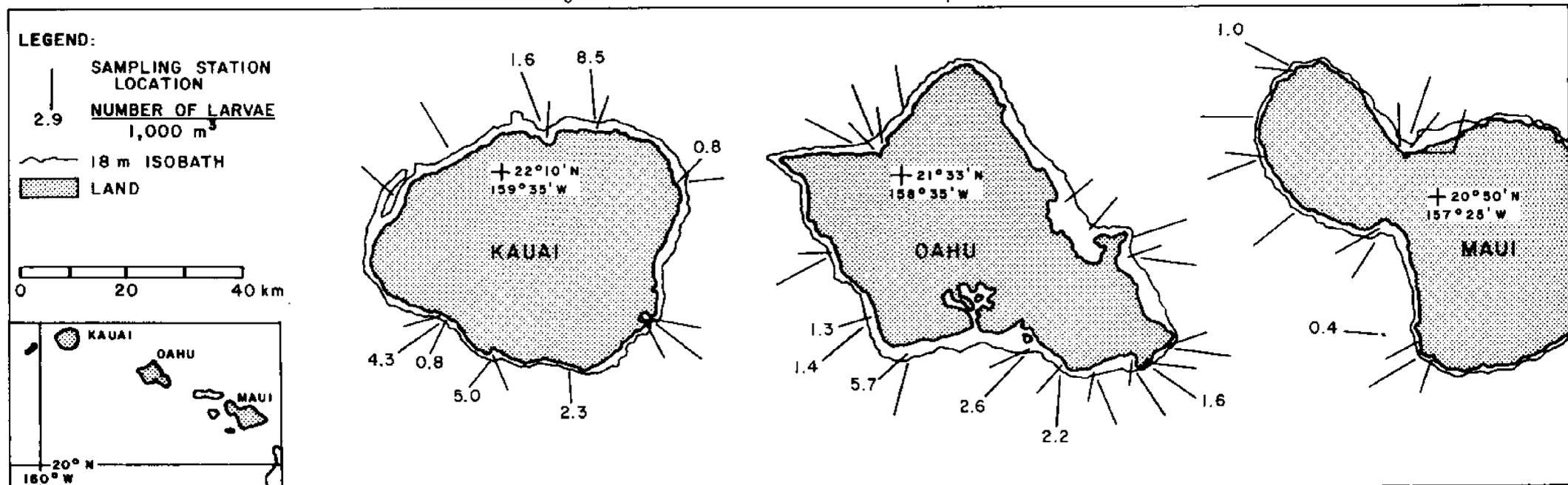


Figure 123. Summer distribution of *Seriola* sp. larvae

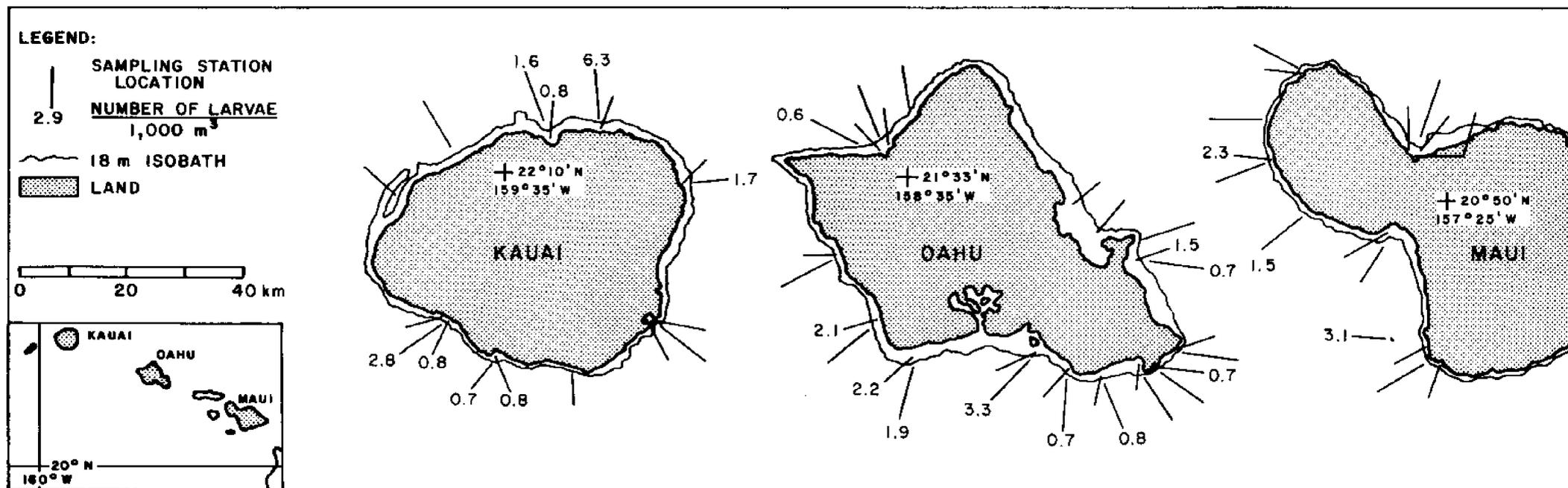


Figure 124. Summer distribution of *Coryphaena hippurus* larvae

126

From the habits of adults, *C. hippurus* larvae might be expected to show the same pattern as tuna (Scombridae) larvae; however, they did not. Scombrid larvae were much less uniformly distributed around Hawaii, suggesting different responses to currents, etc.

During the winter survey, only five specimens were collected off Kauai, four off Oahu, and one off Maui. The pattern and average density off Oahu in April were similar to those in summer, so a broad summer spawning season is indicated, with less spawning activity in winter. *C. hippurus* larvae in all other samples followed this pattern.

POMACENTRIDAE

Abudefduf abdominalis

A. abdominalis larvae were about twice as abundant in summer as in winter, but their distribution was about the same for both seasons (Figures 125 and 126). *A. abdominalis* larvae were about equally abundant on the windward and leeward coasts and in shallow and deep tows. Most of the larvae were caught off Oahu.

Watson and Leis (1974) found *A. abdominalis* larvae year-round in Kaneohe Bay with a peak of abundance in early spring. Their maximum catch, however, occurred in October (140 larvae/1,000 m³). No strong diel cycle was apparent. Watson (1974) found *A. abdominalis* larvae were most abundant in the upper 3 m of the water during the day, but the larvae dispersed somewhat by late afternoon and at night. They remained more abundant toward the surface at night, however. *A. abdominalis* larvae were taken regularly at other stations throughout the year, with maximum catches of about 50 larvae/1,000 m³ at south Maalaea Bay and off Molokini Island in March.

Eupomacentrus fasciolatus

E. fasciolatus larvae were the second most abundant of the pomacentrid species, but considerably less abundant than *A. abdominalis*. Their distributions were quite different. About equal numbers of *E. fasciolatus* larvae occurred in the winter and summer tows (Figures 127 and 128), about 90 percent occurring in shallow tows.

Watson and Leis (1974) did not distinguish *E. fasciolatus* from *A. abdominalis* in their analyses; however, the proportion was about the same as the survey.

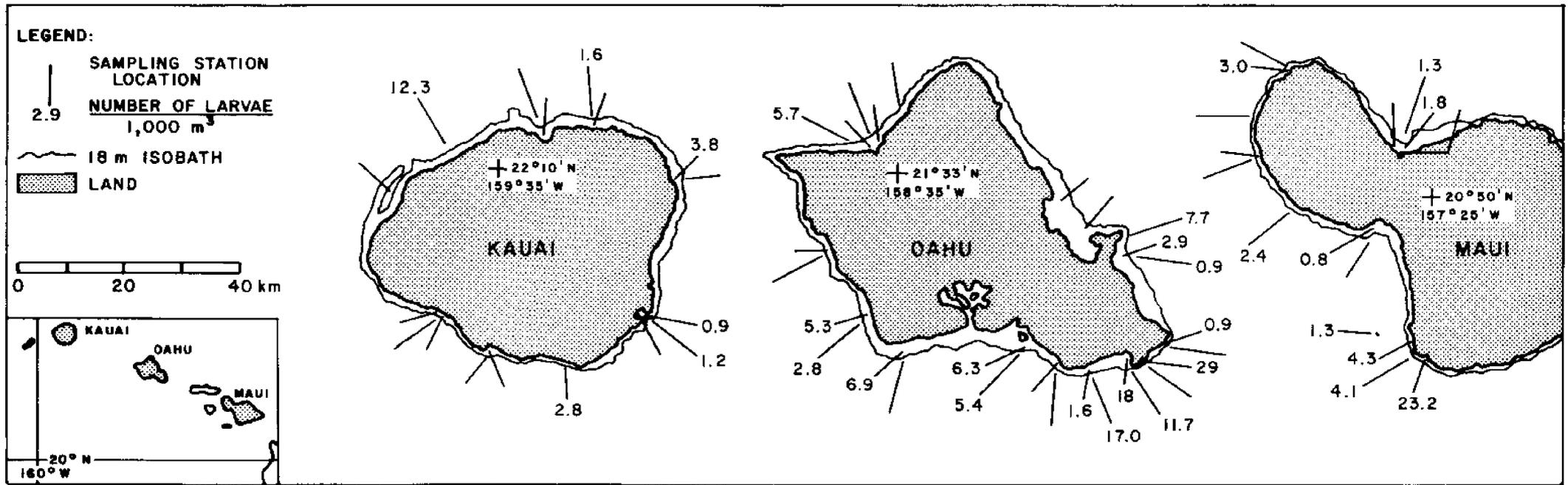


Figure 125. Winter distribution of *Aburdefduf abdominalis* larvae

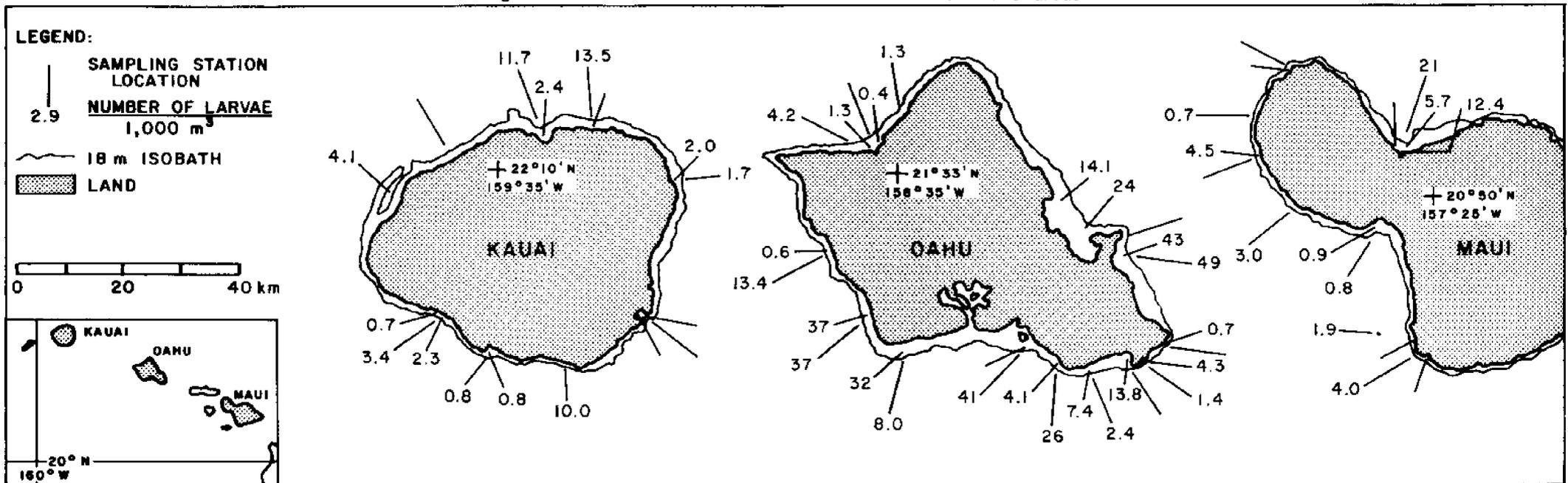


Figure 126. Summer distribution of *Aburdefduf abdominalis* larvae

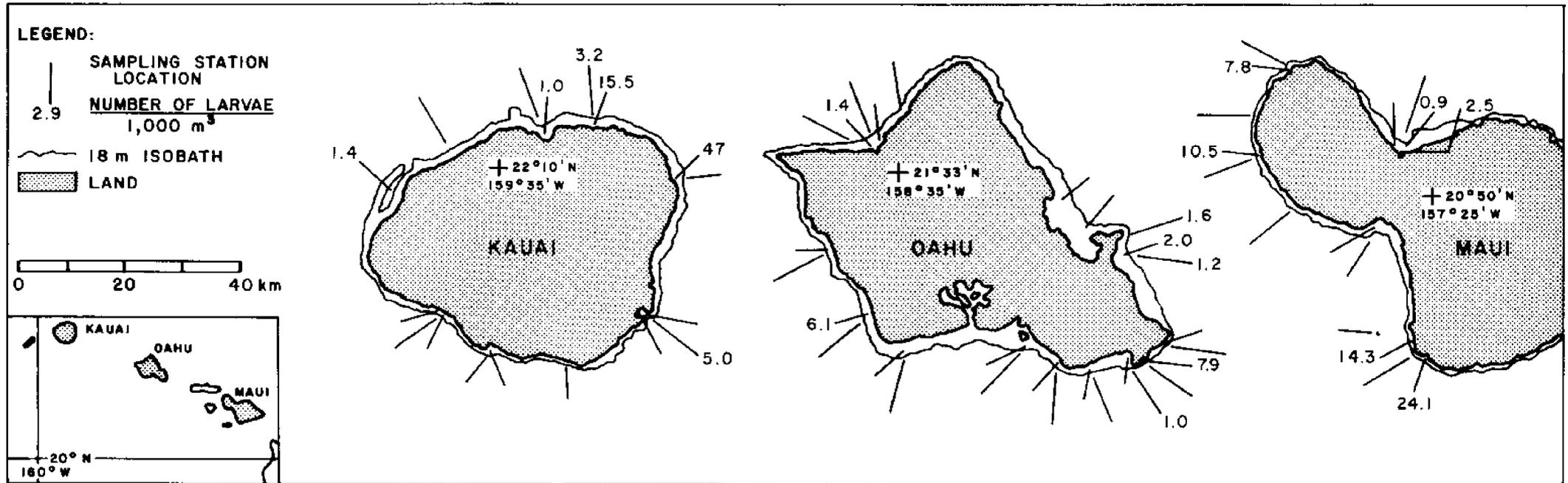


Figure 127. Winter distribution of *Eupomacentrus fasciolatus* larvae

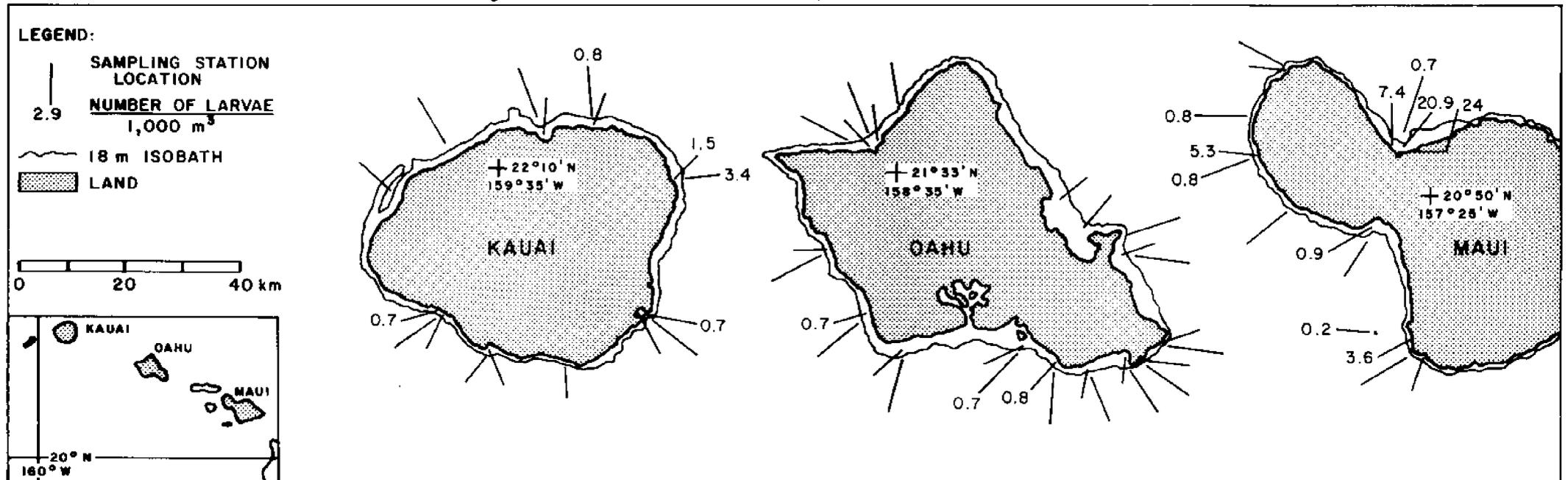


Figure 128. Summer distribution of *Eupomacentrus fasciolatus* larvae

Eighty percent *A. abdominalis* and 20 percent *E. fasciolatus* larvae were often taken in the other tows. No exceptional catches were recorded.

LABRIDAE

Labrid L-3

Labrid L-3 larvae occurred infrequently and in low densities at both windward and leeward stations in both winter and summer. Six of the seven stations which yielded positive tows in summer were located off Kauai and five of these were offshore. A single larva was taken at Kahe Point (inshore) in summer. In winter, no larvae were taken off Kauai, but they were present in offshore hauls from three stations off Oahu and two off Maui. All but two positive tows contained a single larva.

The largest catches of Labrid L-3 larvae occurred at Molokini Island in March, with a maximum single catch of 233 larvae/1,000 m³. Watson and Leis (1974) took few larvae from Kaneohe Bay. This species was not encountered in the other tows.

SCOMBROLABRACIDAE

Scombrolabrax heterolepis

Only five specimens of *S. heterolepis* larvae were taken during the winter survey; one each inshore at Waimea Bay, Kahala, Honolulu Bay, and Barking Sands, and one offshore at Lahaina. Additional specimens were taken at Kahe Point between September and April. The few larvae taken suggest winter spawning. None were taken from Kaneohe Bay (Watson and Leis, 1974).

GEMPYLIDAE

All gempylid larvae were lumped together because only *Gempylus serpens* larvae were identified to species in the survey samples. About three-fourths of the gempylid larvae taken were *G. serpens*.

About equally small numbers of gempylid larvae were taken in winter and summer (Figures 129 and 130). About three-fourths of the gempylid larvae were taken at the offshore stations. The modal number of specimens in the tows was one, so gempylids appear to be widely distributed. No windward-leeward pattern

was apparent. The maximum single tow density was 5.8 at Molokini Island in summer.

Watson and Leis (1974) took nine larvae in daytime samples from the Kaneohe Bay Sampan Channel from October to May. An exceptionally large catch (65.6) of *G. serpens* larvae occurred at Molokini Island in March 1973, but larvae occurred with similar frequencies and density as the survey in all other samples.

