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A LIST OF THE FRESHWATER AND ANADROMOUS FISHES OF CALIFORNIA [1]

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This list is the second revision of the check list of the freshwater, anadromous, and euryhaline fishes of California published by Shapovalov and Dill (1950) and first revised by Shapovalov, Dill, and Cordone (1959). The present list consists of a main list of native and established exotic species and five supplementary lists: (i) native species extinct in California, (ii) exotic species unsuccessfully introduced or of uncertain status, (iii) marine fishes successfully introduced into the Salton Sea, (iv) forms and names new to the main list since 1959, and (v) forms and names removed from the main list since 1959. The main list is composed of 124 full species, comprising 66 native freshwater and anadromous species, 13 native euryhaline or marine species which occasionally penetrate into fresh water, and 45 introduced species. The 124 species comprise 25 families and 64 genera.

INTRODUCTION

Two previous editions of this list have been published (Shapovalov and Dill 1950; Shapovalov, Dill, and Cordone 1959). Since publication of the 1959 list, many changes have occurred in both the composition of this fauna and the nomenclature applied to many of its fishes.

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[1] Accepted for publication September 1980.
[2] Retired.
[3] Currently: Fishery Consultant, 730 North Campus Way, Davis, CA 95616.

First, a number of fishes have been introduced into the State. Some of these have been introduced by the California Department of Fish and Game as part of its research and management program. Others have been introduced illegally, either deliberately or inadvertently, especially by sportsmen and aquarists, or through escape from ornamental fish farms.

Second, some forms have become extinct in State waters.

Third, some new forms have been described and the taxonomic or nomenclatural status of a number of others has been revised. Some of these revisions have been made in the direction of condensation, simplification, and uniformization of group names; others have been in the opposite direction of greater diversification. With full recognition that opinions on taxonomy and nomenclature may differ decidedly, we have attempted to include in the list all revisions that have been proposed in scientific publications and not subsequently refuted.

The list itself is preceded by several introductory sections. Those entitled "Scientific Names" and "Common Names", which are of a background nature, are printed here with little change from our previous list.

PURPOSE

Two major objectives in publishing a check list of California freshwater and anadromous fishes were cited in the 1950 edition and reiterated in the first revision (1959). These were to: (i) establish the basis for compilation of a detailed handbook of these fishes, and (ii) promote stability and uniformity in both their common and scientific names. Publication of a key to these species by Kimsey and Fisk (1960) and especially, the publication of "Inland Fishes of California" by Moyle (1976), have aided in achievement of the first goal. The second objective has neared achievement with regard to common or vernacular names. However, uniformity in the nomenclature of scientific names continues as a never-to-be attained goal.

This list, like the previous ones, will of course become obsolete in time, and another edition will be necessary. We suggest that its future authors, or any who propose to publish local, state, or nationwide lists, can materially advance stability in fish nomenclature by attempting to resolve differences through consultation with those who have authored existing lists. We have done this consistently, have invariably met with cooperation, and have thereby resolved most nomenclatural problems.

SCIENTIFIC NAMES

In scientific naming, stability is largely dependent upon the thoroughness and care of the taxonomist. Any proposed revisions must be carefully evaluated. For example, Schultz (1957:48–49) stated:

"The evaluation of generic characters and recognition of genera is possible only when a comprehensive study is made of a family on a world-wide basis and when there is established the nature of the similarities and differences among groups of species. . .

"The problem of how far to progress nomenclatorially in recognizing generic categories must be resolved in a practical manner so that biologists are not presented with a confusion of ill-defined genera. Usually this confusion and lack of agreement among ichthyologists and fishery biologists results from inadequate studies of a family. Obviously, no dependable solution is possible on how many genera and subgenera to recognize in a family until the zoological relationships of all its species have been adequately compared morphologically, physiologically, and as to habits. No doubt, after this work has been done, a middle of the road or even a conservative attitude on the number of phyletic lines to name would meet with general acceptance. Too often in ichthyology there is a tendency either to unite genera without adequate study or to establish new genera without any attempt to review the family. The least confusion results if the present status of each genus in a family is retained until such time as it is thoroughly studied."

We are in accord with this opinion but believe that the ideas expressed are applicable to species and subspecies as well. Subspecies in particular are subject to much lumping and partitioning, at times without secure evidence. Some ichthyologists have questioned the existence of certain forms in our list while, on the other hand, they have proposed hitherto unknown forms for inclusion. In almost every case, we have let the decision hinge on the appearance in the literature of substantiating data. The publication of new scientific names and elimination of familiar ones without sufficient supporting evidence simply creates further confusion in fish nomenclature.

Bailey (1956:328–329) has given considerable thought to the problem of subspecies: ". . . the common taxonomic practice of dividing geographically variable species into named races, or subspecies, has been subjected to critical scrutiny. It has been noted that the pattern of geographic variation in some species takes the form of a rather gradual and progressive gradient, termed a cline. It is now agreed by many taxonomists that despite the high biological significance of this type of variation it is undesirable to assign subspecific names on the basis of clinal gradients. . .

"Commonly the differences between geographic subspecies are slight and are best expressed as average conditions applying to a considerable fraction of individuals, but not to all. It is my revised opinion that acceptable subspecies should evidence high uniformity over the respective ranges and should differ one from another with high constancy. Zones of intergradation should be rather narrow. If they are wide the variation merges insensibly into a clinal gradient. . .

"The ichthyologist, in studying material, often perceives differences among populations from various parts of the geographic range of a species. Such discoveries may presage the definition of validly recognizable subspecies. The premature use of such information without publication of the full data is disconcerting to other workers, who are unable to evaluate the basis for the action. The different stocks sometimes turn out to be fully distinct species. . ."

Another excellent discussion of the subject which supplements the above statements was presented by Bailey, Winn, and Smith (1954:148–150). The following excerpt seems particularly pertinent:

"Many clinal variations in the morphology of fishes may be caused partly or wholly by gradients of environmental factors, especially temperature. The assumption that all taxonomic characters, such as meristic counts, are governed solely by genetic factors is no longer tenable. . . Whether the gradient is caused by heredity or the environment, we reject the practice of establishing subspecies on characters that show clinal variation. Furthermore, the insistence that a cline be a perfectly smooth gradient, we regard only as an academic problem. Minor irregularities are to be anticipated because of local genetic emphasis, sampling errors, environmental variations that impose structural change, and other vagaries."

We concur in the statements above and in keeping with them have employed binomials instead of trinomials wherever sufficient published evidence exists to show that a cline truly exists. This has been done, for example, for *Notemigonus crysoleucas* (Hart 1952: 33–38, *77;* Bailey et al. 1954: 123–124, 149); and *Ictalurus punctatus* (Bailey et al. 1954: 130). Subspecific partitioning of many species in the main list may be of questionable validity; however, we retain the status quo and await the publication of evidence showing whether the trinomials are justified.

Scientific names used in this list conform to the provisions of the International Code of Zoological Nomenclature, 1964, and subsequent amendments.

Space does not permit an explanation of each change in scientific names used in bringing this list up to date. However, most of the major changes are discussed in appropriate text sections. Recourse to the references will provide further details. Some of the more important relatively recent references include: Miller (1958), Bond (1961), Walker, Whitney, and Barlow (1961), Bailey and Bond (1963), Rosen and Bailey (1963), Bailey and Uyeno (1964), Smith (1966), Hubbs (1967), Kljukanov (1970), Hopkirk (1973), Ross (1973), Moyle (1976), and Hubbs, Follett, and Dempster (1979).

COMMON NAMES

Stability in common names can best be achieved by adhering closely to a workable set of criteria, as outlined below.

The selection of common names for fishes in this list is complicated by two somewhat paradoxical factors: the multiplicity of names which have already been applied to certain species and, in the case of certain other forms, the dearth of common names. Thus, members of the genus *Cyprinodon* have been called by such varied names as desert minnow, desert killifish, pursy minnow, pygmy fish, and pupfish. Conversely, a large number of native cyprinids are so similar and indistinctive in appearance that the layman has never recognized their specific differences nor called them by any name other than the rather general ones, such as chub or shiner. This list attempts to reconcile such difficulties by assigning one official common name to each species and subspecies.

The basic rules or criteria for the selection of common names remain essentially identical with those presented in our previous lists. Such guides are necessary to prevent arbitrary selection based on personal preference, and have again proved of practical value in the objective establishment of the revised common names. Insofar as possible, we have adhered to them, as follows:

1. Names should agree with those in actual common use; or when there is no common or vernacular use, with those in published literature. Strictly "book names" should be avoided.
2. Names should agree, if possible, with those in other authoritative lists, especially those of the Committee on Names of Fishes of the American Fisheries Society (Robins et al. 1980) and Hubbs et al. (1979).
3. Names should indicate relationship and not confuse it.
4. Names should be descriptive.
5. Preference should be given to names which are short, distinctive, interesting, catchy, romantic, or euphonious.

Each of these qualifications has exceptions which make it useless by itself. Therefore, each principle listed above should be read as though it were prefaced by the words, "Other considerations being equal . . ." For example, the name Sacramento perch does not meet either Rule 3 or 4 above, since this species (*Archoplites interruptus*) is not a true perch. However, since this name is so commonly used (Rule 1) and since it agrees fully with the name used in lists such as those cited in Rule 2, it would be foolish to select another.

Aside from such considerations, in this revision, as in the previous one, we have attempted continued advancement of the twin ideals of stability for individual names and the designation of relationships through the selection of common names according to a definite plan. Such aims, long recognized by ornithologists, are well exemplified by the names listed in "The Distribution of the Birds of California" (Grinnell and Miller 1944). Thus, in our list, wherever possible the same basic common name has been given to all members of a single genus, with prefixes added to that common name for each full species of that genus. In the case of subspecies, additional prefixes have been added to the specific name. For example, all members of the genus *Gila* have been termed chub, members of the *Gila bicolor* group have been termed tui chub, and each subspecies of that group is further designated by an additional term such as Mohave for *G. b. mohavensis,* the Mohave tui chub.

It should be noted that this method will permit the retention of at least part of the common name even if the species or subspecies undergoes a revision which will change the scientific name. This, in part, answers the criticism of the Committee on Names of Fishes of the American Fisheries Society (Robins et al. 1980): "The practice of applying a name to each genus, a modifying name for each species, and still another modifier for each subspecies, while appealing in its simplicity, has the defect of inflexibility." Further, "If a fish is transferred from genus to genus, or shifted from species to subspecies or vice versa, the common name should nevertheless remain unaffected. It is not a primary function of common names to indicate relationship."

We contend, nevertheless, that an important and vital function of common names is to reveal rather than confuse relationships. It is quite true that some of the most deeply rooted vernaculars are completely misleading; little can now be done in these cases to establish meaningful names. Furthermore, when a name is entered in an official list it should not be changed unless there are important reasons to do so. However, changing a name to demonstrate the proper relationship of a form known to professional fisheries people but unfamiliar to laymen does not present a serious problem and to us is justifiable. In any event, long usage of both the first and present revisions has shown that the system is workable and has meaning, with no major difficulties encountered.

Some authors; e.g., Robins et al. (1980) and Alden H. Miller (Grinnell and Miller 1944), believe that generally only full species deserve common names. Nevertheless, we have listed common names for each subspecies, with full recognition that a number of them may not endure. One reason prompting this decision is that certain subspecies have been distinguished as entities almost from the beginning, and it would seem unfortunate to obscure (through omission) such names as Paiute or Kamloops.

It should also be noted that a number of systematists have disagreed with certain of our groupings; e.g., that for the native trouts, in which assignment to specific or subspecific status is, in some instances, original with the authors. However, a firm nomenclature has never been developed for some of these plastic groups. And, as we have stated before, even after some decided changes in scientific nomenclature, most of our common names can still be retained with enough recognizable parts to promote stability.

SCOPE

The main list covers both native and successfully established exotic species. The supplementary lists include native species believed to be extinct in California and exotic species unsuccessfully introduced or of uncertain occurrence.

We have attempted to include all native forms whose occurrence has been reported and not disproved in the literature, as well as those verified through examination of collections. The existence of some of these as valid species or subspecies (*Catostomus occidentalis lacusanserinus*, for example) has been questioned by some workers. Our criterion for inclusion of such forms is very simple: we have tried to include all forms whose taxonomic identity has not yet been disproved in published literature.

Possibly certain other records of occurrence are based on misidentification. Possibly some of the native species are no longer a part of our fauna. Native forms which now appear to be extinct in State waters include *Salvelinus malma, S. confluentus, Gila crassicauda, G. elegans, Pogonichthys ciscoides, Ptychocheilus lucius, Cyprinodon nevadensis calidae,* and *C. n. shoshone*. It is practically impossible, however, to prove or disprove such suppositions. Hence, in the case of the native species it has been thought best to err on the side of inclusiveness and continue them in the main list. On the other hand, only those exotic or introduced species of which breeding populations are known to have survived are included in this list.

Fishes recorded only from outside California have not been included even if the stream in question flows into or out of this State; e.g., the Klamath and Truckee rivers. However, in the case of the Colorado River, a boundary stream, fishes recorded from the Arizona side of the stream have been included.

Hybrids have also been omitted. Both interspecific and intergeneric hybrids of a number of the species listed have been recorded from the natural waters of California (see, for example, Hubbs and Miller 1943).

Marine Fishes Successfully Introduced into the Salton Sea

Most of the fishes in the main list are strictly freshwater or anadromous. For the sake of completeness, we have also listed those marine and brackishwater species which we know have penetrated into fresh water. Strictly marine species from the Gulf of California which have been introduced into and have successfully spawned in the Salton Sea, an inland body of water with salinity exceeding that of ocean water are, however, omitted from the main list. They are included below, since they have established breeding populations in an inland body of water. The history of these introductions by the California Department of Fish and Game has been related by Anon. (1958) and Walker et al. (1961).

HAEMULIDAE—grunt family

Anisotremus davidsonii (Steindachner)—sargo

Introduced in 1951. The first sargo known to have been spawned in the Sea, a juvenile young-of-the-year, was taken in October 1956. The first verified catch of an adult was made on 17 September 1958. Since then sargo up to 305 mm in length have been taken in considerable numbers by sport fishermen.

SCIAENIDAE—croaker family

Bairdiella icistia (Jordan and Gilbert)—bairdiella

First introduced in October 1950, the population of bairdiella is now very large.

Cynoscion xanthulus Jordan and Gilbert—orangemouth corvina

First introduced in October 1950, it is now present in large numbers, and like the sargo and bairdiella, should remain so unless the salinity of the Sea becomes too high.

The shortfin corvina, *Cynoscion parvipinnis*, also introduced in 1950, established a breeding population but has not been observed for a number of years.

Forms and Names New to the Main List Since 1959

Numerous changes in scientific and common names have taken place since the 1959 check list was prepared. Changes involving common names and minor revisions in scientific names are not discussed. Forms and scientific names not listed in or differing from those listed in the 1959 check list are included in this revised edition, with a brief explanation for their inclusion. Included are 19 species and subspecies of exotic fishes which have become established in California waters since 1959.

Although the California freshwater fish fauna has been studied for many years, some undiscovered species may remain. Collecting in coastal fresh waters may uncover additional euryhaline forms. Taxonomists may be expected to continue to describe new forms but at a lesser rate than in the past. For example, some taxonomists have recognized a trout from northern California as a distinct species and have proposed the common name of redband trout, but have not yet published a scientific name (Hoopaugh 1974). The escape or release into the wild of tropical and other ornamental fishes may be anticipated and some of these may become established.

And, although such activities have a much lower priority now than in the past, the introduction of exotic game and forage fishes by the California Department of Fish and Game may also result in addition of other species. The fish management program of the Inland Fisheries Branch includes an evaluation of the various aquatic habitats and what might constitute the most suitable game and/or forage species, either native or exotic, for them. Each potential import is thoroughly studied and screened to insure against detriment to existing aquatic resources.

PETROMYZONTIDAE—lamprey family

Lampetra folletti (Vladykov and Kott)—Modoc brook lamprey

Vladykov and Kott (1976*b*) described this nonparasitic species of lamprey from the Klamath River system in Modoc County, California, as *Entosphenus folletti*. We follow Hubbs (1971) in treating *Entosphenus* as a subgenus of *Lampetra*.

Lampetra hubbsi (Vladykov and Kott)—Kern brook lamprey

Vladykov and Kott (1976*a*) described this nonparasitic species of lamprey from the Friant-Kern Canal, east of Delano, San Joaquin Valley, as *Entosphenus hubbsi*. We follow Hubbs (1971) in treating *Entosphenus* as a subgenus of *Lampetra*.

Lampetra lethophaga Hubbs—Pit-Klamath brook lamprey

The addition of this species is based on its description by Hubbs (1971). It is found in the drainage basin of the Pit River in northeastern California, and in the upper Klamath River in south-central Oregon. In the past it has been misidentified as *Lampetra planeri* and *Entosphenus tridentatus*.