SCOMBRIDAE

At least six species of scombrid larvae were taken during the survey and in other samples. In decreasing order of abundance, the six larval species in the survey samples were *Thunnus albacares*, *Auxis* sp., *Thunnus obesus*, *Acanthocybium solandri*, *Euthynnus affinis*, and *Scomber australicus*. In addition, some species of *Katsuwonus pelamis* larvae were taken in other samples. Over 80 percent and 15 percent of the scombrid larvae taken were *T. albacares* and *Auxis* sp., respectively. Over 99 percent of the scombrid larvae were taken in summer.

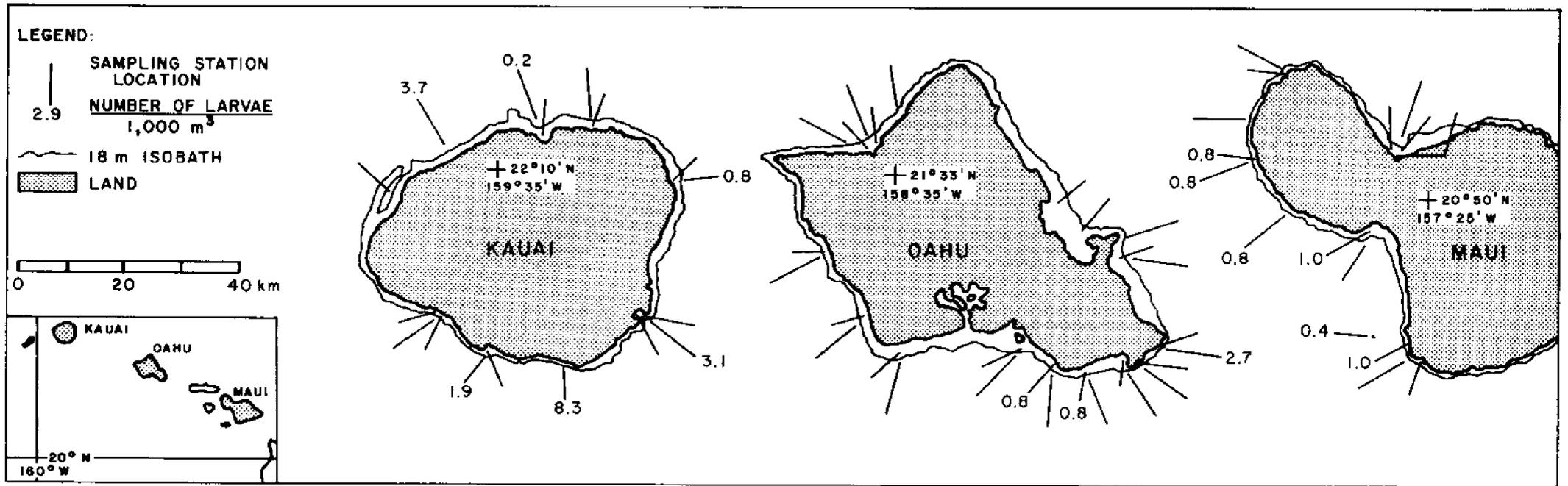
Auxis sp.

Auxis sp. larvae ranked second in nearshore abundance among scombrids and occurred, like *T. albacares*, almost exclusively in summer. Their distribution in summer (Figure 131) was more restricted than *T. albacares*, and none were taken off Kauai during this season. The only winter occurrence of *Auxis* sp. larvae was a single specimen off Poipu. The maximum density of *Auxis* sp. larvae occurred inshore at Hawaii Kai (22.3) and Kahala (13.7).

Watson and Leis (1974) took one *Auxis* sp. larva from Kaneohe Bay in March. Other samples showed similarly low numbers and a predominant summer distribution.

Thunnus albacares

T. albacares larvae were widely distributed in small numbers during the summer (Figure 132). Usually one or two specimens were taken at a station; however, densities of 49 inshore at Lahaina, 25 off Molokini Island, and 22.2 at Mokuleia were exceptions. No larvae were taken in the winter survey. *T. albacares* larvae occurred at many nearshore stations in low densities and, infrequently, at densities far exceeding the average density (ca. 4 larvae/1,000 m³) in the more



130

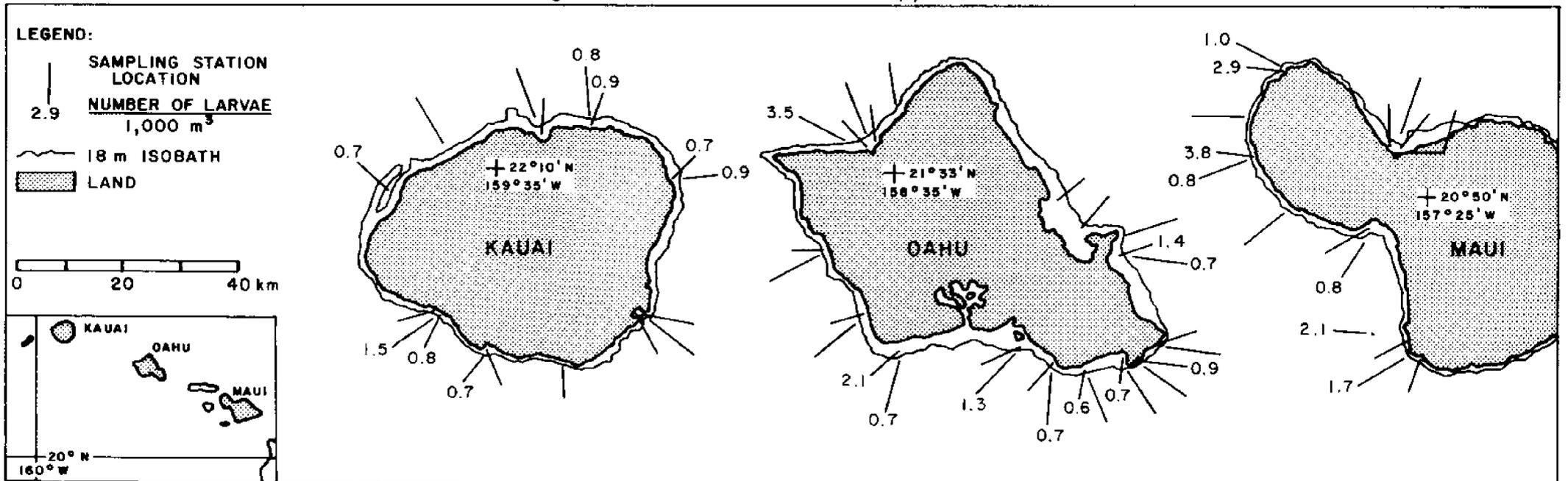


Figure 130. Summer distribution of Gempylidae larvae

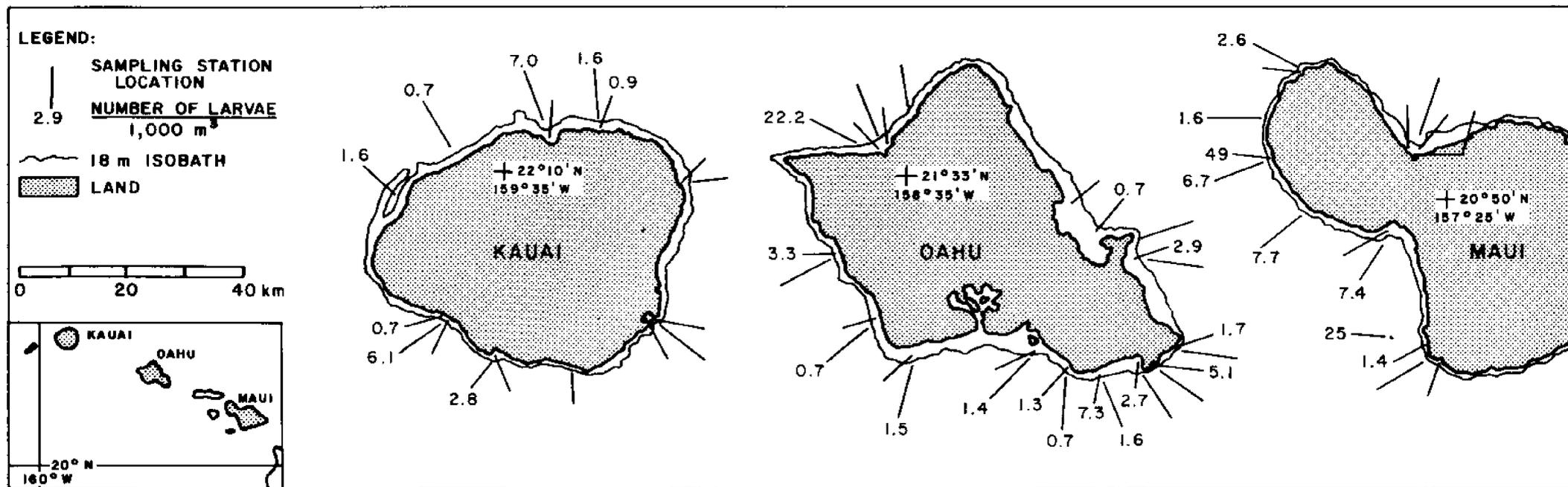


Figure 131. Summer distribution of *Auxis sp.* larvae

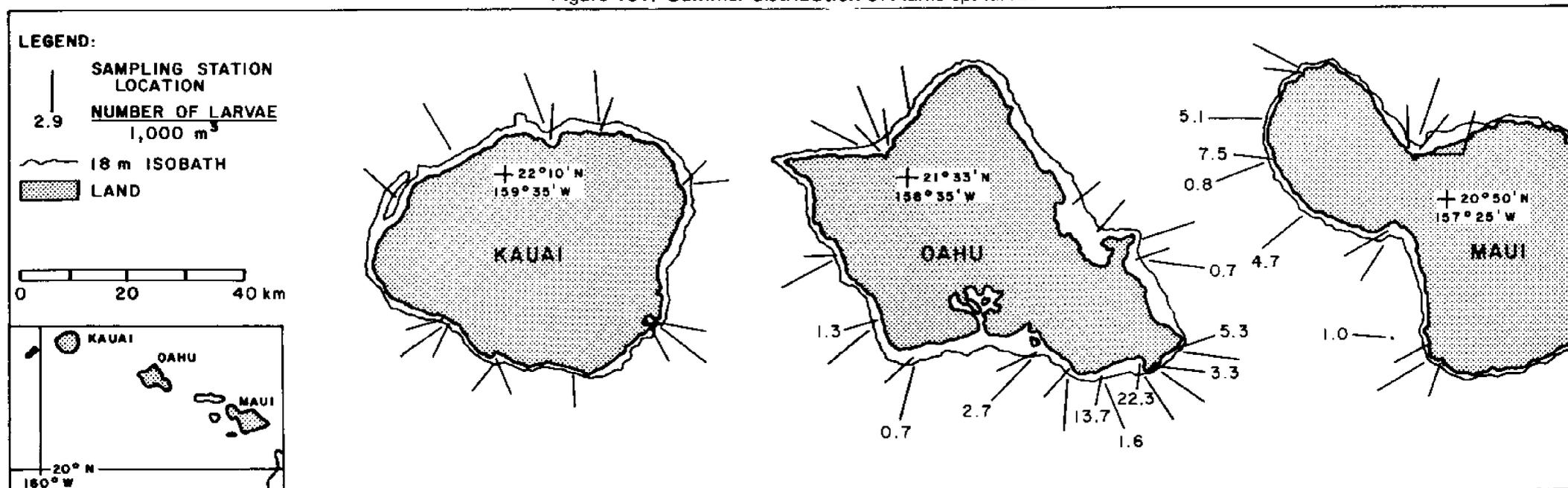


Figure 132. Summer distribution of *Thunnus albacares* larvae

open waters of the Central Pacific (Strasburg, 1960). The other samples showed the same pattern.

Watson and Leis (1974) took only 13 larvae from Kaneohe Bay on five occasions from March to July. Summer samples at Kahe Point showed similarly low densities, with outstanding exceptions in July 1972 and July 1973. During these months, the number of *T. albacares* larvae was as high as 441. Further discussion of these nearshore occurrences of scombrid larvae is found in Miller (1979).

Acanthocybium solandri

Seven larvae were taken in summer only: one each at Barking Sands and offshore of Waimea, two inshore at Lahaina, and three off Molokini Island. None were taken at other stations.

Scomber australicus

132 *S. australicus*, like *A. solandri* and other scombrid larvae, were rarely encountered. In winter, single specimens were taken off La Perouse Bay and Barking Sands. In summer a single specimen occurred inshore at east Waimea Bay. None were taken in other samples.

Katsuwonus pelamis

A single *K. pelamis* larva occurred off Kahala in summer.

Euthynnus yaito = E. affinis

E. yaito larvae occurred only in summer with single specimens taken inshore at Honolulu Bay and west Waimea Bay and offshore at Kahala and Sand Island. None were taken in other samples.

Euthynnus affinis

E. affinis larvae were taken at two stations in summer inshore at Kahe Point (4.4) and offshore at Kahala (4.8). Watson and Leis (1974) took 16

larvae in the Kaneohe Bay Sampan Channel in March. This was the only other occurrence.

Thunnus obesus

T. obesus larvae also occurred exclusively during the summer. Single specimens were found in two tows at east Waimea Bay and inshore at Kahala and also inshore at Barbers Point. Off Kahala the density was 7.1. None were taken in other samples.

GOBIIDAE

Psilogobius mainlandi

P. mainlandi larvae appeared to reflect the distribution of gobies in general. Gobies, consisting of 13 types, occurred at most stations and in no definite pattern (Figures 133 and 134). *P. mainlandi* larvae occurred at much lower densities and at fewer stations (Figures 135 and 136). In both cases, most of the highest densities were leeward, but relatively high densities also occurred at windward stations.

About the same number of *P. mainlandi* larvae were found in winter as in summer. Positive catches were about evenly distributed among shallow and deep-water tows; however, all of the exceptionally large catches occurred in shallow water.

Most gobies, certainly *P. mainlandi*, appear to spawn year-round; however, since the taxonomy is poorly understood and each type comprised a small fraction of the catch, little else can be inferred.

The 21 "types" of gobies found in Kaneohe Bay (Watson and Leis, 1974) appeared to exhibit spring and fall peaks of abundance. Owing to the poor state of taxonomy, the contributions of individual species to this pattern are unknown. *P. mainlandi* larvae were frequently taken in small numbers in other tows. Gobies were about five times more abundant at night than during the day in Kaneohe Bay (Watson and Leis, 1974).

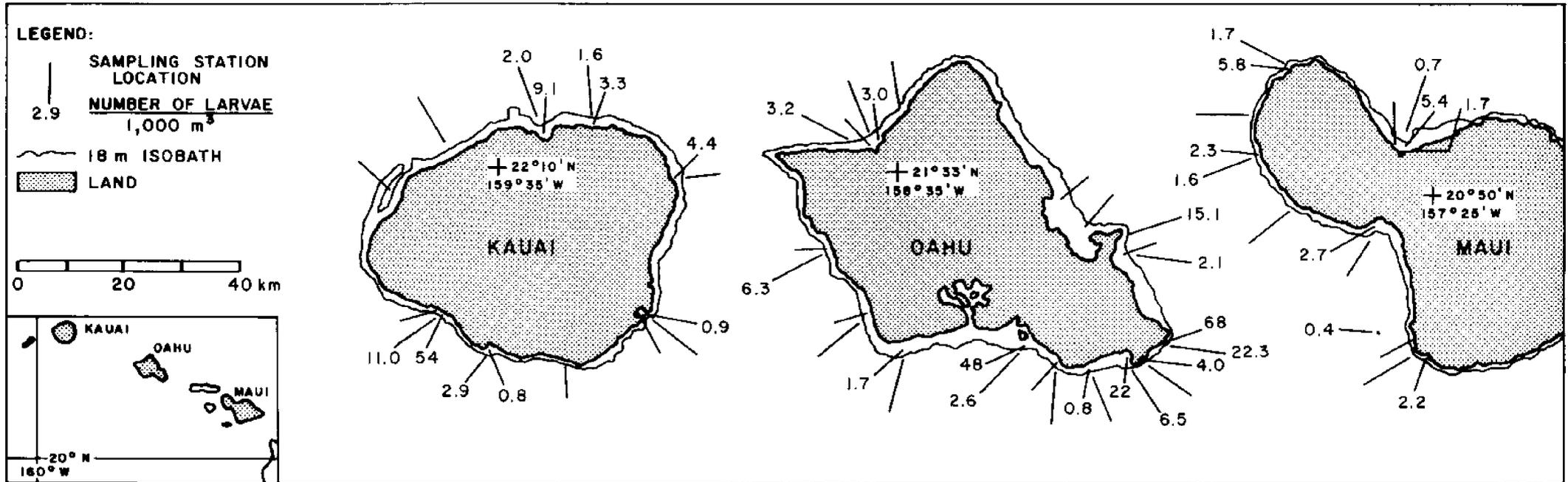


Figure 133. Winter distribution of Gobiidae larvae

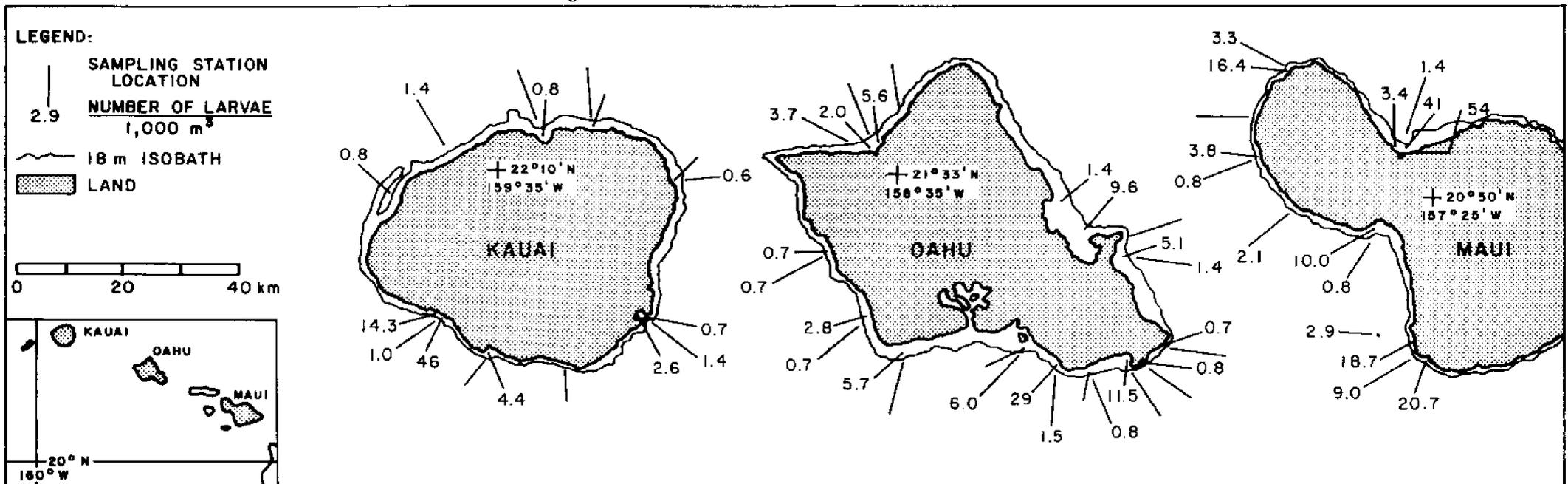


Figure 134. Summer distribution of Gobiidae larvae

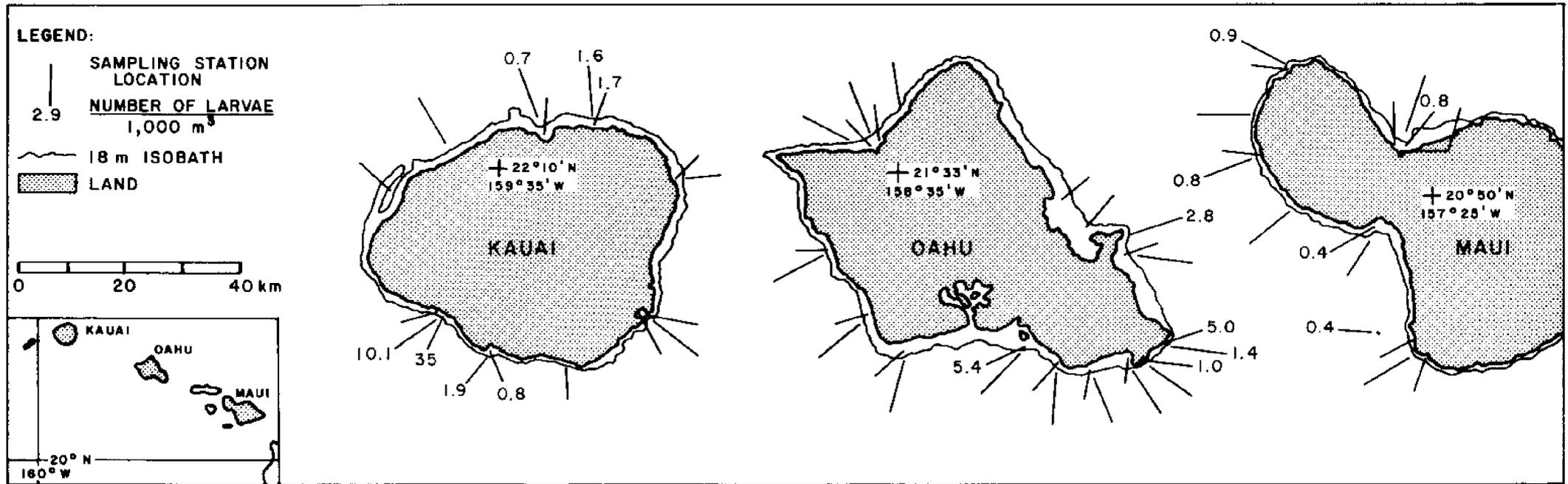


Figure 135. Winter distribution of *Psilogobius mainlandi* larvae

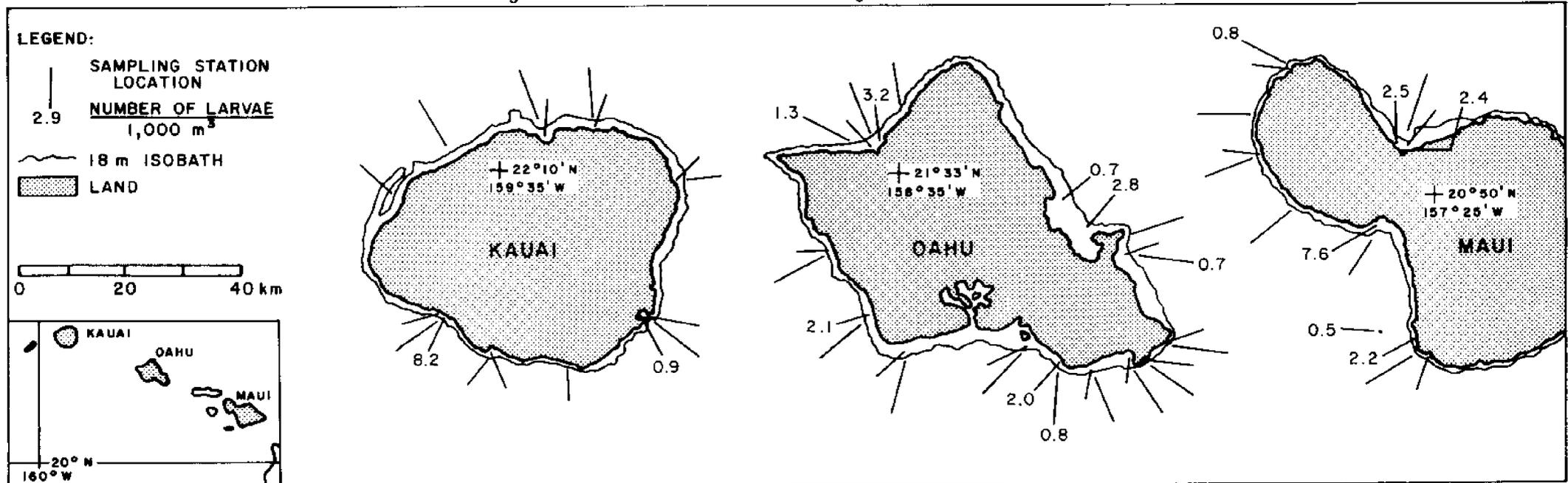


Figure 136. Summer distribution of *Psilogobius mainlandi* larvae

TRIPTERYGIIDAE

Tripterygion atriceps

T. atriceps larvae occurred at most stations in about equal numbers during both summer and winter (Figures 137 and 138) and at higher densities than most other species. Ninety-one percent of all *T. atriceps* larvae were taken in shallow tows. Apparently *T. atriceps* are better able to avoid being carried offshore than most other species of similar size. Moderate and high densities occurred both windward and leeward.

Watson and Leis (1974) found summer and winter peaks of abundance in the Kaneohe Bay Sampan Channel. No strong diel pattern was indicated. Studies by Leis (1978) at Kahe Point have disclosed relatively high densities of *T. atriceps* larvae mid-way in the water column in shallow water (6 m). Perhaps the larvae at ca. 4 mm SL simulate the behavior of the small (2.5 cm) adults in hiding in coral heads. This might also explain their marked inshore distribution. Also, it is possible that these larvae were considerably older than similar-sized larvae. No exceptional catches occurred in other samples, although *T. atriceps* larvae were commonly taken.

NOMEIDAE

Cubiceps pauciradiatus

C. pauciradiatus larvae were taken only in summer and in small numbers. Single specimens occurred at east Waimea Bay, Hanapepe Harbor, Sand Island, and Hawaii Kai; three specimens were taken in Hanauma Bay. *C. pauciradiatus* larvae were slightly more abundant off leeward Maui. Two or three larvae were taken in La Perouse Bay, off Molokini Island, off Lahaina, and off Kekaa. The largest catch (21) occurred inshore at Lahaina.

Watson and Leis (1974) found three *C. pauciradiatus* larvae in the Sampan Channel in June. Nomeid larvae were rare in other samples.

BLENNIIDAE

Enchelyurus brunneolus

E. brunneolus larvae were taken during both summer and winter off all three islands (Figures 139 and 140). Considerably higher densities were encountered in summer than in winter, and more larvae were caught off Oahu and Maui than Kauai. In general, greater concentrations of larvae occurred at windward stations. At stations where *E. brunneolus* larvae were taken both offshore and inshore, the latter usually had higher densities. The highest abundance of *E. brunneolus* larvae encountered was along windward Oahu. *E. brunneolus* larvae comprised from 42 to 55 percent of the total catch in the vicinity of Kailua Bay in summer. Another high percentage (65 percent) occurred off Kahului Harbor, Maui, also in summer.

Watson and Leis (1974) took *E. brunneolus* larvae all year in Kaneohe Bay, mainly from the Sampan Channel. More larvae were caught during the day than at night. *E. brunneolus* larvae concentrate near the surface during the day and disperse over the upper 5 m at night (Watson, 1974).

No exceptionally large concentrations of *E. brunneolus* were encountered at other stations.

Exallias brevis

E. brevis were taken at nearly all stations during both summer and winter (Figures 141 and 142). They were slightly more abundant in winter, with the highest catches at the more windward stations. The highest abundance (79) occurred at the inshore station in Anahola Bay, Kauai in winter.

E. brevis was the third most common blenny larva taken by Watson and Leis (1974) in the Sampan Channel of Kaneohe Bay. This species was rare in their samples of the inner bay.

The distribution of *E. brevis* larvae is probably representative of most small (ca. 4 mm) salariine and blenniine blenny larvae. Larger (ca. 5 to 6 mm) *Cirripectus* and *Entomacrodus marmoratus* larvae were taken infrequently during the survey; however, those that were taken were mainly from offshore tows. For example, exceptionally large catches of *E. marmoratus* (331 larvae/1,000 m³) and *Cirripectus* (88 larvae/1,000 m³) occurred at Molokini Island in March.