Lampetra pacifica Vladykov—Pacific brook lamprey

This small, nonparasitic lamprey was described as a new species by Vladykov (1973). In California, it is recorded from various streams in the Sacramento-San Joaquin River system. It is quite similar to *L. richardsoni* and may not be specifically distinct from it. Before 1973 it had frequently been recorded as *L. planeri* or *L. richardsoni*.

Lampetra richardsoni Vladykov and Follett—western brook lamprey

Vladykov and Follett (1965) described this new nonparasitic species of lamprey from " . . . streams of British Columbia, Washington, Oregon, and possibly Alaska". Follett subsequently informed J. D. Hopkirk that the range of the western brook lamprey was more recently known to include California (Hopkirk 1973:20). Various authors had previously listed it as *L. planeri*, the name used in our 1959 check list, but now removed from our main list.

Lampetra tridentata (Gairdner)—Pacific lamprey

The Pacific lamprey was listed as *Entosphenus tridentatus* in our 1950 and 1959 check lists, but we now follow Hubbs (1971) in treating *Entosphenus* as a subgenus of *Lampetra*.

ACIPENSERIDAE—sturgeon family

Acipenser medirostris medirostris Ayres—American green sturgeon

We follow Lindberg and Legeza (1965:33) in recognizing this subspecies. In our 1959 check list we listed only the full species, *Acipenser medirostris* Ayres.

CLUPEIDAE—herring family

Clupea harengus pallasii Valenciennes—Pacific herring

In our 1959 list the Pacific herring was listed as *Clupea pallasii*. However, Svetovidov (1952) has shown that this form is actually a subspecies of *C. harengus*.

OSMERIDAE—smelt family

Hypomesus nipponensis McAllister—freshwater smelt

This species was introduced into California from Japan as a forage fish (air shipment of eggs) in 1959 (Wales 1962). At the time it was misidentified as *H. olidus*. This strictly freshwater species has since become firmly established in at least several waters in California.

Hypomesus transpacificus McAllister—delta smelt

In his revision of the smelt family, McAllister (1963) described this new species, known only from the lower parts of the Sacramento and San Joaquin rivers. It had previously been referred to in the literature as *Hypomesus olidus,* the name we used in our 1959 check list.

McAllister described two subspecies, *H. transpacificus transpacificus* and *H. transpacificus nipponensis.* However, we follow Kljukanov (1970) in treating the two as distinct species.

COREGONIDAE—whitefish family

Prosopium williamsoni (Girard)—mountain whitefish

Our 1959 list placed this species in the genus *Coregonus.* We now follow Norden (1961), who described the characters separating the two genera.

SALMONIDAE—salmon and trout family

Salmo clarkii pleuriticus Cope—Colorado River cutthroat trout

This subspecies was dropped from the main list in our 1959 check list because published reports of its occurrence in the Salton Sea were dubious. The reported specimens may have been misidentified; in any case, if correctly identified they almost certainly consisted of individuals washed into the basin from the Colorado River many years ago. No specimens from the Salton Sea are known to exist in any collections.

On 11 September 1974, the California Department of Fish and Game collected 21 specimens of this subspecies from the lower three of the five Williamson Lakes of the southern Sierra Nevada. These trout were descendant from a 1931 plant of Colorado River cutthroat trout fry hatched from eggs taken from Trapper's Lake, Colorado (Gold, Gall, and Nicola 1978).

Salvelinus confluentus (Suckley)—bull trout

Although the view that the Dolly Varden, *Salvelinus malma,* is the only recognizable member of the genus in the American northwest has been widely accepted, the subject has been a matter of some controversy for over a century. Morton (1970) concluded that *S. malma* was the only valid species and that there were no valid subspecies. More recently, Cavender (1978) presented morphometric, meristic, osteological, and distributional evidence to support his view that there are two widely distributed forms of *Salvelinus* native to the western United States and Canada: the Dolly Varden, *S. malma,* and the bull trout, *S. confluentus.* He records both species from the McCloud River drainage in California, although his only record from there of *S. malma* consists of two specimens in the National Museum of Natural History (then U.S. National Museum) labeled as having been sent by Livingston Stone from the McCloud River in 1877. It is on the basis of this publication that we have included both species in our main list, even though we think it virtually inconceivable that both species could have coexisted within the confines of the McCloud River.

CYPRINIDAE—carp or minnow family

Gila bicolor (Girard)—tui chub

Bailey and Uyeno (1964) changed the name of this species from *Siphateles bicolor,* the name used in our 1959 check list, to *Gila bicolor.*

Gila bicolor mohavensis (Snyder)—Mohave tui chub

Although this fish had been accorded full species rank for many years, Miller (1973) regarded it as a subspecies because he was unable to discover characters that would separate it specifically from all populations of *Gila bicolor* in the Lahontan Basin.

Gila bicolor snyderi Miller—Owens tui chub

This subspecies was described by Miller (1973). In our previous check list it was listed as *Siphateles bicolor obesus.* It is confined to the isolated Owens Valley in eastern California.

Gila bicolor thalassina (Cope)—Goose Lake tui chub

This subspecies was not included in the 1950 and 1959 check lists because of the belief that it was extinct in Goose Lake, Modoc County (Hubbs and Miller 1948:70–71). A prolonged drought (1929–1934), when Goose Lake was virtually dry, may have led Hubbs and Miller to this conclusion. Recent collections made by T. J. Mills (Calif. Dep. Fish and Game, pers. commun.) revealed that this chub is once again abundant in Goose Lake. Its identity as *G. b. thalassina* was confirmed by C. E. Bond (15 August 1978 letter to T. J. Mills).

Gila bicolor vaccaceps Bills and Bond—Cowhead Lake tui chub

Tui chubs from Cowhead Lake, Modoc County, were first recognized as distinct by Hubbs and Miller (1948) and ultimately described by Bills and Bond (1980). The Lake is now dry and the chubs are confined to the small outlet slough.

Gila coerulea (Girard)—blue chub

This species, from the Klamath River system, was listed in our 1959 check list as *Gila bicolor.* Bailey and Uyeno (1964) have explained why it should be called *G. coerulea.*

Gila elegans Baird and Girard—bonytail chub

In our 1959 check list we used the name *Gila robusta,* and treated the form from the Colorado River as a subspecies, *G. robusta elegans. G. robusta elegans* is regarded as having specific status by Minckley and Deacon (1968) and Hopkirk (1973:32).

Hesperoleucus symmetricus mitrulus Snyder—upper Pit western roach
Hesperoleucus symmetricus navarroensis Snyder—Navarro western roach
Hesperoleucus symmetricus parvipinnis Snyder—Gualala western roach
Hesperoleucus symmetricus venustus Snyder—Venus western roach

In our 1959 check list these subspecies were accorded full specific rank. We now concur with Moyle (1976:180) and Hubbs et al. (1979) that they should be treated as subspecies of *H. symmetricus.* Hopkirk (1973: 48–51) discusses some of the taxonomic problems involved and the need for a thorough revision of the genus.

Lavinia exilicauda chi Hopkirk—Clear Lake hitch

Hopkirk (1973:55–56) described this subspecies from Clear Lake in central California, separating it from *Lavinia exilicauda exilicauda* of previous authors. He remarked that it ". . . is a lake-adapted subspecies with a high number of gill rakers. In this respect, it agrees with *Pogonichthys ciscoides* and *Hysterocarpus traskii lagunae* from Clear Lake basin."

Pogonichthys ciscoides Hopkirk—Clear Lake splittail

Hopkirk (1973:30–31) described this species from Clear Lake in central California, distinguishing it from *Pogonichthys macrolepidotus* of previous authors. He noted that it ". . . is a lake-adapted species with fine gill rakers, terete body, terminal mouth, and small fins."

CATOSTOMIDAE—sucker family

Catostomus fumeiventris Miller—Owens sucker

This species was described by Miller (1973). Originally confined to the Owens Valley in eastern California, it has been introduced into June Lake in the Mono Lake Basin, and possibly into the Santa Clara River Basin by way of the Los Angeles Aqueduct.

Catostomus luxatus (Cope)—Lost River sucker

We follow Hubbs et al. (1979) in placing the species listed in our 1959 edition as *Deltistes luxatus* in the genus *Catostomus.*

Catostomus occidentalis humboldtianus Snyder—Humboldt western sucker

Catostomus occidentalis mniotiltus Snyder—Monterey western sucker

These subspecies were treated as full species in our 1959 list. They are currently recognized as subspecies of *Catostomus occidentalis* (Hopkirk 1973:69; Moyle 1976:214; Hubbs et al. 1979).