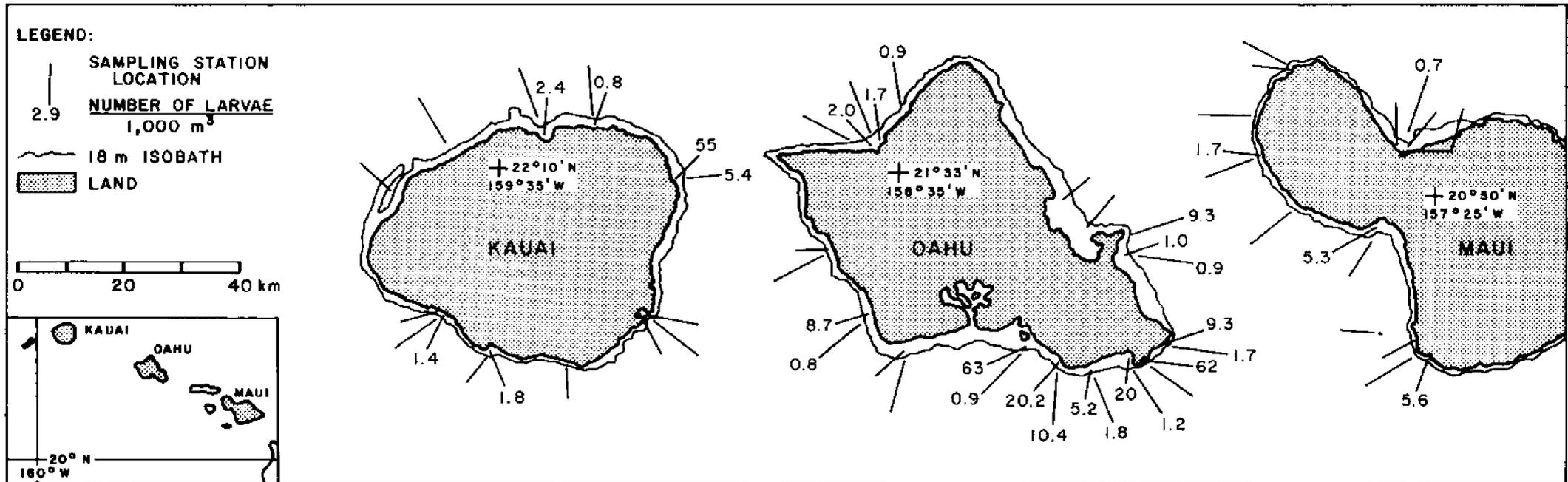


Figure 137. Winter distribution of *Tripterygion atriceps* larvae

136

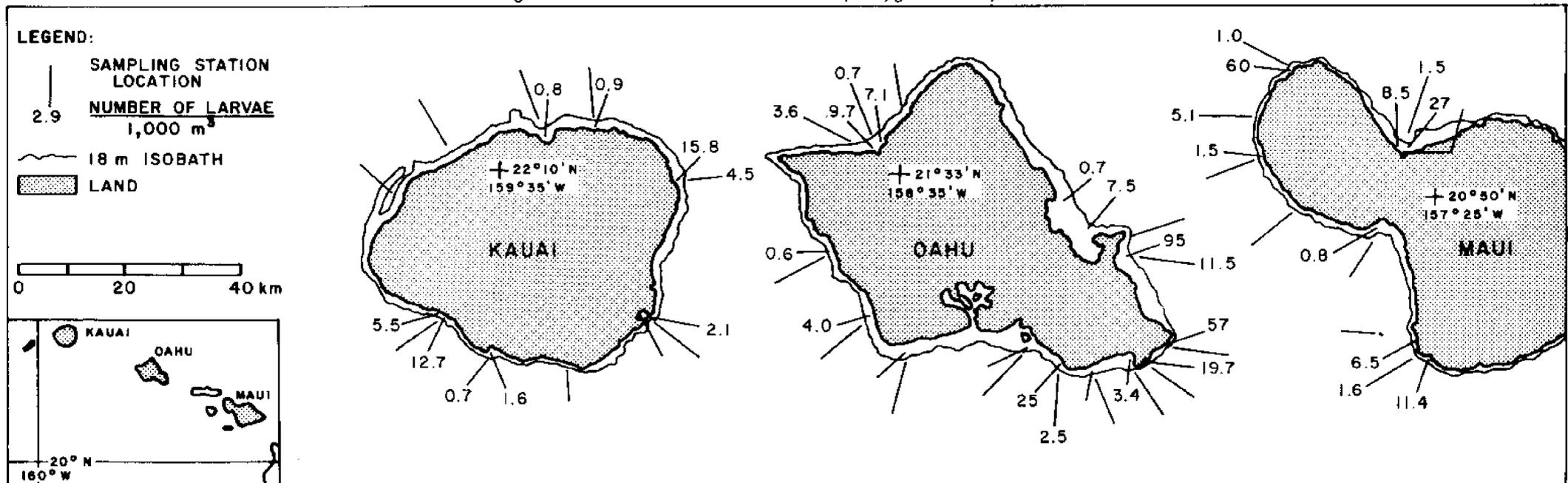


Figure 138. Summer distribution of *Tripterygion atriceps* larvae

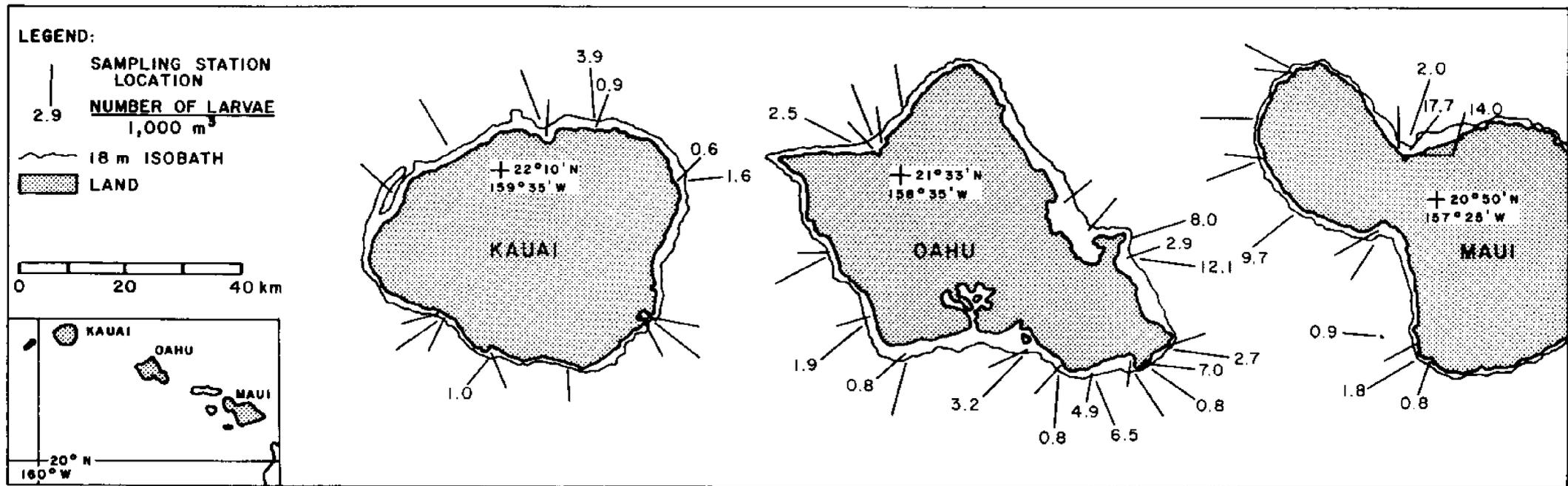


Figure 139. Winter distribution of *Enchelyurus brunneolus* larvae

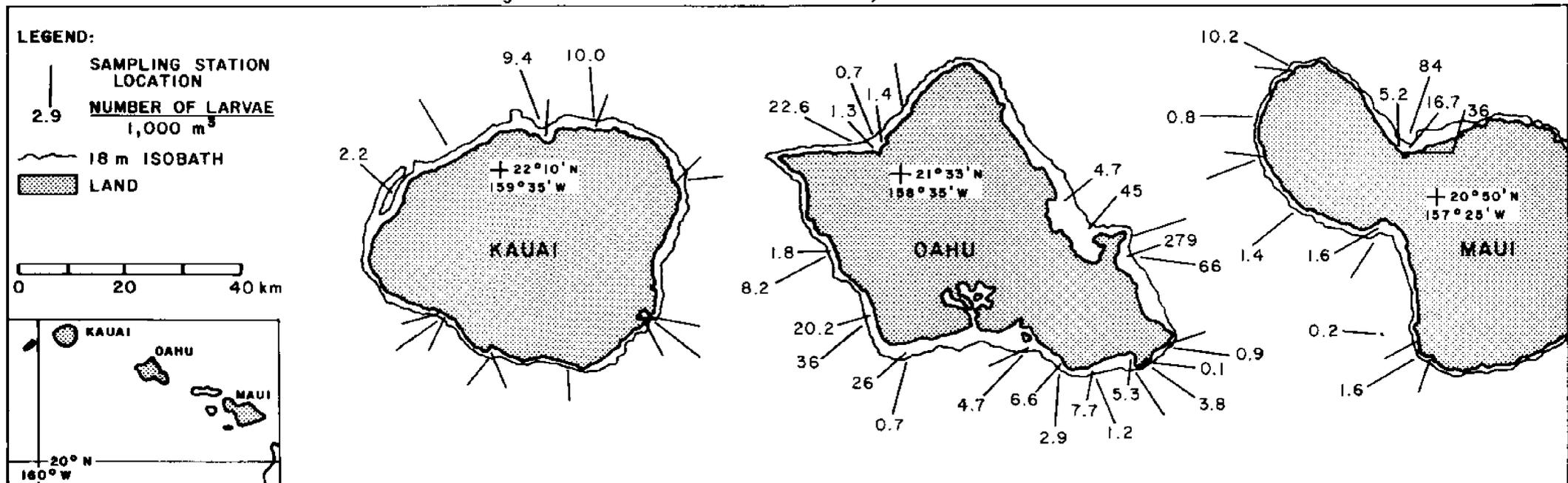


Figure 140. Summer distribution of *Enchelyurus brunneolus* larvae

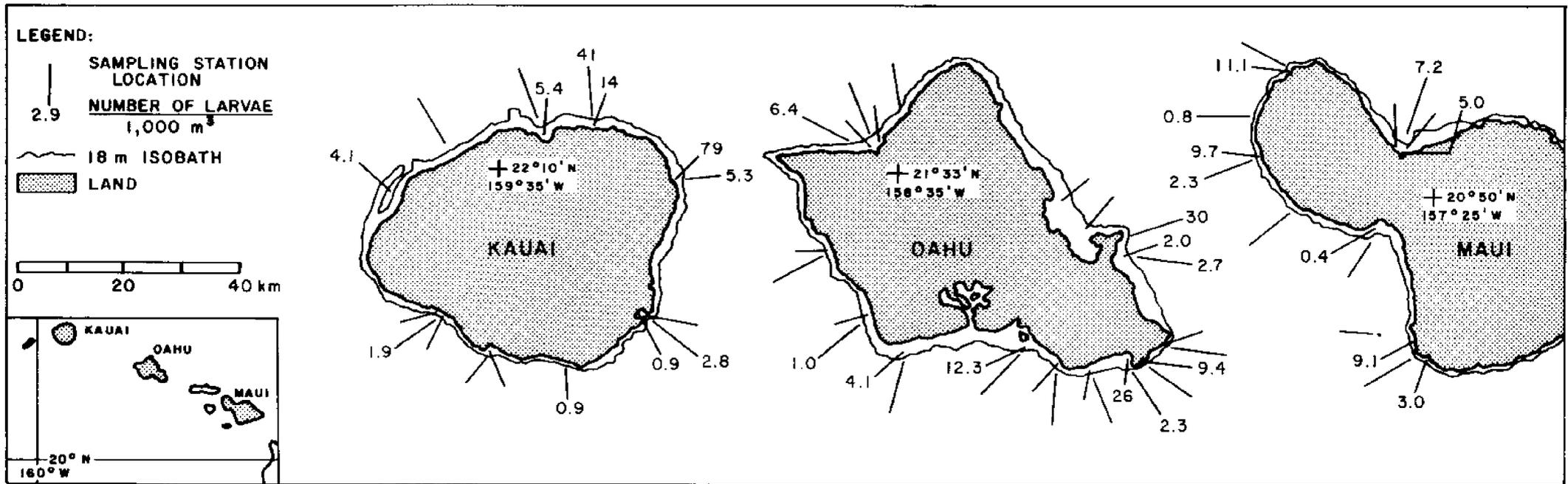


Figure 141. Winter distribution of *Exallias brevis* larvae

138

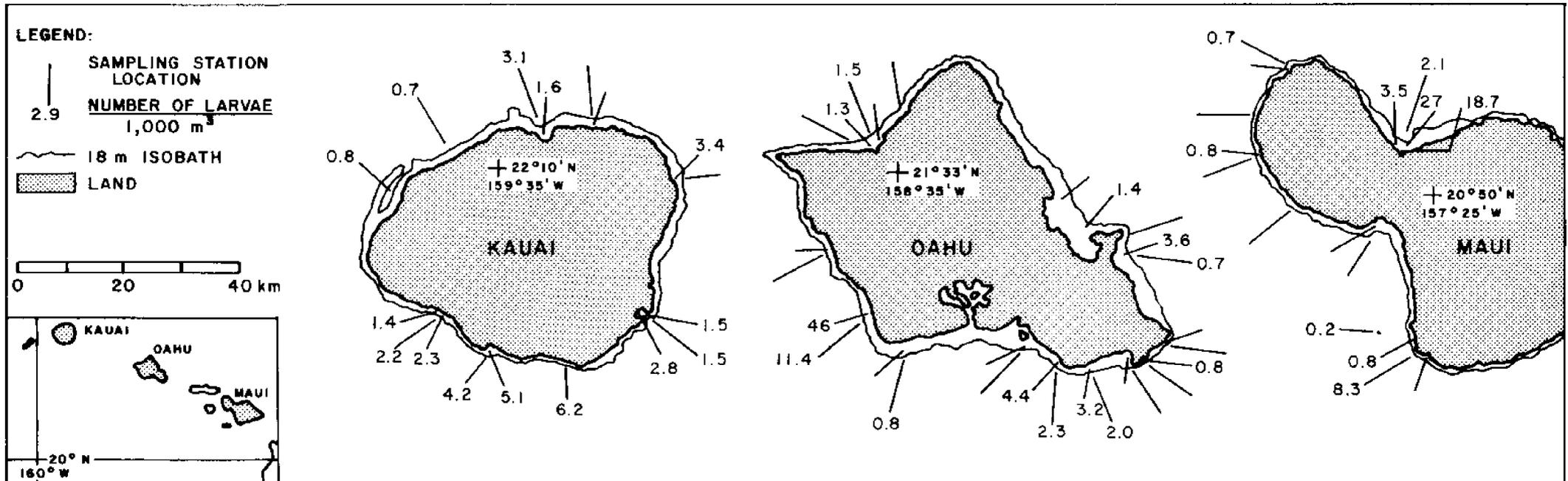


Figure 142. Summer distribution of *Exallias brevis* larvae

SCHINDLERIIDAE

Schindleriidae pietchmanni

Schindleria pietchmanni was about 10 times as abundant as *S. praematurus*. They are discussed together since there were no obvious differences in their distributions.

Schindleria larvae (or sub-adults) were taken during both summer and winter in about equal numbers. The vast majority of larvae were taken in shallow tows from both leeward and windward stations (Figures 143 and 144).

Watson and Leis (1974) found a similar ratio of the two species in their Kaneohe Bay study and took virtually all of their specimens at night. In view of this marked diurnal pattern, the numbers taken during the survey are even more exceptional. The maximum number of *S. pietchmanni* taken by Watson and Leis was 625 larvae/1,000 m³ in July. *Schindleria* larvae were infrequently encountered in other day samples; however, they were common in night tows everywhere. At night, both were taken only in the upper 5 m of southern Kaneohe Bay, while the single *S. pietchmanni* taken during the day was from a 3-m depth (Watson, 1974).

SCORPAENIDAE

Scorpaenid S-3 larvae were taken in about equally small numbers during both summer and winter and in both inshore and offshore tows. All but three of the 22 positive tows contained a single larva. There was no obvious windward or leeward distributional pattern. This larva occurred consistently in small numbers throughout the year in samples from Kahe Point and Molokini Island. Watson and Leis (1974) encountered scorpaenid larvae even less frequently in the Kaneohe Bay Sampan Channel.

CALLIONYMIDAE

Callionymid larvae (*Pogonimus* and *Callionymus*) had similar distributions and both were taken infrequently. Of the 22 positive tows, 16 contained a single individual. The inshore bay distribution of adults of both species (Gosline, 1960) was reflected by the larvae. Most of the positive tows were in or near shallow, relatively enclosed bays or harbors. About equal numbers were taken during winter and summer.

Watson and Leis (1974) took *C. decoratus* (up to 12 larvae/1,000 m³) from Kaneohe Bay all year, but more in winter and spring and more inside the bay than in the Sampan Channel. Unlike the survey, however, few *P. pogognathus* were taken. Watson and Leis (1974) took significantly more callionymid larvae at night than during the day. *C. decoratus* larvae in southern Kaneohe Bay displayed a bimodal vertical distribution, being most abundant day and night above 3 m and below 5 m (Watson, 1974).

TETRAODONTIDAE

At present the five Hawaiian species (Gosline and Brock, 1960) of tetraodontid larvae (excluding Canthigasteridae) cannot be differentiated, so the distribution data presented are for the family as a whole.

Tetraodontid larvae were taken at 31 stations in summer and 9 stations in winter (Figures 145 and 146). In both seasons their distribution was predominantly leeward. Most larvae were taken off Maui; none was taken off Kauai in winter. Although extensively distributed in summer (Figure 146) the larval density was never high (maximum of 21.5 at Ahihi Bay and 33 at Barbers Point). At most other stations one or two individuals were taken.

Watson and Leis (1974) took only seven larvae from Kaneohe Bay; no exceptional catches were recorded in other sampling.

MOLIDAE

Ranzania laevis

In winter *R. laevis* larvae occurred at all except two Kauai stations, at all except four leeward stations on Oahu, and at only four stations on Maui (Figure 147). Exceptionally high densities were encountered off Kailua Bay (309), Kahala (187), and Hanalei Bay (102). Where larvae occurred at both inshore and offshore stations, offshore densities were nearly always higher, suggesting an offshore source of larvae.

Several *Ranzania* larvae were taken off Molokini Island in March (maximum single tow density 90) and a few larvae were taken off Kahe Point in March. None were present in the August or October Molokini Island or Kahe Point samples, suggesting a winter spawning season from December to April or May.

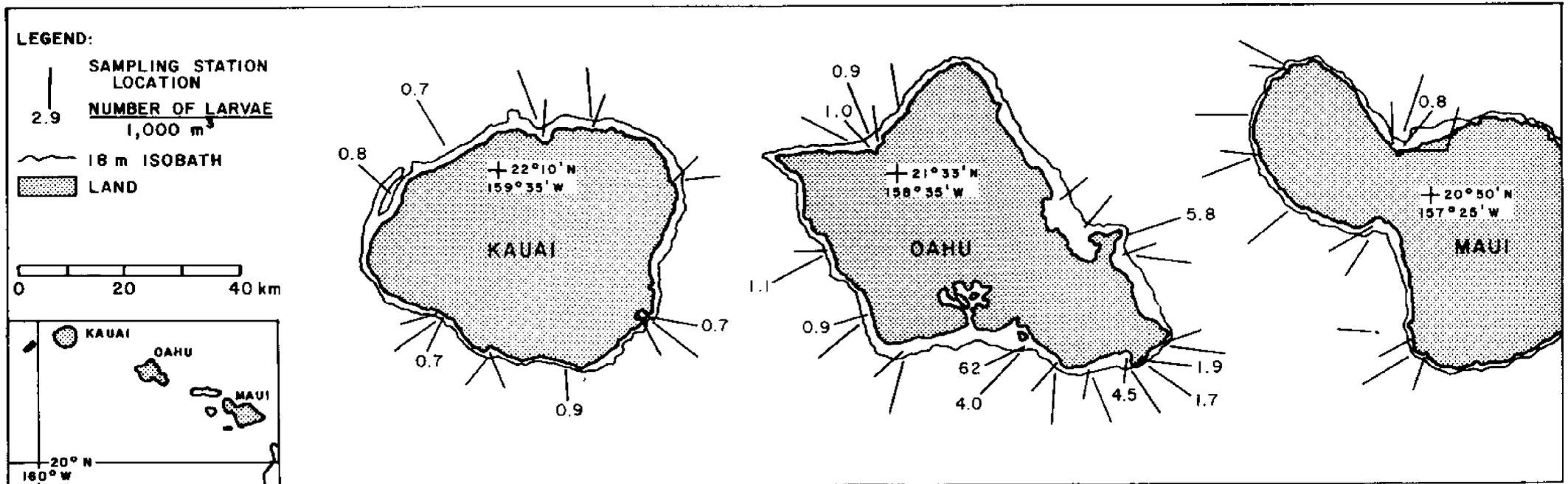


Figure 143. Winter distribution of Schindleriidae larvae

140

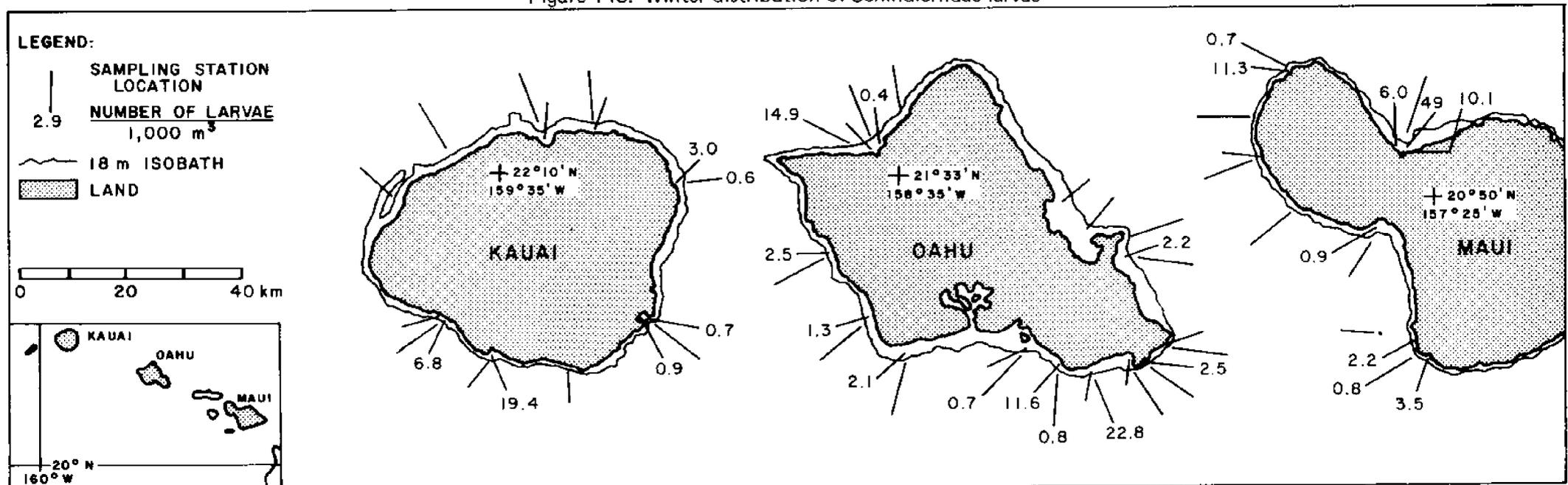


Figure 144. Summer distribution of Schindleriidae larvae

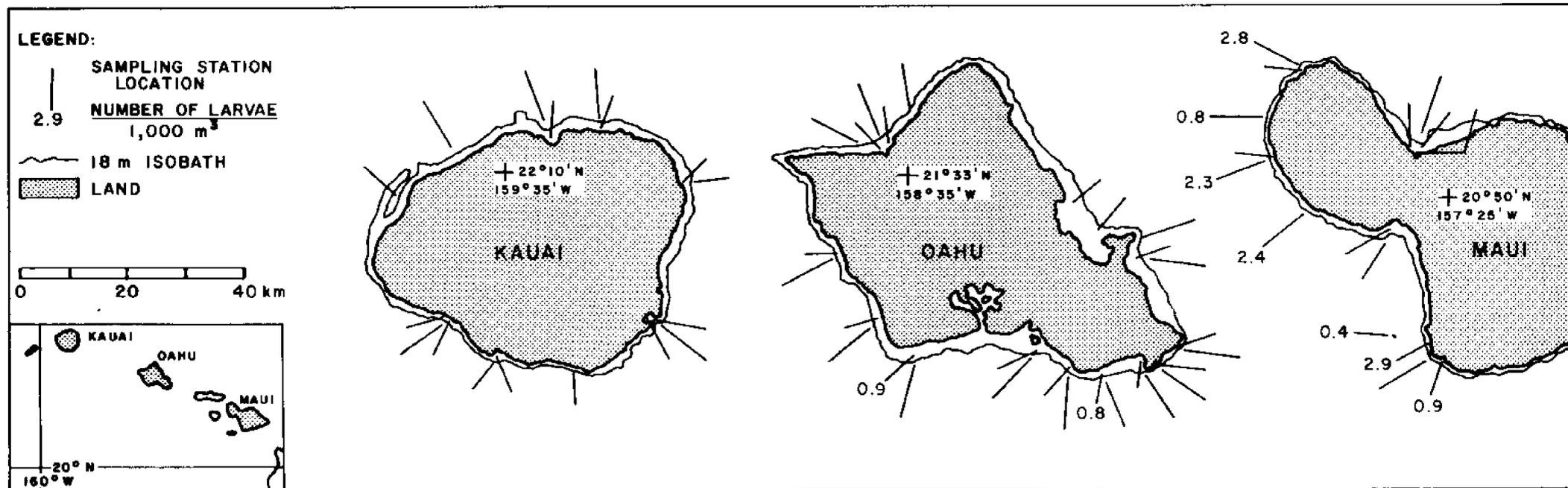


Figure 145. Winter distribution of Tetraodontidae larvae

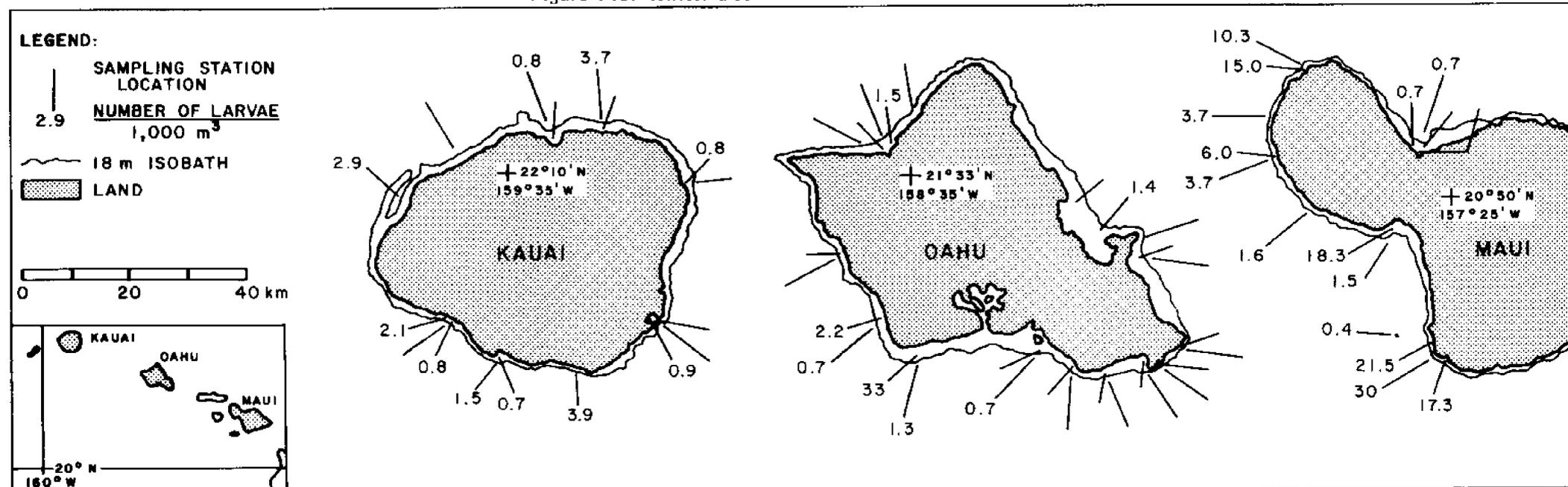


Figure 146. Summer distribution of Tetraodontidae larvae

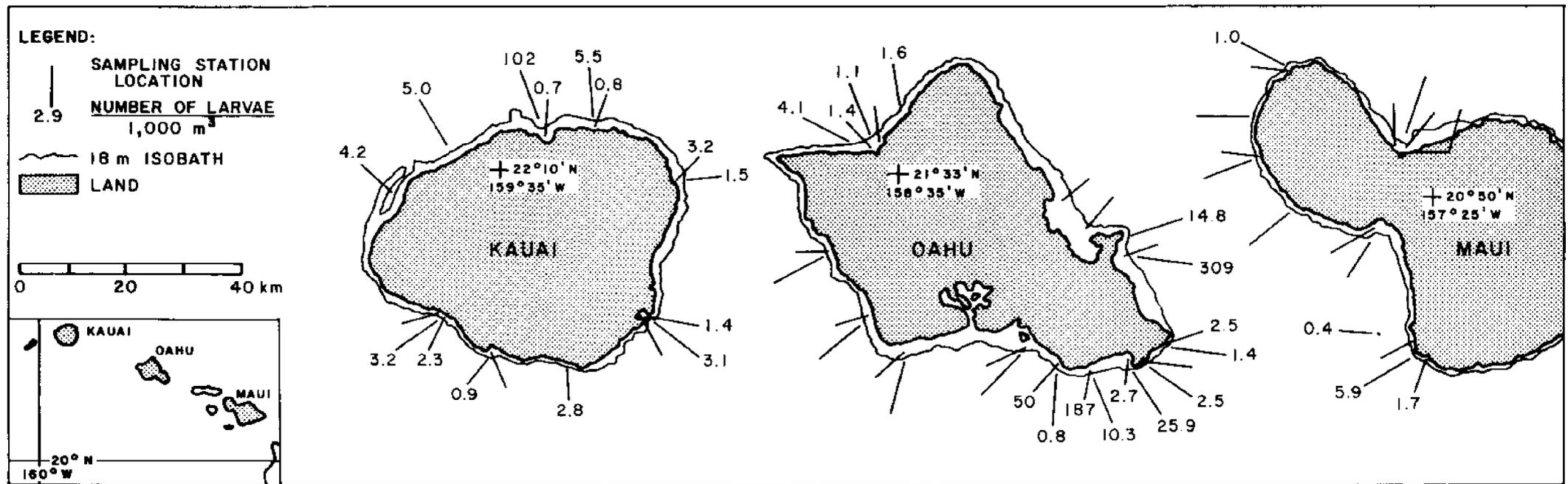


Figure 147. Winter distribution of *Ranzania laevis* larvae

MELANOCETIDAE

Melanocetus johnsoni

M. johnsoni occurred in a higher percentage of tows off Kauai as compared with either Oahu or Maui. This basic distributional pattern resembles that of *Ranzania laevis*. Generally, low densities were encountered during both winter and summer (Figures 148 and 149). About equal numbers occurred during winter and summer in inshore and offshore tows. *M. johnsoni* larvae were absent from tows made off windward Maui and the northwest half of Oahu.

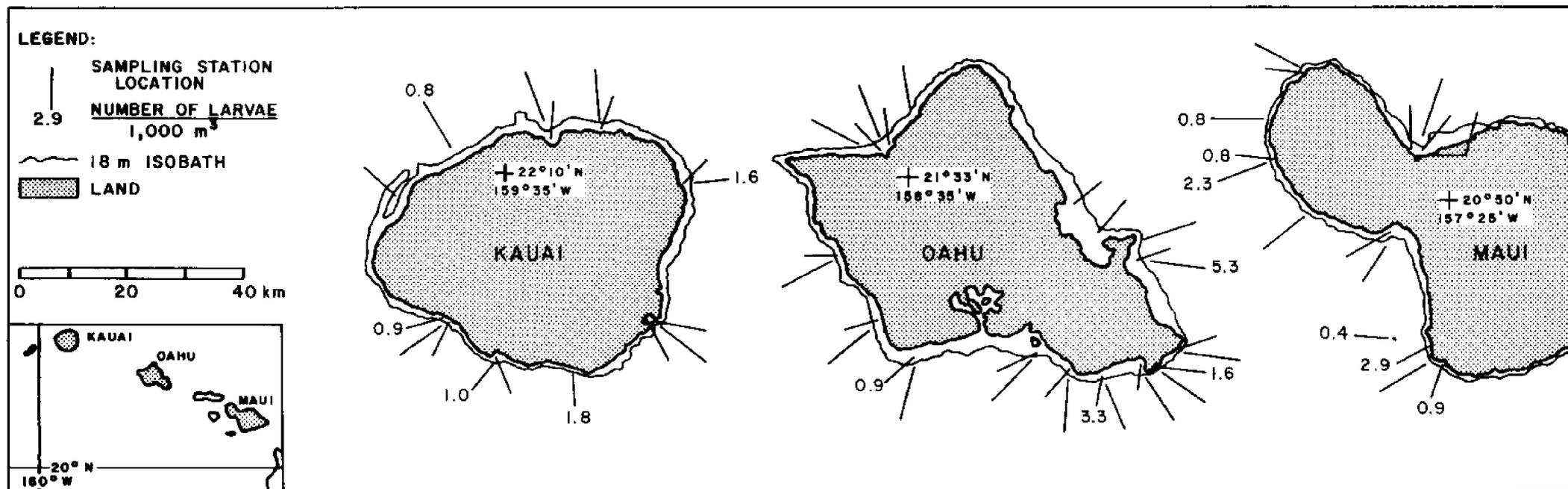


Figure 148. Winter distribution of *Melanocetus johnsoni* larvae

143

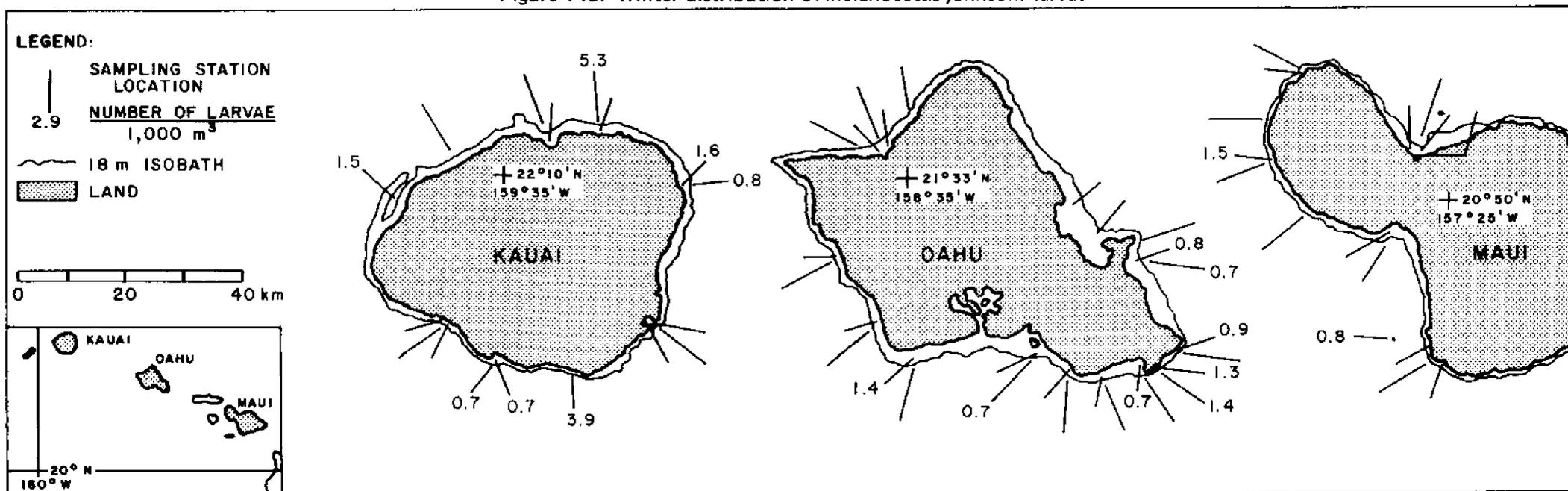


Figure 149. Summer distribution of *Melanocetus johnsoni* larvae

PATTERNS OF DISTRIBUTION

Abundance of larvae

The mean abundance of fish larvae at all 117 stations was 94 (standard deviation = 98). The range was from 1 to 511. Mean abundance (and standard deviation) figures for the individual islands were: Kauai 66 (61), Oahu 121 (108), and Maui 95 (104).

The all-island mean abundance in winter was 73 (79). By island the figures were Kauai 67 (59), Oahu 109 (97), and Maui 42 (41). Corresponding mean abundance figures in summer were: all islands 116 (111), Kauai 66 (63), Oahu 135 (116), and Maui 148 (122).

Separating the data into inshore and offshore categories yielded the following respective mean abundances (standard deviations): all islands 118 (117) and 71 (71), Kauai 62 (63) and 71 (59), Oahu 157 (114) and 87 (91), and Maui 134 (134) and 56 (39). By season these inshore and offshore means were as follows: winter—all islands 83 (79) and 62 (78), Kauai 63 (76) and 71 (50), Oahu 135 (89) and 82 (104), and Maui 52 (49) and 32 (25); summer—all islands 152 (137) and 81 (64), Kauai 62 (61) and 70 (74), Oahu 178 (138) and 92 (81), and Maui 215 (162) and 50 (37).

The all-island average abundance in winter (73) was significantly different from summer (116) (F-test, $p < 0.01$). Similarly, the difference between mean inshore (118) and offshore (71) abundance was significant (F-test, $p < 0.01$). When separated by season, the summer difference remained significant ($p < 0.01$), but the winter difference did not. The inshore-offshore difference was significant for both seasons on Maui, but was not significant for either season on Kauai or Oahu.

Although insignificant, the differences between inshore and offshore abundance off Oahu, especially in summer, were considerably greater than that for Kauai.

The abundance of fish larvae was thus lower in winter than in summer and lower at the offshore stations than at the inshore ones. And, especially in the case of Maui, the numbers were less variable offshore than inshore.

The lowest inshore station abundances in winter (Figure 150) occurred at the stations in semi-enclosed bays or harbors, e.g., Nawiliwili Harbor, Hanapepe Harbor, Kaiaka, Haleiwa Harbor, Kahului Harbor, and Maalaea Bay. This was also

true for summer data (Figure 151), but to a lesser extent. There appeared to be no pattern for offshore station abundances for either season.

The increase in mean abundance between winter (73) and summer (111) occurred mainly at inshore stations: winter 79; summer 152. The mean abundance at offshore stations increased only slightly from 78 in winter to 81 in summer. The inshore variability (standard deviation) increased from 79 in winter to 137 in summer; respective offshore values were 78 and 64.

The diversity of fish larvae for both seasons, as indicated by the number of species per station (Figures 152 and 153), ranged from one at west Kahului Harbor in winter to 62 inshore at Sand Island in summer. The mean number of species at the inshore stations were: winter 22 and summer 30. Corresponding numbers for offshore stations were: winter 17 and summer 24. The unusually small number of species at certain inshore stations (e.g., Nawiliwili Harbor, Kaihiwai, Haleiwa Harbor, Kaiaka, and Kahului Harbor) greatly depressed the inshore mean. Of the 40 stations with the highest species numbers, 27 were higher inshore.

Besides higher numbers of species occurring at inshore stations, these were distributed unevenly around the islands. The highest numbers of species per station occurred mostly along the leeward (southwest) and southern coasts of the islands (Figures 152 and 153). A notable exception was 39 species at Mokapu in winter. The south coast of Oahu, Barbers Point to Sandy Beach, had consistently high species numbers for both seasons.

Since the number of species at a station is more sensitive to absolute abundance than the Shannon-Weaver index of diversity (Pielou, 1969), the latter was also calculated for each station according to the formula:

$$H' = \sum P_i \log P_i \quad (1)$$

where P_i is the fraction of the i^{th} species in the tows from that station.

Patterns of H' (Figures 154 and 155) and number of species (Figures 152 and 153) were similar. Relatively large differences in the ranks of these two indices occurred at certain offshore stations where the number of species was low but, owing to low and similar numbers of each species (i.e., species evenness), the diversity index was high. In this category were winter offshore stations at Waimea Bay, Haleiwa Harbor, and Lahaina and summer offshore stations at Kalalau and Hanauma Bay. Similar index differences occurred at certain inshore stations: in winter at Hanalei Bay and Nawiliwili Harbor; in summer at Hanapepe Harbor and Kaiaka.

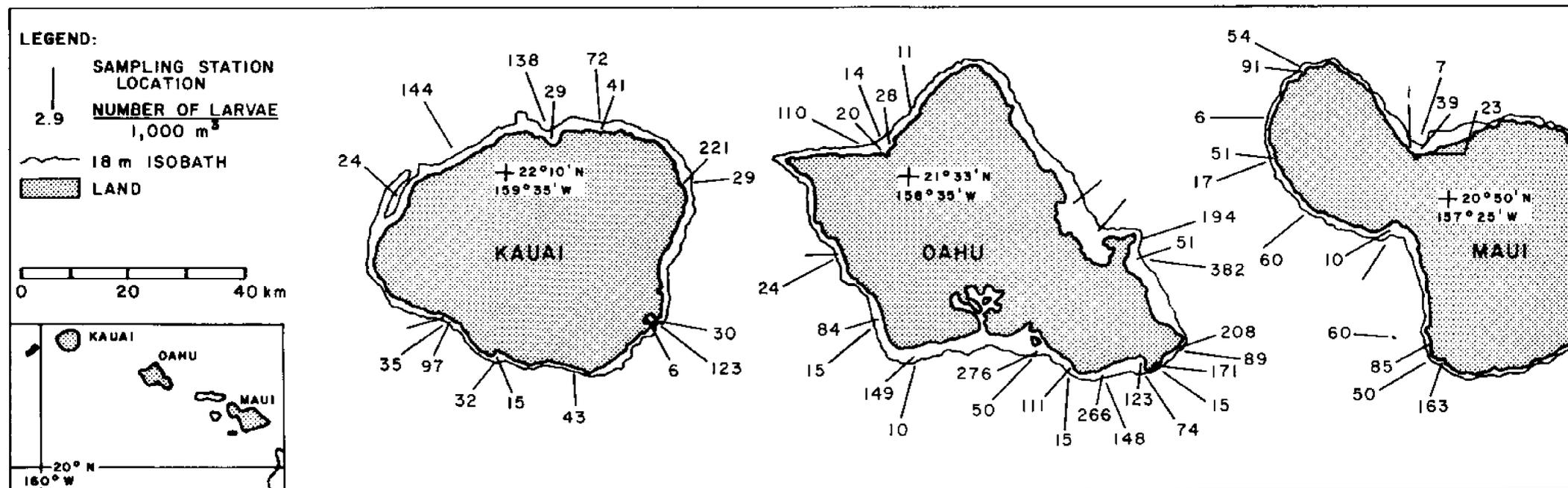


Figure 150. Winter distribution of total fish larvae

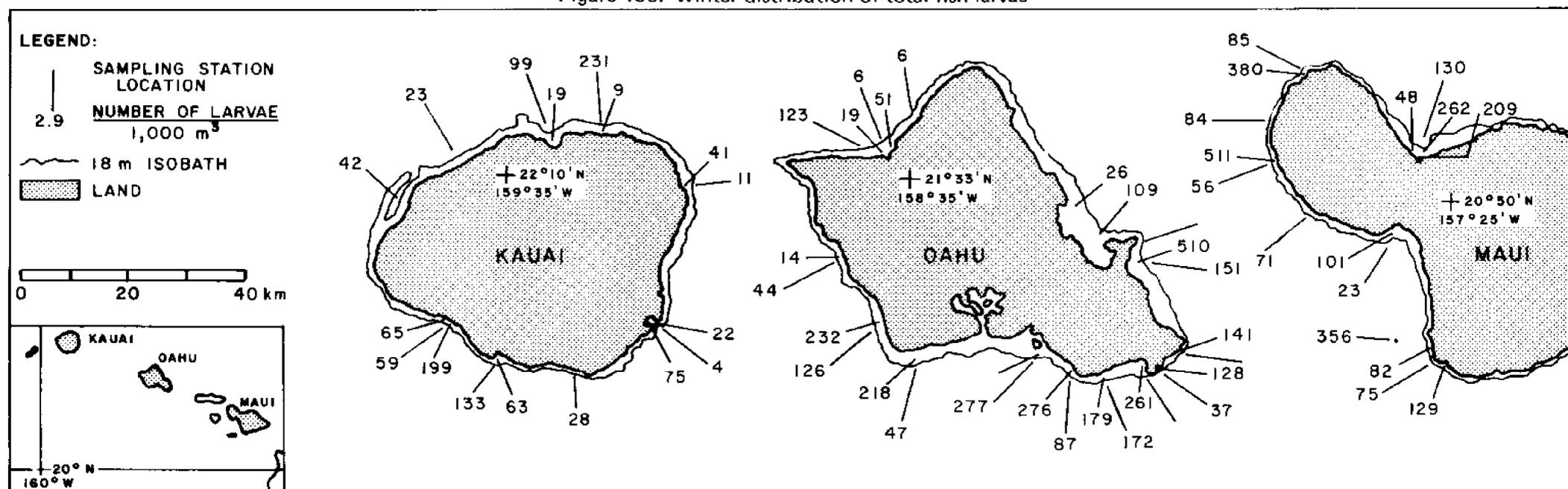
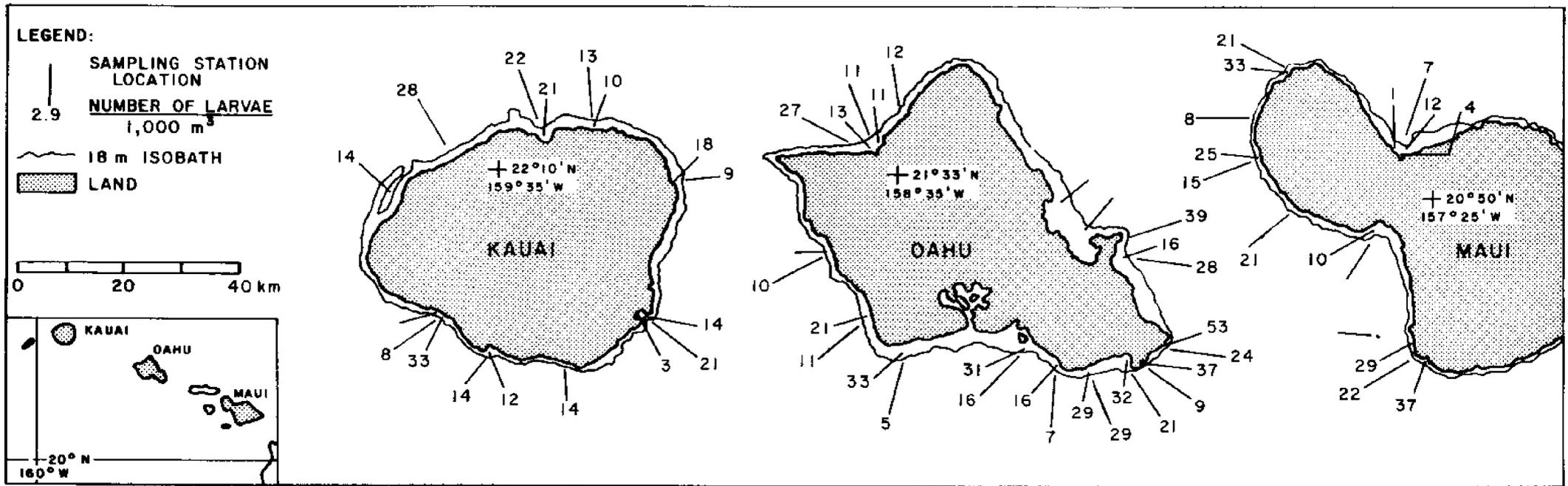