Catostomus platyrhynchus (Cope)—mountain sucker

In our 1959 check list we listed *Pantosteus lahontan,* Lahontan mountain sucker. Smith (1966) united *Pantosteus platyrhynchus* and *P. lahontan* as *Catostomus platyrhynchus.*

Catostomus santaanae (Snyder)—Santa Ana sucker

In our 1959 check list this species was listed as *Pantosteus santaanae* Snyder. Smith (1966) relegated *Pantosteus* to a subgenus of *Catostomus.*

COBITIDIDAE—loach family

Misgurnus anguillicaudatus (Cantor)—oriental weatherfish

On 12 April 1968, J. A. St. Amant collected loaches in a portion of the Westminster flood control channel, Orange County (St. Amant and Hoover 1969). Identified as *Misgurnus anguillicaudatus* by C. L. Hubbs, this was the first verified record of free-living loaches in California. Their source is believed to be the Pacific Goldfish Farm, from which some loaches escaped into the channel as early as the 1930's. A thriving population was present upstream from the original collection site in 1977 and another population was discovered in the adjacent Bolsa Chica Channel in 1979 (F. G. Hoover, pers. commun.).

ICTALURIDAE—North American freshwater catfish family

Ictalurus furcatus (Lesueur)—blue catfish

The blue catfish is presently established in four reservoirs and several ponds in San Diego and Riverside counties and several ponds at the Imperial Wildlife Area in Imperial County. The initial plant of blue catfish in California was made by the California Department of Fish and Game in October 1966, when 1,758 fish from Stuttgart, Arkansas, were released in Lake Jennings, San Diego County (Richardson et al. 1970). A single 1.7-kg specimen was collected from the San Joaquin River near Mossdale, San Joaquin County, in December 1978 by the Department's Bay-Delta Study (Taylor 1980). Currently about 20 commercial fish farmers in California are licensed to rear and sell this species.

Pylodictis olivaris (Rafinesque)—flathead catfish

A collection of four young-of-the-year specimens from the Highline Canal and its tributaries, near Niland, Imperial County, constituted the first California record for this species (Bottroff, St. Amant, and Parker 1969). They were probably progeny from the original introduction by the Arizona Game and Fish Department of 600 fish into the Colorado River above Imperial Dam. The flathead catfish is now common in the Colorado River and adjacent waters from Imperial Dam upstream to Headgate Rock Dam near the town of Parker. It is also common in the All American Canal system, including various drains and canals in Imperial Valley.

CYPRINODONTIDAE—killifish family

Cyprinodon milleri LaBounty and Deacon—Cottonball Marsh pupfish

LaBounty and Deacon (1972) described this pupfish from Cottonball Marsh, located in an isolated sector of the northwest portion of Death Valley. Previously these pupfish had been considered to be a population of *C. salinus*.

Lucania parva (Baird)—rainwater killifish

Hubbs and Miller (1965) describe the establishment of this cyprinodont in streams and sloughs tributary to San Francisco Bay and in Irvine Lake, Orange County. With respect to the Bay, where it was first recorded in 1958, the authors state, "It is obvious that *Lucania parva* has become well established about San Francisco Bay and contiguous waters, with vast increase in numbers and in range." However, only a few specimens (three in November 1963 and six in June 1964) were taken from Irvine Lake and the status of this population is unknown. Another population was discovered in 1976 in Arroyo Seco Creek, a tributary of Vail Lake, Riverside County (McCoid and St. Amant 1980).

POECILIIDAE—livebearer family

Poecilia latipinna (Lesueur)—sailfin molly

In our 1959 check list we listed *Mollienesia latipinna. Mollienesia* was synonymized with *Poecilia* by Rosen and Bailey (1963). The 1959 report mentioned that this species was established in canals and ditches tributary to the Salton Sea. It is now by far the most abundant species in these habitats, as well as in the shallow margins of the Sea itself (Black 1980).

Poecilia mexicana mexicana (Steindachner)—Orizaba shortfin molly

The Orizaba shortfin molly has been established in the Salton Sea area for many years. It was first reported in 1964 from a small pond and its tributary about 8 km north of the Salton Sea (St. Amant 1966). Further collections were made in this general area in subsequent years.

Populations of shortfin mollies have persisted in scattered locations in the drains and natural watercourses entering the Salton Sea and in the margins of the Sea itself (Black 1980). Although much less abundant and widespread here than the sailfin molly, *Poecilia latipinna,* it may nevertheless be considered a permanent member of the fish fauna in these waters.

Poeciliopsis gracilis (Heckel)—Porthole livebearer

Mearns (1975) reported the collection of four specimens of this species on 27 July 1974, from an irrigation canal near Mecca, Riverside County. He suggested the common name porthole livebearer. The specimens were identified by C. L. Hubbs. Later in the year Mearns collected additional specimens at the same site. The presence of recently born young, the wide range of sizes, and the persistence of the fish for at least a 4-month period suggested that *P. gracilis* was a reproducing resident of this canal. Introduction was presumably through direct release by aquarists or escapement from a nearby tropical fish farm. Additional collections of this species from the same canal have been made as late as 1980 (J. A. St. Amant, pers. commun.).

ATHERINIDAE—silverside family

Menidia audens Hay—Mississippi silverside

The Mississippi silverside was introduced into the Blue Lakes and Clear Lake in Lake County in 1967 to test its effectiveness in controlling the Clear Lake gnat and chironomid midges (Cook and Moore 1970). These fish were obtained from Lake Texoma, Oklahoma. The Blue Lakes plant was authorized by the Fish and Game Commission whereas the Clear Lake plant was not. About 6,000 fish were released in Upper Blue Lake and 3,000 in Lower Blue Lake and Clear Lake. Within a year progeny from the original plant were abundant in the last two waters, and since then a virtual population explosion of silversides has taken place.

A combination of experimental introductions by the Department of Fish and Game, illegal introductions by bait fishermen, and dispersal via man-made waterways has resulted in wide distribution of this species. Moyle, Fisher, and Li (1974) reported the presence of silversides in Putah and Cache creeks in Yolo County and in eight reservoirs and ponds in Alameda and Santa Clara counties. Collections described by Meinz and Mecum (1977) demonstrated the occurrence of an abundant, reproducing population in the Sacramento-San Joaquin Delta. From here they have ready access to the California Aqueduct, the Delta-Mendota Canal, and associated water storage and conveyance systems and eventually southern California reservoirs.

SYNGNATHIDAE—pipefish family

Syngnathus leptorhynchus Girard—bay pipefish

The bay pipefish has been recorded from the mouth of the San Lorenzo River, Santa Cruz County, and from the Navarro River, Mendocino County (Moyle 1976:283).

COTTIDAE—sculpin family

Cottus perplexus Gilbert and Evermann—reticulate sculpin

A collection of reticulate sculpins was made from the Middle Fork of the Applegate River (Rogue River drainage) in California on 2 March 1971, by F. H. Everest and recorded by Bond (1973). *Cottus perplexus* is the most abundant representative of the genus in the Rogue. It is not known from coastal streams south of the Rogue.

Cottus pitensis Bailey and Bond—Pit sculpin

Bailey and Bond (1963) described this sculpin as a new species. This common species of the Pit river system in northeastern California had been collected frequently over the years but had been considered to be *Cottus gulosus,* except by Bond (1961), who treated it as an undescribed species.

PERCICHTHYIDAE—temperate bass family

Morone chrysops (Rafinesque)—white bass

Von Geldern (1966) described the original introductions of white bass into California by the California Department of Fish and Game, under the name *Roccus chrysops.* We follow Robins et al. (1980) and others in placing this species in the genus *Morone.*

About 160 fingerlings were planted in Nacimiento Reservoir, San Luis Obispo County, in November 1965 and 64 adults were released into the same water in February 1966. The fingerlings were obtained from Lake McConaughy in Nebraska and the adults from Tenkiller Reservoir in Oklahoma. Additional plants in Nacimiento included 600 yearlings and adults in July 1968 from Lahontan Reservoir in Nevada and 200 adults in February 1967 from Utah Lake in Utah. The Nacimiento population is now well established.

The California Department of Fish and Game and the Arizona Game and Fish Department cooperated in a series of plants of white bass in the lower Colorado River in 1968 and 1969. However, the species failed to become established in this location.

The popularity of white bass at Nacimiento Reservoir has led to illegal introductions into other waters of the State. One such water is Kaweah Reservoir, Tulare County, where it is firmly established.