Figure 151. Summer distribution of total fish larvae



146

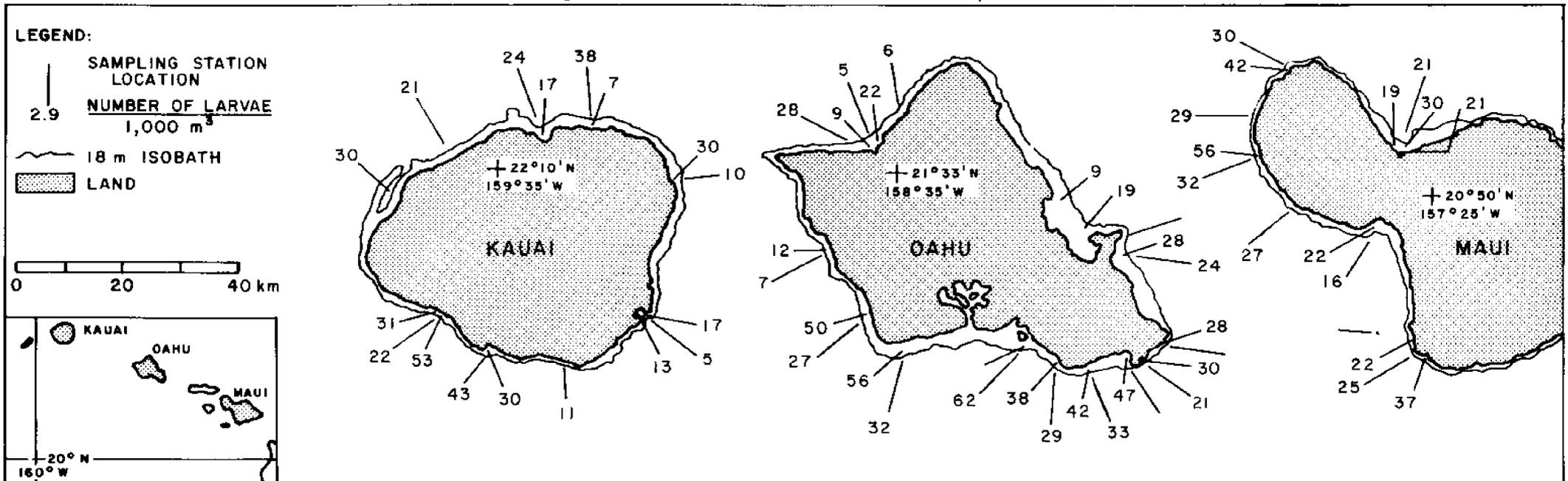


Figure 153. Summer distribution of number of species

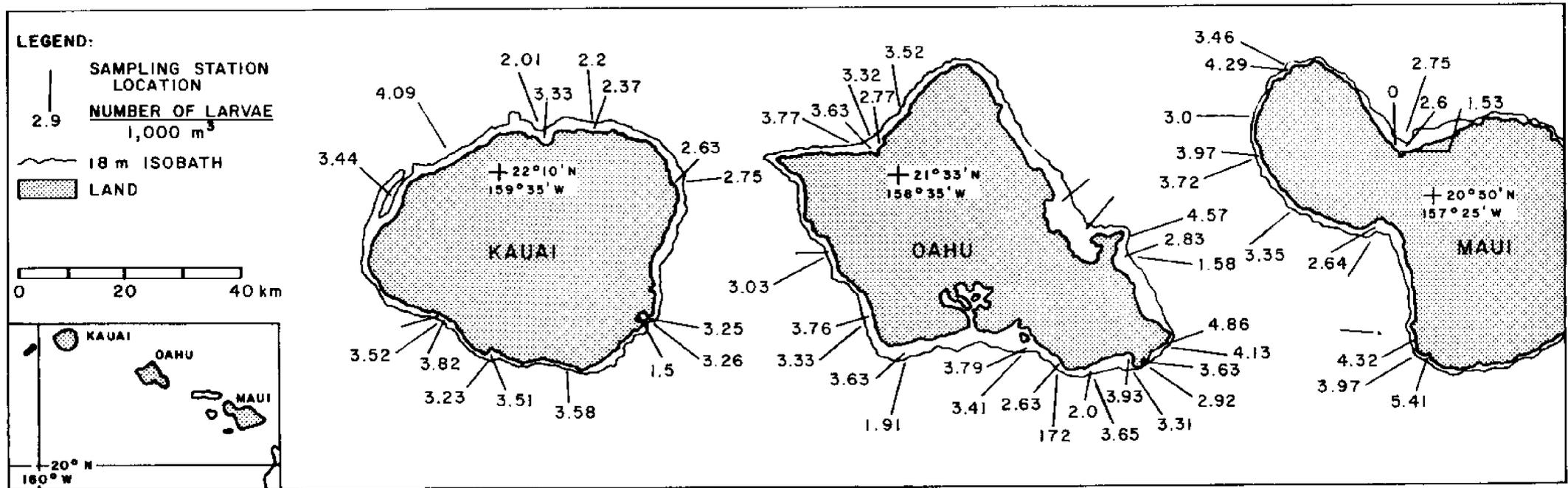


Figure 154. Winter distribution of species diversity H'

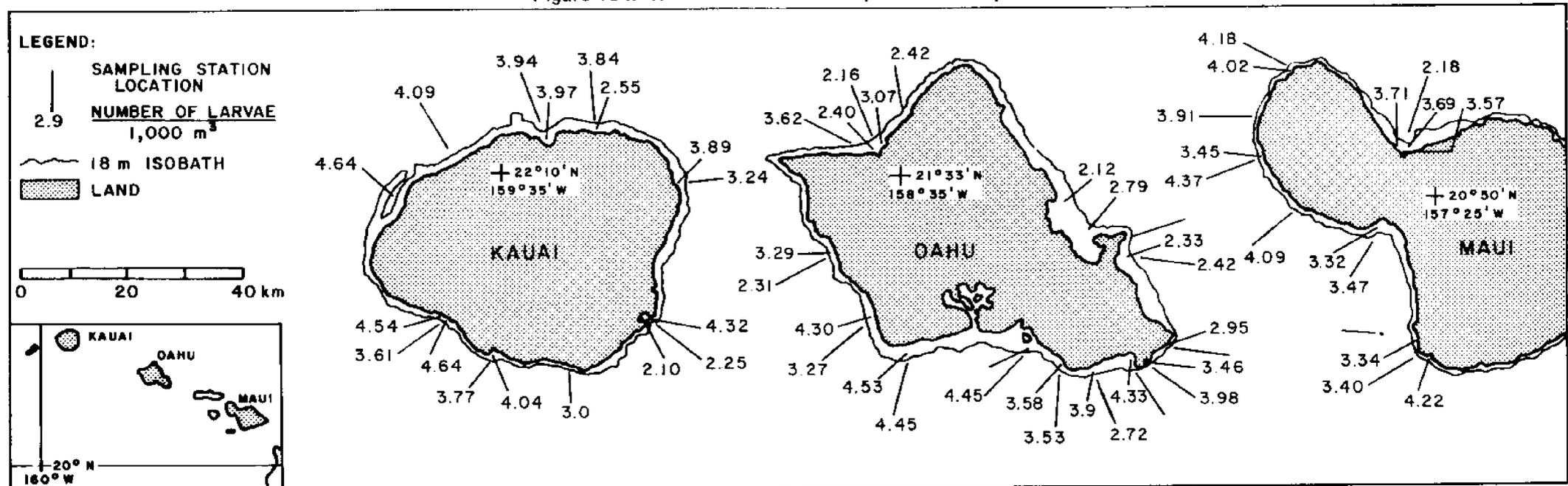


Figure 155. Summer distribution of species diversity H'

A second cause for the large difference in the ranks of species number and diversity index occurred where the catch was dominated by one or two species, but the total number of all species was high. For this reason difference between the two indices occurred in winter at offshore stations at Kalihiwai and Hanalei Bay and inshore stations at Anahola Bay and Kahala. In summer this was true for inshore stations at Kahala, Kailua Bay, and Lahaina.

Species composition

The most striking feature of the Hawaiian nearshore ichthyofauna is the high proportion of oceanic and deepwater forms (Miller, 1974; Leis and Miller, 1976). For example, larvae of Myctophidae and Gonostomatidae ranked first and third, respectively, in overall abundance. Together these families accounted for nearly 30 percent of all the larvae taken during the survey. The 15 most common families were Myctophidae (16.3 percent), Blenniidae (13.9 percent), Gonostomatidae (11.8 percent), Gobiidae (11.3 percent), Pomacentridae (8.9 percent), Tripterygiidae (6.7 percent), Molidae (6.4 percent), Mullidae (3.5 percent), Apogonidae (3.3 percent), Carangidae (3.2 percent), Scombridae (3.0 percent), Schindleriidae (2.3 percent), Exocoetidae (2.2 percent), Tetraodontidae (1.4 percent), and Gempylidae (0.5 percent). Over 90 percent of the larvae taken during the survey belonged to one of these families. Seventy additional families were represented in the samples.

Besides the occurrence of rarely encountered species, the composition of the survey catches differed markedly. To interpret these compositional differences the sources of the larvae and the water at the stations must be considered. Overall, it would seem that the hydrography of a location is the major determinant of the species composition. Larval fishes, in the size range taken in towed nets, seem to have little ability to choose their environment by swimming against the relatively strong currents (25 to 50 cm sec⁻¹ average) nearshore in Hawaii (Laevestu et al., 1964). Blaxter (1969) summarized the reported sustained swimming speeds of larval fishes, which averaged about three body lengths sec⁻¹. For the usual size of fish larvae taken during the survey, that is 4 to 8 mm, the sustained swimming speed would be about 1 to 3 cm sec⁻¹. Of course even small larvae could exercise considerable control over their location by selecting currents or making vertical migrations, but little is known about either of these, especially on a small scale and more especially in the case of Hawaiian species. Further, the nearshore currents around Hawaii (and elsewhere) are poorly understood on a small scale, so attempting precise analysis is premature at this time. Still, for purposes of making environmental decisions, some interpretation of data is necessary. For example, a high abundance of fish larvae at a location may mean it is an important nursery ground for inshore larvae or that large numbers of offshore

larvae are transported there. These interpretations have markedly different implications for perturbations. What follows is a general analysis of the survey data, using some more common species as indicators. Albeit a general and somewhat hypothetical analysis, many decisions regarding developments around Hawaiian shorelines will be made in ensuing months and years, each of which will have potential impact on the adjacent nearshore nursery grounds; for this reason the above differences are important.

Miller (1974) found an inverse relationship between the abundance of Myctophidae and Blenniidae larvae at certain inshore locations in Hawaii. Since blenny larvae arise from demersal eggs and myctophids are offshore (mesopelagic) species, this inverse relationship is not unexpected. At locations where the water residence time is long, high abundance of blenny larvae, as well as other nearshore-spawned species, is expected. On the other hand, locations which are rapidly flushed with offshore waters would have fewer inshore-spawned larvae and more offshore-spawned larval types. Thus, assuming an equal abundance of offshore larvae in offshore water and a constant rate of reproduction of inshore larvae, the ratio of inshore to offshore fish larvae would be directly proportional to the water residence time at a location.

Offshore water flushing a bay, for example, may come from two sources. Surface water can be advected inshore (for example, along windward coasts) or subsurface offshore water can be upwelled. Miller (1979) hypothesized this kind of upwelling as the source of high abundance of tuna (Scombridae) larvae at certain leeward Hawaiian locations. Insofar as offshore larvae are vertically separable into surface and subsurface types, their respective abundance near shore would be indicative of offshore water of surface or subsurface origins. Diel migrations of larvae would complicate this. However, little is known about vertical distribution of open coast Hawaiian fish larvae.

For purposes of analysis, the following were chosen as representative of the three "types" of larvae presumably representing the three sources of water:

- Type A, inshore-spawned larvae: *Enchelyurus brunneolus* (Blenniidae)
- Type B, offshore subsurface larvae: *Ceratoscopelus warmingi* (Myctophidae)
- Type C, offshore surface larvae: *Ranzania laevis* (Molidae) in winter and *Cypselurus* (2 spp.) (Exocoetidae) in summer

These larvae were chosen because of their relatively high abundance. Their respective categorizations are detailed in Watson (1974).

The expected distributions of the three types of larvae are as follows: Type B (offshore subsurface) larvae should mutually exclude both Type A (inshore) and Type C (offshore surface) larvae and be especially abundant on leeward coasts. Type C larvae should also exclude (flush) Type A larvae, however to a lesser extent than Type B larvae, since on windward coasts offshore surface water may be wind-advected near shore, but may not necessarily flush a windward bay owing to an Anstau condition ("piling up" of water). Type C larvae should exclude Type B larvae since an Anstau condition would oppose upwelling. Long-shore transport of larvae would obscure the picture considerably.

The stations were ranked according to their winter and summer abundances of the three types of larvae. Comparison of the stations with the 10 highest ranks of the three types of larvae showed a pattern in agreement with the above predictions of distribution.

Among the 10 summer stations with the highest abundance of *Enchelyurus brunneolus* larvae were four stations with high *Cypselurus* spp. abundance and no stations with high *Ceratoscopelus* abundance. Only one station with high *Cypselurus* abundance was among the high *Ceratoscopelus* stations. The probabilities of the inverse relationships between both (a) *Enchelyurus brunneolus* and *Ceratoscopelus* and (b) *Ceratoscopelus* and *Cypselurus* events occurring by chance are less than 0.05 (Spearman rank correlation test).

In winter, among the stations with the 10 highest abundance of *Enchelyurus brunneolus* was one with the ten highest abundance of *Ceratoscopelus*. Four of the 10 stations with the highest *Ranzania laevis* abundance occurred at stations which also had high *Enchelyurus brunneolus* abundance. And four stations with the highest *Ceratoscopelus* abundances occurred at stations having high *Ranzania laevis* density. The latter may be a reflection of the more variable winds and currents in winter or *Ranzania laevis* having a slightly different depth distribution than the *Cypselurus* species. Therefore, the winter relationships, while slightly more variable than in summer, were also in agreement with the predictions of distribution.

Comparison of the distribution of other species taken in sufficient quantities during the survey with the distributions of *Enchelyurus brunneolus*, *Ranzania laevis*, *Cypselurus* spp., and *Ceratoscopelus warmingi* revealed the following similarities (and thus classifications):

- Type A (*E. brunneolus*), inshore-spawned larvae: *Abudefduf abdominalis*, *Eupomacentrus fasciolatus*, Gobiidae (all species lumped), *Psilogobius mainlandi*, *Tripterygion atriceps*, Schindleriidae
- Type B (*Ceratoscopelus warmingi*), offshore subsurface larvae: *Cyclothone* sp., *Vinciguerria nimbaria*, *Diaphus* sp., *Hygophum proximum*, Muliidae, *Trachurops crumenophthalmus*, Tetraodontidae
- Type C (*Cypselurus* spp. and *Ranzania laevis*), offshore surface larvae: *Melanocetus johnsoni*

The remainder of the species caught either exhibited none of the above patterns or were taken too infrequently to characterize their distributions. It is important to emphasize that similarities in distribution could occur with either similar spawning habits or similar depth preferences.

In summary, species showing Type A distributions are generally most abundant at windward stations, in relatively enclosed bays or harbors, and in inshore areas. Type B larvae are more variable than Type A, but are usually most abundant at leeward inshore stations, especially in summer. Type C larvae are more evenly distributed among inshore and offshore stations and are usually most abundant at windward stations.

It must be emphasized that none of these patterns is without exception and that all types of larvae were encountered in low abundance at many stations. The most important conclusion from the above analysis is that larval abundance and composition near shore in the Hawaiian Islands seem closely linked, in a loosely predictable way, to the peculiar hydrographic regime of a location. Furthermore, to assess the importance of nearshore nursery grounds, species composition, as well as abundance of larvae, must be considered. For example, if high numbers of offshore larvae (Type B or C) are found at a station, perturbing this area may be less detrimental than in a bay where the high numbers are of Type A larvae.

To assist the state of Hawaii in making decisions regarding the development of its shorelines, an index of nursery ground potential was calculated for each survey station. This index is a sum of the ranks of (1) abundance of larvae, (2) number of species, and (3) diversity index. In Figures 156 and 157, it is apparent that certain bays and segments of coastline are considerably more valuable by this standard than others. The difference in ranks between any two stations is generally less than the numbers which were ranked. Therefore the figures showing species number (Figures 152 and 153) and diversity (Figures 154 and 155) should be consulted when assigning relative importance to a given bay or

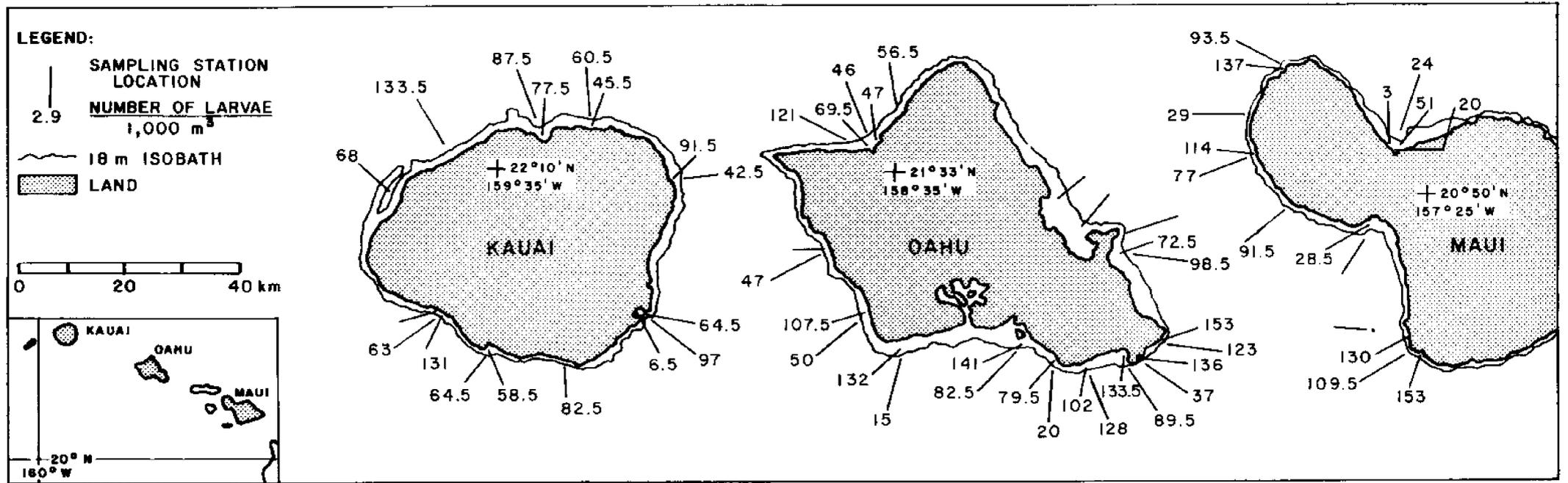


Figure 156. Sum of ranks of density, species, and diversity of fish larvae in winter

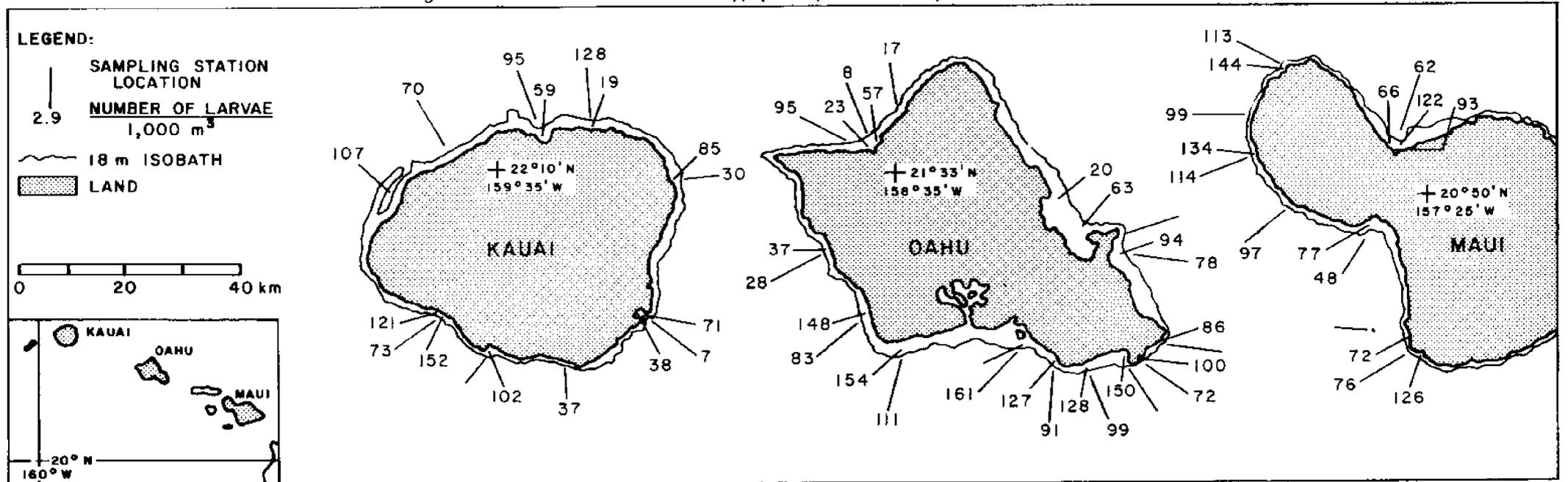


Figure 157. Sum of ranks of density, species, and diversity of fish larvae in summer

segment of coastline for planning shoreline developments. And where potentially extensive or intensive perturbations (e.g., silt, or a toxic effluent) may accompany shoreline development at a location, further study should be undertaken.