Morone saxatilis (Walbaum)—striped bass

In the 1959 list this species was listed as *Roccus saxatilis.* We follow Robins et al. (1980) and others in placing it in the genus *Morone.*

CENTRARCHIDAE—sunfish family

Lepomis gulosus (Cuvier)—warmouth

The warmouth was designated *Chaenobryttus gulosus* in our 1959 list. However, for reasons described by Bailey et al. (1970:75), we believe that *gulosus* should be regarded as a species of *Lepomis.*

Lepomis macrochirus purpurescens Cope—southeastern bluegill

In June 1975, 88 adult southeastern bluegill were stocked in Perris Lake, Riverside County, by the California Department of Fish and Game (Henry 1979). They were obtained through the cooperation of the Florida Game and Fresh Water Fish Commission from one of its hatcheries. They have reproduced and are firmly established. Specimens collected from Perris Lake have been stocked in several small ponds for experimental purposes and use as broodstock for future plants.

Micropterus coosae Hubbs and Bailey—redeye bass

Kimsey (1954) recorded the original importation into California of 40 redeye bass for use as broodstock by the California Department of Fish and Game at Central Valleys Hatchery, Elk Grove, California. In reviewing the history and status of this introduction (Kimsey 1957) concluded, "No redeye bass were planted in the open waters of the State and none are now present in California."

A second attempt to establish the redeye bass in California was successful (Goodson 1966). Broodstock imported from Tennessee and Georgia in the spring of 1968 spawned successfully at Central Valleys Hatchery, and their progeny were stocked in seven widely separated waters: Lake Oroville, Butte County; Alder Creek, Sacramento County; South Fork Stanislaus River, Tuolumne County; Dry Creek, Nevada County; Santa Ana River, Riverside County; Sisquoc River, Santa Barbara County; and Santa Margarita River, San Diego County. Several thousand fingerlings and yearlings were stocked in these waters. It appears that only the Lake Oroville and South Fork Stanislaus River populations are firmly established (Lambert 1980). The remainder apparently did not survive.

Micropterus punctulatus henshalli Hubbs and Bailey—Alabama spotted bass

This subspecies is thriving in Perris Lake, Riverside County. The original introduction consisted of 94 2-year-olds stocked by the California Department of Fish and Game in January 1974 (Brown, Aasen, and von Geldern 1977). An additional 29 fish were taken to the Department's Central Valleys Hatchery to provide a broodstock. These spotted bass were collected by the Alabama Department of Conservation and Natural Resources from Lewis Smith Lake, Alabama.

Reproduction of the bass held at Central Valleys Hatchery provided fish for a second introduction into Perris Lake in August 1974. In late 1974 between 2,000 and 3,000 fingerlings from this hatchery were stocked in Millerton Lake, Fresno County. In early 1975, this plant was supplemented with 150 adults collected from Perris Lake. Another 300 adults and subadults collected from Perris Lake in March and April 1977 were released in San Vicente Reservoir, San Diego County. Both the Millerton and San Vicente populations are successfully established. Additional bass from Perris have since been stocked in New Hogan Reservoir, Calaveras County; Lake Isabella, Kern County; and Lake Oroville, Butte County.

Micropterus salmoides salmoides (Lacepède)—northern largemouth bass

Micropterus salmoides floridanus (Lesueur)—Florida largemouth bass

The nominate subspecies is the form widely distributed throughout the State. The Florida largemouth bass was imported into California in May 1959. A shipment of about 20,400 fingerlings from Holt State Fish Hatchery near Pensacola, Florida, was planted in upper Otay Reservoir, San Diego County, on an experimental basis (Sasaki 1961; Bottroff and Lembeck 1978). A self-sustaining population was soon established and transplants were made to other San Diego County reservoirs. It is now established in other waters in the State.

PERCIDAE—perch family

Percina macrolepida Stevenson—bigscale logperch

In our 1959 check list we listed and described the introduction of *Percina caprodes,* the logperch, into California. Since then, Stevenson (1971) described the bigscale logperch from Texas. Subsequent examination of specimens from California revealed them to be *P. macrolepida* rather than *P. caprodes* (Sturgess 1976).

EMBIOTOCIDAE—surfperch family

Hysterocarpus traskii traskii Gibbons—Sacramento tule perch
Hysterocarpus traskii lagunae Hopkirk—Clear Lake tule perch
Hysterocarpus traskii pomo Hopkirk—Russian River tule perch

Hopkirk (1973:83–92) revised the genus *Hysterocarpus.* He described the tule perch from the Russian River as a new subspecies and remarked, "The subspecies *pomo* is adapted for existence in small rivers. In body shape and in certain meristic characters, it represents an evolutionary parallel, not a relative, of the nominate subspecies." In his description of the new subspecies of tule perch from the Clear Lake Basin in central California, Hopkirk noted that it ". . . is adapted for pelagic or lacustrine existence, as evidenced by the attenuate body, higher number of gill rakers, and silvery coloration." Remaining populations in the State are apparently referable to the nominate subspecies.

CICHLIDAE—cichlid family

Tilapia mossambica Peters—Mozambique tilapia

The first breeding population of this tilapia species in California was discovered in 1964 in a small pond and its tributary near the Salton Sea in Imperial County (St. Amant 1966). This population, which may no longer exist, originated from a nearby tropical fish farm (Sargent's). Subsequent authorized introductions in various ponds and waterways in the late 1960's and early 1970's for mosquito and aquatic weed control, plus unauthorized introductions and natural movement of fish from one area to another, have culminated in the establishment of the Mozambique tilapia in southern California.

Hoover and St. Amant (1970) observed free-living populations of *T. mossambica* in irrigation canals and drains in Bard Valley, Imperial County, in 1968. They remain abundant there as well as in similar habitat in the Palo Verde Valley, Imperial and Riverside counties. Isolated populations have been reported from drains in the Imperial Valley, Imperial County, and the Coachella Valley, Riverside County. Lake Elsinore in Riverside County and the Salton Sea support abundant, reproducing populations. The identity of this tilapia from the Salton

Sea, however, remains uncertain, having been variously identified as *T. mossambica* or *T. aurea*.

In recent years *T. mossambica* has established breeding populations in a series of watercourses entering the Pacific Ocean in Orange and Los Angeles counties (Knaggs 1977). They are concentrated in the estuarine portions of various flood control channels and channelized river beds such as the Los Angeles, Santa Ana, and San Gabriel rivers.

Tilapia zillii (Gervais)—redbelly tilapia

The redbelly tilapia was one of three tilapia species authorized by the Fish and Game Commission in 1971 for use in California. Its purported ability to control aquatic weeds was responsible for the interest in this species. During the early 1970's, it was stocked in several ponds in central California and in numerous ponds, canals, and drains in southern California. Except for the very southeastern corner of the State, it was believed that *T. zillii* could not survive winter temperatures and that small fish would have to be introduced periodically to achieve weed control. Howver, until killed by the exceptionally cold winter of 1972–73, they overwintered in the central California ponds. It was this unexpected tolerance to cold temperatures that prompted the Fish and Game Commission in 1974 to place the redbelly tilapia on the prohibited species list for that portion of the State north of the Tehachapi Mountains.

Stocking in southern California, on the other hand, led to the permanent establishment of *T. zillii* and the likelihood of further spread of this highly adaptable species. They are abundant and breeding in all drains entering the Salton Sea and are also abundant in the Sea itself (Black 1980). They are likely to be encountered in certain canals and ditches in Bard and Imperial valleys, Imperial County, and in the Coachella Valley, Riverside County. Breeding populations have been discovered in four backwaters of the Colorado River downstream from the Palo Verde Diversion Dam and in Lake Cahuilla, Riverside County. Two specimens have been reported from the marine environment near Huntington Beach and in Newport Bay, Orange County (Knaggs 1977).

GOBIIDAE—goby family

Acanthogobius flavimanus (Temminck and Schlegel)—yellowfin goby

This species was first collected by personnel of the California Department of Fish and Game in the San Joaquin River off Prisoners Point on 18 January 1963 (Brittan, Albrecht, and Hopkirk 1963). It soon spread rapidly (Brittan et al. 1970) and is now widely established in the Sacramento-San Joaquin Delta, the San Francisco Bay area, and various coastal lagoons. The origin of these fish is not known; they may have been carried in a ship's seawater system.

Tridentiger trigonocephalus (Gill)—chameleon goby

Miller and Lea (1972), who list this species as occurring in the shallows of both Los Angeles Harbor and San Francisco Bay, state that it was inadvertently introduced from the Orient. Moyle (1976:344) remarks that it, ". . . has not yet been collected in fresh water in California but can be expected there, since it occurs in brackish Lake Merritt in Oakland and in the lower reaches of streams in its native Asia." Hubbs and Miller (1965:44), however, refer to data indicating that Lake Merritt is a freshwater lake, although it connects directly with San Francisco Bay.