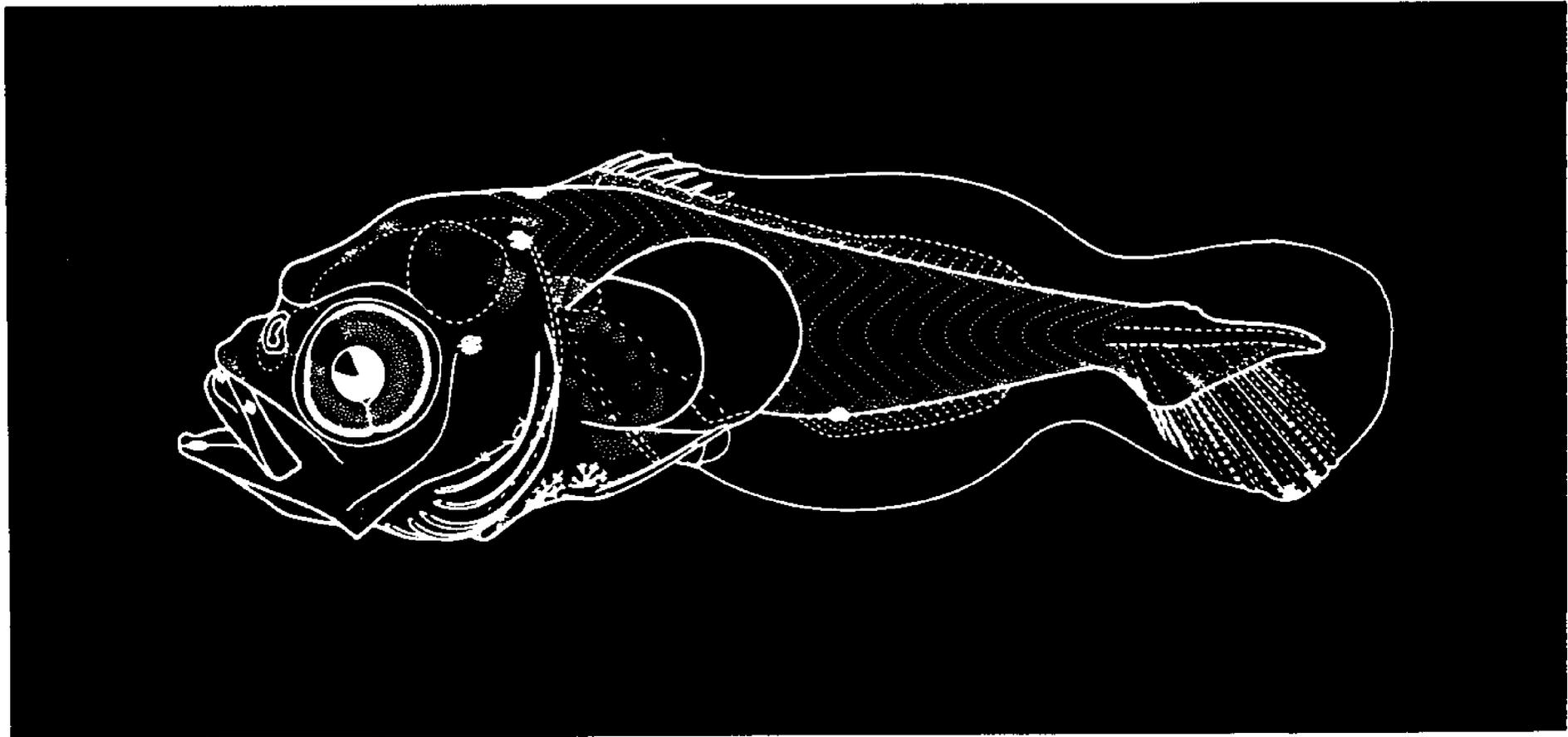
The generalizations presented here are based on only two samplings at most locations and it is likely that the results have been markedly influenced by hydrographic conditions on those dates (note especially stations where the index changed markedly seasonally). Thus, these analyses should be regarded as tentative and probably subject to much temporal variation at each station. As such they mainly indicate the wide range of values to be expected at specific locations and should be coupled with more intensive studies at any specific location being considered for development.

Finally, a limitation of the above indices is, no relative value of species has been included. For example, several stations with low indices are known to be important nurseries for the locally important tuna baitfish, or nehu (*Stolephorus purpureus*).

Insofar as larval fishes are considered in environmental planning the authors have tried to emphasize the need for both taxonomic and ecological research on individual species. Knowledge of the collective abundance of fish larvae at a station is inadequate to predict effects of effluents and therefore may be misleading. For example, de Sylva and Scotton (1972) argued that the occurrence of Stomioid fish larvae in Biscayne Bay, Florida was evidence that recycling of offshore water (and thus effluents) occurred. If the source of these larvae was, in fact, offshore subsurface water, then the reverse would be true. That is, the occurrence of offshore forms inshore would indicate more rapid displacement (flushing) of effluents by offshore water, not necessarily recycling.

While species composition of larval fishes may be indicators of at least types of hydrographic regimes, there is no substitute for small-scale studies of the hydrographic regime since the latter can profoundly affect the importance and nature of a nearshore nursery area.

Part III. Bibliography and Systematic Index



INTRODUCTION

The literature on the identification of tropical fish larvae is sparse and widely scattered. Because of this, a bibliography consisting of titles the authors feel are important for identifying Hawaiian fish larvae has been compiled. This bibliography should not be considered an exhaustive listing of titles on tropical larval forms. Throughout the bibliography, heavy reliance has been placed on two works: Uchida et al. (1958) and the series edited by Lo Bianco (1931 to 1956). Uchida et al. is entirely in Japanese and Lo Bianco in Italian. Fortunately, the first two sections of Lo Bianco (1931, 1933) have been translated into English (I.P.S.T. #T.T. 68-50346); the page numbers given for these two sections are for the English translation.

Following the bibliography is a "Systematic Index to Literature" section in which an attempt has been made to list all titles dealing with species known to occur in Hawaii and to list two or three titles for each family for which no references were available on indigenous species. As a result many species which do not occur in the tropics or even in the Pacific are represented; it was felt that references which might help identify larvae, if only to family, are useful and preferable to no entry. In some cases a number of titles are listed where one would have been adequate; this was done when the papers appeared in journals which might not be widely available.

The "Systematic Index to Literature" section is an alphabetical listing of each family. The list of families was taken primarily from Gosline and Brock (1960), with a few additions, mainly from Clarke (1972, 1974, and personal communication), Struhsaker (1973) and unpublished work of the authors of this study. The classification follows Gosline (1971) because it is closer to that used in Gosline and Brock (1960) than in Greenwood et al. (1966).

In the listing by families, page numbers are given only if a small portion of the listed reference is of relevance, and species are listed in parenthesis if this information is not evident in the title of the reference.

It should be noted that many families are included with no citations, indicating that the authors were unable to find a paper to cite. Listing of families without references was done to indicate the scope of the work on larval systematics remaining to be done and, hopefully, to stimulate investigators to fill the gaps.

Work on this bibliography was essentially completed during January 1975. Journal abbreviations follow those given in Biosis 1973 List of Serials

(BioSciences Information Service of Biological Abstracts, 2100 Arch Street, Philadelphia, Pa.).

The bibliography was compiled primarily for larvae; see Watson and Leis (1974) for further information on Hawaiian pelagic fish eggs.

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SYSTEMATIC INDEX TO LITERATURE

Acanthuridae: Aboussouan, 1965; Nellen, 1973 (pp. 32-33, fig. 38a-c); Randall, 1955a, 1955b, 1956, 1961.

Albulidae: Alexander, 1961; Eldred, 1967.

Alepocephalidae: Beebe, 1933.

Alepisauridae: Rofen, 1966b (pp. 474-475).

Aluteridae:

Amarsipidae: Fourmanoir, 1971a (*Amarsipus carlsbergi*).

Ammodytidae: Norcross et al., 1961.

Anoplogasteridae:

Anopteroidea:

Antennariidae: Adams, 1960; Fujita and Uchida, 1959; Mito, 1963b.

Antigoniidae: Nakahara, 1962.

Apogonidae: Bertolini, 1933a; Breder, Jr., and Rosen, 1966; de Gaetani, 1937; Fahay, 1975 (*Apogon maculatus*, p. 20, fig. 13).

Aracanidae:

Argentinidae: Sanzo, 1931b.

Ariommidae:

Astronesthidae: Ahlstrom, 1971; Pertseva-Ostroumova and Rass, 1973 (*Borostomias panamensis*, pp. 22-23).

Ateleopidae:

Atherinidae: Chase, 1969; Kuntz and Radcliffe, 1917; Vialli, 1937a.

Aulopidae: Okiyama, 1974a.

Aulostomidae:

Balistidae: Aboussouan, 1966a; Tortonese, 1956.

Barbourisiidae:

Bathylagidae: Ahlstrom, 1965, 1969; Pertseva-Ostroumova and Rass, 1973 (*Bathylagus nigrigenys*, pp. 12-15).

Bathypteroidae: Okiyama, 1974a.

Belonidae: D'Ancona, 1931 (pp. 147-153); Uchida et al., 1958 (p. 22).

Bembropsidae: see Percophidae

Blenniidae: Brock, 1948; Chapman and Schultz, 1952; Dotsu and Oota, 1973; Fives, 1970; Fourmanoir, 1971b; Hildebrand and Cable, 1938 (pp. 573-611); Mito, 1954 (this species referred to as *Istiblennius* by Smith-Vaniz and Springer, 1971); Strasburg, 1956; Watson, 1974 (*Omobranchus elongatus*, pp. 36-51).

Bothidae: Amaoka, 1970, 1971, 1973; Ochiai and Amaoka, 1963; Brunn, 1937.

Bramidae: Mead, 1972.

Branchiostegidae (=Malacanthidae): Berry, 1958; Hubbs, 1958.

Bregmacerotidae: Aboussouan, 1968; D'Ancona and Cavinato, 1965; Clancey, 1956.

Brotulidae: Mito, 1962c (*Brotula multibarbata*); de Sylva, 1970 (Fig. 83, "Redfin Brotula"); Wourms and Bayne, 1973.

Callionymidae: Demir, 1972; Mito, 1962c; Watson, 1974; Watson and Leis, 1974.

Canthigasteridae:

Caproidae: Fage, 1918.

Caracanthidae:

- Carangidae: Aprieto, 1974 (*Elagatis*, *Seriola*, *Decapterus*, *Selene* and *Oligoplites*); Berry, 1959; Delsman, 1926a, 1926b (*Alectis ciliaris*); Jordan and Evermann, 1903; Leis and Miller, 1976; Miller and Sumida, 1974; Munro, 1967; Okiyama, 1970; Sanzo, 1931a; Shojima, 1962 (*Decapterus maruadsi*); Uchida et al., 1958 (*Seriola* spp., pp. 52-56); Watson and Leis, 1974.
- Carapidae: Padoa, 1956e; Strasburg, 1961.
- Caristiidae:
- Centriscidae:
- Ceratiidae: Bertelsen, 1951.
- Cetomimidae: The larvae of this family have not been described as such, but Robins (1974) indicated that the mirapinniform fishes (Bertelsen and Marshall, 1956) are in fact the prejuveniles of the cetomimids. This allocation must be considered tentative.
- 170 Chaetodontidae: Burgess, 1974; Lutken, 1880 (pp. 608-609).
- Champsodontidae: Fourmanoir, 1973 (*Champsodon* sp.); Mito, 1962a.
- Chanidae: Blanco and Villadolid, 1951; Delsman, 1926c, 1929.
- Chauliodontidae: Mito, 1961; Sanzo, 1931d (pp. 73-77).
- Chaunacidae:
- Cheilodactylidae: Hattori, 1964; Vooren, 1972.
- Chiasmodontidae: Johnson and Cohen, 1974.
- Chlorophthalmidae: Ahlstrom, 1971; Taning, 1918 (pp. 4-7).
- Cirrhitidae: Fourmanoir, 1971a (*Oxycirrhites*), 1973 (*Cyprinocirrhites*).
- Clupeidae: Berry and Whitehead, 1968; Houde and Fore, 1973 (*Sardinella anchovia*).
- Congridae: Castle, 1964a; Raju, 1974a.
- Coryphaenidae: Aboussouan, 1969; Gibbs and Collette, 1959; Mito, 1960.
- Cyemidae: Castle, 1964b.
- Cynoglossidae: Fujita and Takita, 1965; Hildebrand and Cable, 1930 (*Symphurus piagiua* pp. 476-482); Mito, 1963a.
- Dactylopteridae: Jones and Kumaran, 1964b; Padoa, 1956c; Uchida et al., 1958 (*Daicocus peterseni* (Nystrom) pp. 87-89).
- Derichthyidae: Castle, 1970.
- Diceratiidae: Bertelsen, 1951.
- Diodontidae: Sanzo, 1930 (series illustrated in plate 6 and tentatively identified as a species of the tetraodontid genus *Crayracion* is actually *Diodon* sp.).
- Draconettidae:
- Dussumieriidae: Delsman, 1925; Houde and Fore, 1973; Mito, 1961a; Uchida et al., 1958 (pp. 5-7); Watson and Leis, 1974.
- Echeneidae: Blache, 1964; Padoa, 1956d.
- Eleotridae:
- Elopidae: Eldred and Lyons, 1966; Gehringer, 1959.
- Emmelichthyidae: Nakahara, 1962.
- Engraulidae: Delsman, 1931; Nakamura, 1970; Ozawa and Tsukahara, 1973; Strasburg, 1960; Tester and Hiatt, 1952; Watson and Leis, 1974; Yamashita, 1951.
- Eurypharyngidae: Tchernavin, 1947 (pp. 298-302).
- Evermannellidae: Rofen, 1966c.
- Exocoetidae: Breder, Jr., and Rosen, 1966; D'Ancona, 1931 (pp. 153-164); Hubbs and Kampa, 1946; Uchida et al., 1958 (pp. 37-44).
- Fistulariidae: Delsman, 1921; Mito, 1961a.

Gempylidae: de Jager, 1955; Fourmanoir, 1970 (*Lepidocybium*); Gilchrist, 1916; Grey, 1960; Jordan and Evermann, 1903; Smith, 1965; Strasburg, 1964; Voss, 1954.

Gigantactinidae: Bertelsen, 1951.

Giganturidae: The larvae of this family have not been described as such, but Greenwood et al. (1966) indicated that the family Rosauridae (Tucker, 1954) is based on the young of a giganturid. This allocation must be considered tentative.

Gobiidae: Delsman, 1926c (*Gobius* sp.); Dotu and Mito, 1955; Gosline and Brock, 1960; Shiogaki and Dotsu, 1972.

Gonorhynchidae: Furukawa, 1951; Hattori, 1964 (p. 12).

Gonostomatidae: Ahlstrom, 1974; Ahlstrom and Counts, 1958; Ahlstrom and Moser, 1969; Grey, 1964; Jespersen and Taning, 1919; Ozawa, 1973; Sanzo, 1931d; Silas and George, 1969.

Grammicolepididae:

Grammistidae (=Pseudochromidae): Aboussouan, 1972.

Gregorynidae: This family may be based on the young of a cheilodactylid, see Cheilodactylidae (above) and Greenwood et al., 1966.

Halosauridae: Mead, 1965; Smith, 1970.

Hemiramphidae: Delsman, 1924; Khrapkova-Kovalevskaya, 1963; Uchida et al., 1958 (pp. 24-26).

Histiopteridae:

Holocentridae: Jones and Kumaran, 1964a; McKenney, 1959.

Hoplegnathidae: see Oplegnathidae.

Hoplichthyidae:

Idiacanthidae: Beebe, 1934.

Ipnopidae: Okiyama, 1972.

Istiophoridae: Gehringer, 1956; Ueyanagi, 1963, 1974.

Krameriidae:

Kuhliidae:

Kyphosidae: Moore, 1962; Uchida et al., 1958 (p. 65); Watson and Leis, 1974.

Labridae: Kuntz and Radcliffe, 1917 (*Tautoga* and *Tautogolabrus*); Mito, 1962d; Nellen, 1973 (*Stethojulis* sp., p. 31); Sparta, 1933a; Watson and Leis, 1974.

Lampridae:

Linophrynididae: Bertelsen, 1951.

Lobotidae: Ranzi, 1933b; Uchida et al., 1958 (*Lobotes surinamensis* (Bloch) pp. 60-61).

Lophiidae: Ahlstrom, 1972; Mito, 1963b; Taning, 1923.

Lophotidae: Sanzo, 1940.

Lutjanidae: Fourmanoir, 1973 (*Symphysanodon*); de Sylva, 1970 ("Snapper"); Fahay, 1975 (*Lutjanus* sp., p. 24).

Macrorhamphosidae: D'Ancona, 1933c; Uchida et al., 1958 (pp. 44-45 + plate 45).

Macrouridae: Sanzo, 1933.

Malacanthidae: see Branchiostegidae.

Malacosteidae:

Melamphidae: Ebeling and Weed, 1973; Pertseva-Ostroumova and Rass, 1973 (*Scopelogadus*, *Scopeloberyx* and *Melamphaes*, pp. 43-47).