Forms and Names Removed from the Main List Since 1959

PETROMYZONTIDAE—lamprey family

Lampetra planeri (Bloch)—brook lamprey

Several different species of "brook lampreys" in California have been listed or identified as *Lampetra planeri* and we included this species in our 1959 list. It should be removed from California faunal lists as it is a European form not found in North America (W. I. Follett, pers. commun.).

OSMERIDAE—smelt family

Hypomesus olidus (Pallas)—pond smelt

The fish we listed in our 1959 check list under this name has since been described as a new species, *H. transpacificus,* by McAllister (1963).

SALMONIDAE—salmon and trout family

Salmo clarkii evermanni Jordan and Grinnell—San Gorgonio cutthroat trout

After finding a record that cutthroat trout from Lake Tahoe had been planted in the southern California stream from which *Salmo evermanni* was later obtained, Benson and Behnke (1961) closely compared the "type" and two "cotypes" of *evermanni* with specimens of *Salmo clarkii henshawi* from Lake Tahoe. They found no significant differences and concluded that *evermanni* was a synonym.

Salmo gairdnerii regalis Snyder—royal silver rainbow trout

La Rivers (1962) questioned the taxonomic validity of both *S. g. regalis* of Lake Tahoe and *S. g. smaragdus* of Pyramid Lake. He argues convincingly against the acceptance of these rainbow subspecies as Great Basin endemics, believing that the specimens examined by Snyder (1914, 1918) were probably either introduced rainbow or rainbow-cutthroat hybrids. Widespread stocking of rainbow trout in the Lahontan system beginning in the 1860's was likely the original source of these specimens.

One of us (Cordone) collected 226 rainbow trout from the limnetic zone of Lake Tahoe in the early 1960's. Seventy-three of these were marked fish, survivors from plants of hatchery-reared rainbow. Many of these specimens, both marked and unmarked, possessed the phenotypic appearance of the royal silver trout noted by Snyder (1918), "It is distinguished by the absence of spots, by the blue or green dorsal surface, the silvery sides and white belly, and the loose scales which, when the fish is caught, adhere to the fingers like bits of foil." Behnke (1972) examined some of these specimens and concluded, "The silvery, smoltlike appearance, supposedly diagnostic for *S. regalis* can be duplicated by hatchery rainbow trout after a period of life in Lake Tahoe."

CYPRINIDAE—carp or minnow family

Pimephales promelas confertus (Girard)—southwestern fathead minnow

We follow Taylor (1954:42) and Vandermeer (1966:465) in not recognizing subspecies in *Pimephales promelas,* primarily because most of the variation over its range appears to be clinal. Even if subspecies were recognized, the populations of the fathead minnow in California are from such diverse out-of-state localities that it would be difficult to single out subspecies.

Plagopterus argentissimus Cope—woundfin

Inclusion of this spiny-rayed cyprinid in our previous check lists was based on its occurrence in the Gila River to its mouth at Yuma, just across the Colorado River from California (Gilbert and Scofield 1898). It has now, however, been removed from the present list because it has not been taken even in the lower Gila River since 1894 (Miller and Lowe 1964), is known today only from the Virgin River system (Miller and Hubbs 1960; Minckley 1973:115), and there are no records of its actual occurence in California. It may be noted, however, that Miller and Lowe (1964) state that it has been used as a baitfish on the "lower Colorado River".

Rhinichthys osculus carringtonii (Cope)—Pacific speckled dace

W. I. Follett (pers. commun.) states: "We are not recognizing *Rhinichthys osculus carringtonii* (originally described from Warm Springs, Box Elder County, Utah) as occurring in California. Dr. Hubbs now regards as a misidentification *Agosia nubila carringtonii* Culver and Hubbs, 1917, Lorquinia, 1(2):83, from Santa Ana River, California." On this basis we are dropping this form from our list.

Siphateles bicolor formosus (Girard)—Sacramento tui chub

If this were a valid subspecies, its current name would be *Gila bicolor formosa.* Moyle (1976:164) comments on it as follows: "The name *G. b. formosa* was originally applied to tui chubs that were supposed to have lived in the Sacramento-San Joaquin Valley. Since only a few poorly preserved specimens of the form are known, the subspecies may be based on a mislabeled collection (C. L. Hubbs, pers. commun.)." For these reasons, we are dropping this form from the main list.

CATOSTOMIDAE—sucker family

Catostomus latipinnis Baird and Girard—flannelmouth sucker

This species, native to the Colorado River system, is now found only in Salt River Canyon, the Virgin River, and the mainstem Colorado River upstream from Lake Mead (Minckley 1973:157). Like *Plagopterus argentissimus,* it may never have occurred in the California portion of the Colorado River except for an occasional specimen washed down from upstream waters.

Ictiobus cyprinella (Valenciennes)—bigmouth buffalo

This exotic species was included in the first two lists on the basis of its occurrence in several reservoirs of the Los Angeles Aqueduct system in Los Angeles and Inyo counties following its illegal introduction in the 1940's, presumably by commercial fishermen (Evans 1950). However, none has been collected from these waters since the late 1960's and they probably no longer exist in the State (F. G. Hoover, pers. commun.). Since this species, along with the black buffalo, *Ictiobus niger,* and the smallmouth buffalo, *Ictiobus bubalus,* are present in Arizona waters, they may be expected on occasion to find their way into the lower Colorado River and connected waters. On the basis of a photograph, C. L. Hubbs and J. A. St. Amant identified a specimen collected from a waterway in southern California in 1969 as *I. bubalus.*

Pantosteus lahontan Rutter—Lahontan mountain-sucker

Smith (1966) united *Pantosteus lahontan* and *P. platyrhynchus* as *Catostomus platyrhynchus,* which replaces *P. lahontan* in our present list.

ICTALURIDAE—North American freshwater catfish family

Ictalurus melas melas (Rafinesque)—northern black bullhead
Ictalurus natalis natalis (Lesueur)—northern yellow bullhead
Ictalurus nebulosus nebulosus (Lesueur)—northern brown bullhead

We follow Hubbs et al. (1979) and Bailey (1956:328–329; pers. commun.) in dropping recognition of these trinomials. They probably represent only clinal variations.

CENTRARCHIDAE—sunfish family

Micropterus dolomieu dolomieu Lacepède—northern smallmouth bass

We follow Hubbs et al. (1979) and Bailey (1956:328–329; pers. commun.) in dropping recognition of this trinomial. It probably represents only clinal variation.

ELEOTRIDIDAE—sleeper family

Eleotris picta Kner and Steindachner—spotted sleeper

This species was added to the 1959 list on the basis of a single specimen caught by a fisherman at the canal spillway between Winterhaven and the Colorado River in Imperial County on 16 April 1952 (Hubbs 1953). However, none has been taken from California waters since that time (Minckley 1973:259; Moyle 1976:70).

REVISED MAIN LIST

Native Species and Established Exotic Species

This revised list consists of 124 full species, which may be subdivided as follows: 66 native freshwater and anadromous species (including 6 which are probably extinct), 13 native euryhaline or marine species which occasionally penetrate into fresh water, and 45 introduced species. The 124 species comprise 25 families and 64 genera.

Species which have been introduced into California waters are denoted by an asterisk (*), marine or euryhaline fishes which occur occasionally in fresh water by an "O", and extinct species by a dagger (†).

PETROMYZONTIDAE—lamprey family

1. *Lampetra ayresii* (Günther)—river lamprey
2. *Lampetra folletti* (Vladykov and Kott)—Modoc brook lamprey
3. *Lampetra hubbsi* (Vladykov and Kott)—Kern brook lamprey
4. *Lampetra lethophaga* Hubbs—Pit-Klamath brook lamprey
5. *Lampetra pacifica* Vladykov—Pacific brook lamprey
6. *Lampetra richardsoni* Vladykov and Follett—western brook lamprey
7. *Lampetra tridentata* (Gairdner)—Pacific lamprey

ACIPENSERIDAE—sturgeon family

8. *Acipenser medirostris* Ayres—green sturgeon
   8a. *Acipenser medirostris medirostris* Ayres—American green sturgeon
9. *Acipenser transmontanus* Richardson—white sturgeon

ELOPIDAE—tenpounder family

10. *Elops affinis* Regan—machete O

CLUPEIDAE—herring family

11. *Alosa sapidissima* (Wilson)—American shad *
12. *Clupea harengus* Linnaeus—herring O
    12a. *Clupea harengus pallasii* Valenciennes—Pacific herring O
13. *Dorosoma petenense* (Günther)—threadfin shad *

OSMERIDAE—smelt family

14. *Hypomesus nipponensis* McAllister—freshwater smelt *
15. *Hypomesus pretiosus* (Girard)—surf smelt O
16. *Hypomesus transpacificus* McAllister—delta smelt
17. *Spirinchus thaleichthys* (Ayres)—longfin smelt O
18. *Thaleichthys pacificus* (Richardson)—eulachon

COREGONIDAE—whitefish family

19. *Prosopium williamsoni* (Girard)—mountain whitefish

SALMONIDAE—salmon and trout family

20. *Oncorhynchus gorbuscha* (Walbaum)—pink salmon
21. *Oncorhynchus keta* (Walbaum)—chum salmon
22. *Oncorhynchus kisutch* (Walbaum)—coho salmon (silver salmon)
23. *Oncorhynchus nerka* (Walbaum)—sockeye salmon (anadromous form); kokanee salmon (freshwater form *)
24. *Oncorhynchus tshawytscha* (Walbaum)—chinook salmon (king salmon)
25. *Salmo aguabonita* Jordan—golden trout
    25a. *Salmo aguabonita aguabonita* Jordan—South Fork Kern golden trout
    25b. *Salmo aguabonita whitei* Evermann—Little Kern golden trout
26. *Salmo clarkii* Richardson—cutthroat trout
    26a. *Salmo clarkii clarkii* Richardson—coast cutthroat trout
    26b. *Salmo clarkii henshawi* Gill and Jordan—Lahontan cutthroat trout
    26c. *Salmo clarkii pleuriticus* Cope—Colorado River cutthroat trout
    26d. *Salmo clarkii seleniris* Snyder—Paiute cutthroat trout
27. Salmo gairdnerii Richardson—rainbow trout
    27a. *Salmo gairdnerii gairdnerii* Richardson—steelhead rainbow trout
    27b. *Salmo gairdnerii aquilarum* Snyder—Eagle Lake rainbow trout
    27c. *Salmo gairdnerii gilberti* Jordan—Kern River rainbow trout
    27d. *Salmo gairdnerii kamloops* (Jordan)—Kamloops rainbow trout *
    27e. *Salmo gairdnerii stonei* Jordan—Shasta rainbow trout
28. *Salmo trutta* Linnaeus—brown trout *
29. *Salvelinus confluentus* (Suckley)—bull trout †
30. *Salvelinus fontinalis* (Mitchill)—brook trout *
31. *Salvelinus malma* (Walbaum)—Dolly Varden †
32. *Salvelinus namaycush* (Walbaum)—lake trout *
    32a. *Salvelinus namaycush namaycush* (Walbaum)—common lake trout *

CYPRINIDAE—carp or minnow family

33. *Carassius auratus* (Linnaeus)—goldfish *
34. *Cyprinus carpio* Linnaeus—common carp *
35. *Gila bicolor* (Girard)—tui chub
    35a. *Gila bicolor bicolor* (Girard)—Klamath tui chub
    35b. *Gila bicolor mohavensis* (Snyder)—Mohave tui chub
    35c. *Gila bicolor obesa* (Girard)—Lahontan coarseraker tui chub
    35d. *Gila bicolor pectinifer* (Snyder)—Lahontan fineraker tui chub
    35e. *Gila bicolor snyderi* Miller—Owens tui chub
    35f. *Gila bicolor thalassina* (Cope)—Goose Lake tui chub
    35g. *Gila bicolor vaccaceps* Bills and Bond—Cowhead Lake tui chub

36. *Gila coerulea* (Girard)—blue chub
37. *Gila crassicauda* (Baird and Girard)—thicktail chub †
38. *Gila elegans* Baird and Girard—bonytail chub †
39. *Gila orcuttii* (Eigenmann and Eigenmann)—arroyo chub
40. *Hesperoleucus symmetricus* (Baird and Girard)—western roach
    40a. *Hesperoleucus symmetricus symmetricus* (Baird and Girard)—Sacramento western roach
    40b. *Hesperoleucus symmetricus mitrulus* Snyder—upper Pit western roach
    40c. *Hesperoleucus symmetricus navarroensis* Snyder—Navarro western roach
    40d. *Hesperoleucus symmetricus parvipinnis* Snyder—Gualala western roach
    40e. *Hesperoleucus symmetricus subditus* Snyder—Monterey western roach
    40f. *Hesperoleucus symmetricus venustus* Snyder—Venus western roach
41. *Lavinia exilicauda* Baird and Girard—hitch
    41a. *Lavinia exilicauda exilicauda* Baird and Girard—Sacramento hitch
    41b. *Lavinia exilicauda chi* Hopkirk—Clear Lake hitch
    41c. *Lavinia exilicauda harengus* Girard—Monterey hitch
42. *Mylopharodon conocephalus* (Baird and Girard)—hardhead
43. *Notemigonus crysoleucas* (Mitchill)—golden shiner *
44. *Notropis lutrensis* (Baird and Girard)—red shiner *
45. *Orthodon microlepidotus* (Ayres)—Sacramento blackfish
46. *Pimephales promelas* Rafinesque—fathead minnow *
47. *Pogonichthys ciscoides* Hopkirk—Clear Lake splittail †
48. *Pogonichthys macrolepidotus* (Ayres)—Sacramento splittail
49. *Ptychocheilus grandis* (Ayres)—Sacramento squawfish
50. *Ptychocheilus lucius* Girard—Colorado squawfish †
51. *Rhinichthys osculus* (Girard)—speckled dace
    51a. *Rhinichthys osculus klamathensis* (Evermann and Meek)—Klamath speckled dace
    51b. *Rhinichthys osculus nevadensis* Gilbert—Amargosa speckled dace
    51c. *Rhinichthys osculus robustus* (Rutter)—Lahontan speckled dace
52. *Richardsonius egregius* (Girard)—Lahontan redside
53. *Tinca tinca* (Linnaeus)—tench *

CATOSTOMIDAE—sucker family

54. *Catostomus fumeiventris* Miller—Owens sucker
55. *Catostomus luxatus* (Cope)—Lost River sucker
56. *Catostomus microps* Rutter—Modoc sucker
57. *Catostomus occidentalis* Ayres—western sucker
    57a. *Catostomus occidentalis occidentalis* Ayres—Sacramento western sucker
    57b. *Catostomus occidentalis humboldtianus* Snyder—Humboldt western sucker
    57c. *Catostomus occidentalis lacusanserinus* Fowler—Goose Lake western sucker
    57d. *Catostomus occidentalis mniotiltus* Snyder—Monterey western sucker
58. *Catostomus platyrhynchus* (Cope)—mountain sucker
59. *Catostomus rimiculus* Gilbert and Snyder—Klamath smallscale sucker
60. *Catostomus santaanae* (Snyder)—Santa Ana sucker
61. *Catostomus snyderi* Gilbert—Klamath largescale sucker
62. *Catostomus tahoensis* Gill and Jordan—Tahoe sucker
63. *Chasmistes brevirostris* Cope—shortnose sucker
64. *Xyrauchen texanus* (Abbott)—humpback sucker

COBITIDIDAE—loach family

65. *Misgurnus anguillicaudatus* (Cantor)—Oriental weatherfish *

ICTALURIDAE—North American freshwater catfish family

66. *Ictalurus catus* (Linnaeus)—white catfish *
67. *Ictalurus furcatus* (Lesueur)—blue catfish *
68. *Ictalurus melas* (Rafinesque)—black bullhead *
69. *Ictalurus natalis* (Lesueur)—yellow bullhead *
70. *Ictalurus nebulosus* (Lesueur)—brown bullhead *
71. *Ictalurus punctatus* (Rafinesque)—channel catfish *
72. *Pylodictis olivaris* (Rafinesque)—flathead catfish *

CYPRINODONTIDAE—killifish family

73. *Cyprinodon macularius* Baird and Girard—desert pupfish
74. *Cyprinodon milleri* LaBounty and Deacon—Cottonball Marsh pupfish
75. *Cyprinodon nevadensis* Eigenmann and Eigenmann—Nevada pupfish
    75a. *Cyprinodon nevadensis nevadensis* Eigenmann and Eigenmann—Saratoga Nevada pupfish
    75b. *Cyprinodon nevadensis amargosae* Miller—Amargosa Nevada pupfish
    75c. *Cyprinodon nevadensis calidae* Miller—Tecopa Nevada pupfish †
    75d. *Cyprinodon nevadensis shoshone* Miller—Shoshone Nevada pupfish †
76. *Cyprinodon radiosus* Miller—Owens pupfish
77. *Cyprinodon salinus* Miller—Salt Creek pupfish
78. *Fundulus parvipinnis* Girard—California killifish
    78a. *Fundulus parvipinnis parvipinnis*—southern California killifish
79. *Lucania parva* (Baird and Girard)—rainwater killifish *