Melanocetidae: Bertelsen, 1951.

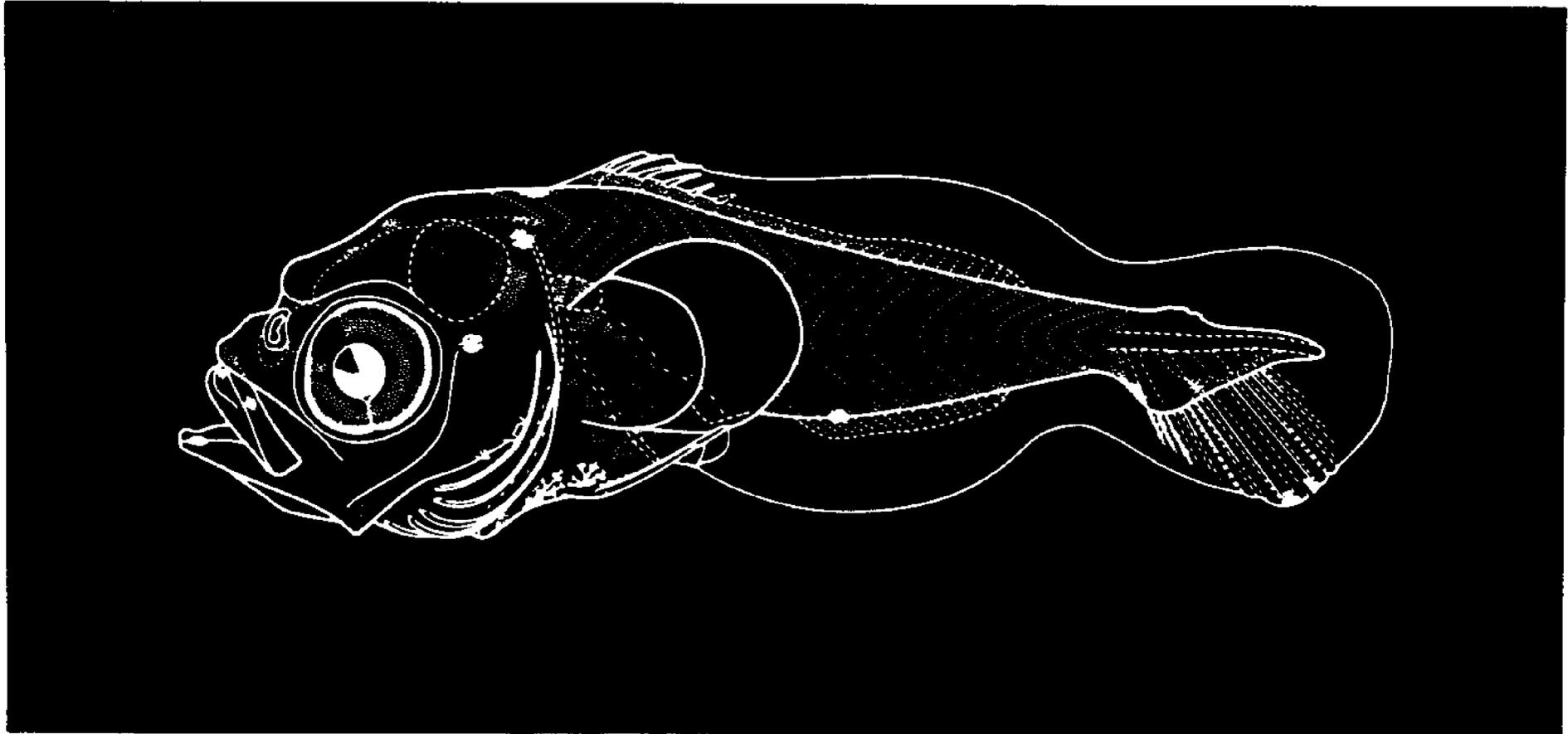
Melanostomiidae: Beebe and Crane, 1939; Sanzo, 1931d (pp. 80-82).

Microdesmidae:

- Molidae: Leis, 1977; Schmidt, 1921a, 1921b; Sherman, 1961.
- Monocanthidae: Aboussouan, 1966a; Fujita, 1955; Hildebrand and Cable, 1930 (*Monocanthus hispidus*, pp. 482-487).
- Monognathidae: Raju, 1974b.
- Moridae: D'Ancona, 1933a; Pertseva-Ostroumova and Rass, 1973 (*Physiculus* sp., p. 42).
- Moringuidae: Castle, 1965d.
- Mugilidae: Anderson, 1958; Tung, 1973.
- Mugiloididae (=Parapercidae): Mito, 1962b; Nellen, 1973 (*Parapercis* sp., p. 31).
- Mullidae: Caldwell, M.C. 1962; Marinaro, 1971; Montalenti, 1937; Uchida et al., 1958 (*Upeneus bensasi* and Mullidae sp., pp. 58-60).
- Muraenesocidae: Blache, 1968.
- Muraenidae: Castle, 1965b.
- Myctophidae: Clarke, 1973; Moser and Ahlstrom, 1970, 1972, 1974; Pertseva-Ostroumova, 1974.
- Nemichthyidae: Castle, 1965a.
- Neoscopelidae: Okiyama, 1974a.
- Nettastomidae: Castle, 1965a; Saldanha and Blanche, 1968.
- Nomeidae: Ahlstrom et al., 1976; Fourmanoir, 1971b (*Psenes arafurensis*); Legaspi, 1956.
- Notosudidae: see Scopelosauridae.
- Ogcocephalidae:
- Omosudidae: Rofen, 1966b.
- Oneirodidae: Bertelsen, 1951.
- Ophichthidae: Castle, 1965c.
- Opistoproctidae: Schmidt, 1918 (pp. 28-29).
- Oplegnathidae (=Hoplegnathidae):
- Ostraciontidae: Breder, Jr., and Clark, 1947; Mito, 1962e; Palko and Richards, 1969.
- Paralepididae: Ege, 1953, 1957; Rofen, 1966a; Shores, 1969.
- Parapercidae: see Mugiloididae.
- Pegasidae: Jones and Kumaran, 1964b.
- Percichthyidae:
- Percophididae (=Bembropsidae):
- Peristediidae: Padoa, 1956b.
- Platycephalidae: Uchida et al., 1958 (*Platycephalus indicus* (Linne) pp. 86-87).
- Pleuronectidae: Mito, 1963a; Nichols, 1971.
- Polymixiidae:
- Polynemidae: Aboussouan, 1966b; Jones and Menon, 1953 (*Polynemus paradiseus* Linne., pp. 259-264).
- Pomacanthidae: Burgess, 1974; Fujita and Mito, 1960.
- Pomacentridae: Ahlstrom, 1965 (*Chromis*); Delsman, 1930; Fujita, 1957; Gosline and Brock, 1960; Helfrich, 1958; Randall and Swerdloff, 1973; Swerdloff, 1970.
- Priacanthidae: Aboussouan, 1969; Caldwell, 1962.
- Pseudochromidae: see Grammistidae.
- Pyramodontidae: Strasburg, 1965.
- Rondelettiidae:

- Scaridae: Mito, 1962d; Randall and Randall, 1963.
- Schindleriidae: Brunn, 1940; Jones and Kumaran, 1964c; Sardou, 1974; Watson and Leis, 1974.
- Scomberesocidae: D'Ancona, 1931 (pp. 147-153); Uchida et al., 1958 (pp. 22-24); Ueyangi and Doi, 1971.
- Scombridae: Chen and Tan, 1973; Jones and Kumaran, 1964d; Matsui, 1967; Matsumoto, 1958, 1959, 1962, 1967; Matsumoto et al., 1972; Miller, 1979; Mito, 1961b; Mori et al., 1971; Richards and Klawe, 1972; Richards and Potthoff, 1974; Uchida et al., 1958.
- Scombrolabracidae: Grey, 1960.
- Scopelarchidae: Johnson, 1974a, 1974b; Merrett et al., 1973; Okiyama, 1974b.
- Scopelosauridae (=Notosudidae): Ahlstrom, 1972; Pertseva-Ostroumova and Rass, 1973 (*Scopelosaurus* sp., pp. 28-29).
- Scorpaenidae: Eschmayer and Randall, 1975; Mito and Uchida, 1958; Moser, 1967; Orton, 1955; Watson and Leis, 1974.
- Scorpididae: Uchida et al., 1958 (*Microcanthus strigatus* (Cuvier et Valenciennes) pp. 71-72).
- Serranidae: Aboussouan, 1972; Bertolini, 1933b; Fourmanoir, 1971a (*Liopropoma*, pp. 272-278); Kendall, 1972; Presley, 1970; Ukawa et al., 1966.
- Serrivomeridae: Castle, 1965a.
- Soleidae: Mito, 1963a.
- Sparidae: Ranzi, 1933a.
- Sphyraenidae: Houde, 1972; de Sylva, 1963; Uchida et al., 1958 (*Sphyraena pinguis*, pp. 46-47); Vialli, 1937b.
- Sternoptychidae: Sanzo, 1931c.
- Stomiidae: Ege, 1918; Sanzo, 1931e (pp. 77-79); de Sylva and Scotton, 1972.
- Stylephoridae:
- Synphobranchidae: Castle, 1965a.
- Syngnathidae: Aboussouan, 1969; D'Ancona, 1933b.
- Synodontidae: Gibbs, 1959; Mito, 1961a; Okiyama, 1974a.
- Tetragonuridae: Grey, 1955.
- Tetraodontidae: Fujita, 1966; Leis, 1978b; Uchida et al., 1958 (*Fugu* spp. and *Lagocephalus* spp., pp. 78-85); Welsh and Breder, 1922.
- Trachichthyidae:
- Trachipteridae: Sparta, 1933b.
- Trichiuridae: Strasburg, 1964; Voss, 1954 ("*Gempylus A*" is *Diplospinus*, see Ahlstrom, 1971).
- Trichonotidae:
- Tripterygiidae: Ruck, 1973; Shiogaki and Dotsu, 1973.
- Veliferidae:
- Xencongridae: Smith, 1969.
- Xiphiidae: Arata, 1954; Padoa, 1956a; Yabe et al., 1959.
- Zanclidae: Strasburg, 1962.
- Zeidae: Sanzo, 1956.

Part IV. Appendix – Larval Fish Collection



LARVAL FISH COLLECTION*

ACANTHURIDAE—mostly juveniles Acanthurus triostegus sandvicensis Acanthurus sp. Ctenochaetus strigosus Naso brevirostris Naso sp. Zebrasoma flavescens Unidentified acronurids	AULOSTOMIDAE Aulostomus chinensis	BROTULIDAE + OPHIDIIDAE Brotula multibarbata—partial series Unidentified species	CHAMPSODONTIDAE Champsodon sp.
ALBULIDAE Albula vulpes	BALISTIDAE—(Monacanthidae ?) —early larvae	CALLIONYMIDAE Callionymus decoratus Pogonemus pogognathus ca. 3 unidentified types	CHANIDAE Chanos chanos
ALEPISAUROIDAE	BATHYLAGIDAE	CANTHIGASTERIDAE Canthigaster sp.	CHAULIODONTIDAE
ANOLOGASTERIDAE Anoplogaster cornuta	BELONIDAE Tylosurus crocodilus	CAPROIDAE ?	CHIASMODONTIDAE Chiasmodon sp. Kali sp. Pseudoscopelus sp.
ANTENNARIIDAE—unidentified early larvae	BLENNIIDAE Blennius sp. Cirripectus sp. Enchelyurus brunneolus Entomacrodus marmoratus Exallias brevis Istiblennius zebra Omobranchus elongatus Plagiotremus (=Runula) goslinei ca. 4 unidentified types	CARANGIDAE Caranx ignobilis ? C. mate—reared series Decapturus (pinnulatus ?) Gnathanodon speciosus Naucrates ductor Scomberoides lysan Seriola rivoliana Trachurops (=Selar) ca. 11 unidentified types	CHLOROPHTHALMIDAE Chlorophthalmus proridens
APOGONIDAE Apogon erythrinus A. maculiferus ? Epigonus atherinoides ? Foa brachygramma—partial reared series ca. 8 unidentified types	BOTHIDAE Arnoglossus debilis Bothus pantherinus B. thompsoni ? Engyproson xenandrus Pelecichthys crumenalis Unidentified spp.	CIRRHITIDAE Amblycirrhitus bimaculata Cirrhitops fasciatus Oxycirrhites typus Unidentified spp.	
ARGENTINIDAE Glossanodon struhsakeri	BRAMIDAE	CONGRIDAE	
ASTRONESTHIDAE—unidentified larvae	BREGMACEROTIDAE Bregmaceros spp.	CORYPHAENIDAE Coryphaena hippurus	
ATHERINIDAE Pranesus insularum Iso hawaiiensis		CYEMIDAE	
		DACTYLOPTERIDAE Dactyloptena orientalis	
		DIODONTIDAE Diodon holocanthus D. hystrix ?	
		CHAETODONTIDAE Chaetodon trifasciatus C. unimaculatus—partial series	

*Collection contains specimens of various developmental stages. Not all species are represented by complete series and some are known only from juveniles.

DUSSUMIERIIDAE Etrumeus teres Spratelloides delicatulus	GOBIIDAE Bathygobius cotticeps B. fuscus Kelloggella oligolepis Oxyurichthys lonchotus Psilogobius mainlandi ca. 10 unidentified types	LABRIDAE Cheilinus sp. Cymolates leclusei Hemipteronotus sp. Pseudocheilinus sp. Stethojulis balteata Thalassoma sp. ca. 3 unidentified types	MUGILIDAE Chelon engeli Mugil cephalus—reared series
ELEOTRIDAE Asteropteryx semipunctatus Eviota epiphanes	GONORHYNCHIDAE Gonorhynchus gonorhynchus	LUTJANIDAE Symphysanodon sp. ca. 6 unidentified types	MUGILOIDIDAE Neopercis roseoviridis Parapercis schauinsland
ENGRAULIDAE Stolephorus purpureus S. buccaneeri	GONOSTOMATIDAE Cyclothone sp. Danaphos (oculatus ?) Diplophos taenia Gonostoma atlanticum G. elongatum Ichthyococcus sp. Valenciennellus tripunctatus Vinciguerria nimbaria	MACROURIDAE Hymenocephalus sp.	MURAENIDAE
EUTAENIOPHORIDAE	HEMIRAMPHIDAE	MALACANTHIDAE Malacanthus parvipinnis	MYCTOPHIDAE Benthoosema sp. Bolinichthys spp. Centrobranchus choerocephalus Ceratoscopelus townsendi-complex Diaphus sp. (slender) Diaphus sp. (stubby) Diogenichthys sp. Hygophum proximum H. reinhardti Hygophum sp. ? Lampadena urophaos L. luminosa Lampanyctus niger L. nobilis Lampanyctus spp. Lobiancha sp. Loweina rara Myctophum sp. Notoscopelus sp. Protomyctophum sp. Symbolophorus (evermanni ?) Taaningichthys bathyphilus T. minimus Triphoturus nigrescens 3 unidentified species
EVERMANNELLIDAE Evermannella sp.	HOLOCENTRIDAE Holocentrus sammara ? Myripristis sp. Unidentified spp.	MALACOSTEIDAE ca. 3 unidentified types	
EXOCOETIDAE ca. 7 unidentified types	IDIACANTHIDAE	MELAMPHAIDAE Melamphaes sp.	
178 FISTULARIIDAE Fistularia petimba Fistularia sp.	ISTIOPHORIDAE Tetrapturus audax T. augustirostris Unidentified sp.	MELANOCETIDAE Melanocetus johnsoni	
GEMPYLIDAE Gempylus serpens Lepidocybium flavobrunneum Nealotus tripes Nesiarchus nasutus Promethichthys prometheus	KUHLIIDAE Kuhlia sandvicensis	MELANOSTOMIATIDAE Bathophilus sp. Eustomius sp. Photonectes sp. ?	
GIGANTACTINIDAE Gigantactis sp.	KYPHOSIDAE Kyphosus vaigiensis	MICRODESMIDAE Gunnellichthys sp.	
GIGANTURIDAE "rosaura" larvae		MOLIDAE Ranzania laevis	NEOSCOPELIDAE Scopelengys tristis
		MORIDAE Physiculus sp. ?	
		MORINGUIDAE	

NOMEIDAE

Cubiceps pauciradiatus
Nomeus gronovii
Psenes (cyanophrys ?)

OGOCEPHALIDAE

Dibranchus erythrinus
 Unidentified species

ONEIRODIDAE**OPHICHTHIDAE****OSTRACIODONTIDAE**

Lactoria spp.
Ostracion meleagris

PARALEPIDIDAE

Lestidium sp.
Stemnosudis macrurus
Sudis atrox
 Unidentified spp.

PEGASIDAE

Pegasus papilio

PERCICHTHYIDAE

Howella sp.

PLEURONECTIDAE

Samariscus corallinus
S. triocellatus

POLYNEMIDAE

Polynemus sexfilis—reared
 specimens

POMACANTHIDAE

Centropyge sp.

POMACENTRIDAE

Abudefduf abdominalis—reared
 specimens
Chromis acares or *C. vanderbilti*
C. ovalis
C. verater
Eupomacentrus fasciolatus
Plectroglyphidon imparipennis
P. johnstonianus
 ca. 9 unidentified types

PRIACANTHIDAE**PSEUDOCHROMIDAE**

Aporops bilinearis
Pseudogramma polycantha

SCARIDAE

Scarus dubius
 Unidentified spp.

SCHINDLERIIDAE

Schindleria pietschmanni
S. praematurus

SCOMBRIDAE

Acanthocybium solandri
Auxis sp.
Euthynnus affinis
Katsuwonus pelamis
Scomber australasicus
Thunnus alalunga ?
T. albacares
T. obesus ?

SCOMBROLABRACHIDAE

Scombrolabrax heterolepis

SCOPELARCHIDAE

Benthabella sp.
Scopelarchus sp.

SCOPELOSAURIDAE

Ahliesaurus brevis
Scopelosaurus smithi ? ?

SCORPAENIDAE

Pterois sphex
Taenianotus triacanthus
 ca. 9 unidentified types

SERRANIDAE

Odontanthias fuscipinnis ?
Pikea aurora
Pseudanthias thompsoni

SOLEIDAE

Aseraggodes sp.
 Unidentified sp.

SPHYRAENIDAE

Sphyræna barracuda
Sphyræna sp. (*helleri ?*)

STERNOPTYCHIDAE

Sternoptyx sp.

STOMIATOID**SYNGNATHIDAE**

Hippocampus kuda
Syngnathus balli
 Unidentified spp.

SYNODONTIDAE

Saurida gracilis
Synodus spp.
Trachinocephalus myops

TETRAODONTIDAE

Arothron sp.
Lagocephalus lagocephalus
 Unidentified spp.

TRACHIPTERIDAE

Trachipterus fukuzakii
Zu cristatus

TRICHIURIDAE

Diplospinus multistriatus

TRICHONOTIDAE

Crystallodytes cookei
Limnichthys donaldsoni

TRIPTERYGIIDAE

Tripterygion atriceps

XIPHIIDAE

Xiphias gladius

ZEIDAE

Zenion sp.

ZOARCIDAE ?

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