POECILIIDAE—livebearer family

80. *Gambusia affinis* (Baird and Girard)—mosquitofish *
    80a. *Gambusia affinis affinis* (Baird and Girard)—western mosquitofish *
81. *Poecilia latipinna* (Lesueur)—sailfin molly *
82. *Poecilia mexicana* Steindachner—shortfin molly *
    82a. *Poecilia mexicana mexicana* Steindachner—Orizaba shortfin molly *
83. *Poeciliopsis gracilis* (Heckel)—porthole livebearer *

ATHERINIDAE—silverside family

84. *Atherinops affinis* (Ayres)—topsmelt O
85. *Menidia audens* Hay—Mississippi silverside *

GASTEROSTEIDAE—stickleback family

86. *Gasterosteus aculeatus* Linnaeus—threespine stickleback
    86a. *Gasterosteus aculeatus aculeatus* Linnaeus—armored threespine stickleback
    86b. *Gasterosteus aculeatus microcephalus* Girard—semiarmored threespine stickleback
    86c. *Gasterosteus aculeatus williamsoni* Girard—unarmored threespine stickleback

SYNGNATHIDAE—pipefish family

87. *Syngnathus leptorhynchus* Girard—bay pipefish O

COTTIDAE—sculpin family

88. *Clinocottus acuticeps* (Gilbert)—sharpnose sculpin O
89. *Cottus aleuticus* Gilbert—coastrange sculpin
90. *Cottus asper* Richardson—prickly sculpin
91. *Cottus asperrimus* Rutter—rough sculpin
92. *Cottus beldingii* Eigenmann and Eigenmann—Paiute sculpin
93. *Cottus gulosus* (Girard)—riffle sculpin
94. *Cottus klamathensis* Gilbert—marbled sculpin
95. *Cottus perplexus* Gilbert and Evermann—reticulate sculpin
96. *Cottus pitensis* Bailey and Bond—Pit sculpin
97. *Leptocottus armatus* Girard—Pacific staghorn sculpin O
    97a. *Leptocottus armatus armatus* Girard—northern Pacific staghorn sculpin O
    97b. *Leptocottus armatus australis* Hubbs—southern Pacific staghorn sculpin O

PERCICHTHYIDAE—temperate bass family

98. *Morone chrysops* (Rafinesque)—white bass *
99. *Morone saxatilis* (Walbaum)—striped bass *

CENTRARCHIDAE—sunfish family

100. *Archoplites interruptus* (Girard)—Sacramento perch
101. *Lepomis cyanellus* Rafinesque—green sunfish *
102. *Lepomis gibbosus* (Linnaeus)—pumpkinseed *
103. *Lepomis gulosus* (Cuvier)—warmouth *
104. *Lepomis macrochirus* Rafinesque—bluegill *
    104a. *Lepomis macrochirus macrochirus* Rafinesque—northern bluegill *
    104b. *Lepomis macrochirus purpurescens* Cope—southeastern bluegill *
105. *Lepomis microlophus* (Günther)—redear sunfish *
106. *Micropterus coosae* Hubbs and Bailey—redeye bass *

107. *Micropterus dolomieu* Lacepède—smallmouth bass *
108. *Micropterus punctulatus* (Rafinesque)—spotted bass *
    108a. *Micropterus punctulatus punctulatus* (Rafinesque)—northern spotted bass *
    108b. *Micropterus punctulatus henshalli* Hubbs and Bailey—Alabama spotted bass *
109. *Micropterus salmoides* (Lacepède)—largemouth bass *
    109a. *Micropterus salmoides salmoides* (Lacepède)—northern largemouth bass *
    109b. *Micropterus salmoides floridanus* (Lesueur)—Florida largemouth bass *
110. *Pomoxis annularis* Rafinesque—white crappie *
111. *Pomoxis nigromaculatus* (Lesueur)—black crappie *

PERCIDAE—perch family

112. *Perca flavescens* (Mitchill)—yellow perch *
113. *Percina macrolepida* Stevenson—bigscale logperch *

EMBIOTOCIDAE—surfperch family

114. *Cymatogaster aggregata* Gibbons—shiner perch O
115. *Hysterocarpus traskii* Gibbons—tule perch
    115a. *Hysterocarpus traskii traskii* Gibbons—Sacramento tule perch
    115b. *Hysterocarpus traskii lagunae* Hopkirk—Clear Lake tule perch
    115c. *Hysterocarpus traskii pomo* Hopkirk—Russian River tule perch

CICHLIDAE—cichlid family

116. *Tilapia mossambica* (Peters)—Mozambique tilapia *
117. *Tilapia zillii* (Gervais)—redbelly tilapia *

MUGILIDAE—gray mullet family

118. *Mugil cephalus* Linnaeus—striped mullet O

GOBIIDAE—goby family

119. *Acanthogobius flavimanus* (Temminck and Schlegel)—yellowfin goby *
120. *Clevelandia ios* (Jordan and Gilbert)—arrow goby O
121. *Eucyclogobius newberryi* (Girard)—tidewater goby
122. *Gillichthys mirabilis* Cooper—longjaw mudsucker O
123. *Tridentiger trigonocephalus* (Gill)—chameleon goby O *

PLEURONECTIDAE—righteye flounder family

124. *Platichthys stellatus* (Pallas)—starry flounder O
    124a. *Platichthys stellatus rugosus* Girard—southern starry flounder O

REVISED SUPPLEMENTARY LISTS

Native Species—Extinct in California

We have included in this section only those native species which, at least according to the literature, at one time were well established. Not included are the woundfin, *Plagopterus argentissimus,* and the flannelmouth sucker, *Catostomus latipinnis,* which rarely, if ever, entered California waters. To avoid confusion, we have also omitted, both from this and the main list, the Clear Lake minnow which was described by Hopkirk (1973:57–59) as *Endemichthys grandipinnis,* from specimens last collected in 1939 and 1940. He observed that it was apparently extinct. He is now reconsidering its generic allocation (J. D. Hopkirk, pers. commun.).

Excluding the above, we believe that the following eight native fishes no longer exist in California.

SALMONIDAE—salmon and trout family

Salvelinus confluentus (Suckley)—bull trout
Salvelinus malma (Walbaum)—Dolly Varden

These species (there is some question that at one time both existed in the McCloud River) have likely become extinct in California as a result of man-made environmental changes and the introduction of exotic trout into the McCloud River drainage. The last known specimens, probably bull trout, were taken in 1975 (Moyle 1976:146). Intensive sampling of the McCloud River and its tributaries in recent years has failed to locate either species (S. J. Nicola, pers. commun).

CYPRINIDAE—carp or minnow family

Gila crassicauda (Baird and Girard)—thicktail chub

This chub was once common in the Central Valley, Clear Lake in Lake County, and at least one tributary to south San Francisco Bay. A combination of man-caused habitat changes and the introduction of exotic fishes has led to its apparent extinction (Miller 1963). The last known specimen was taken in 1957 from Steamboat Slough in the Sacramento River Delta (Calif. Dep. Fish and Game 1978). A report to Moyle (1976:172) that a specimen was collected from Cache Slough, near Rio Vista, in 1958 was in error (P. B. Moyle, pers. commun.).

Gila elegans Baird and Girard—bonytail chub

This species, listed in our 1959 list as *Gila robusta elegans,* Colorado River bonytail chub, has not been found in the California portion of the Colorado River in recent years and may be considered extinct in the State (Colorado River Wildlife Council 1977; Calif. Dep. Fish and Game 1978).

Pogonichthys ciscoides Hopkirk—Clear Lake splittail

It was not until Hopkirk (1973) published the results of his studies that the Clear Lake splittail was recognized as a distinct species. By this time it was probably already extinct, since none had been collected since the late 1960's. Cook, Moore, and Conners (1966) described the early history of the species. It was very abundant until the early 1940's, when it declined drastically, and occasional resurgences did nothing to halt the overall decline. Habitat destruction and exotic fishes are believed responsible for its extinction.

Ptychocheilus lucius Girard—Colorado squawfish

Although still present in a few localities in the upper Colorado River drainage, the Colorado squawfish apparently has become extinct in California waters. Once abundant in the lower Colorado River, it was probably already extinct in this area by the early 1960's (Moyle 1976:195). It has not been collected there since 1952 (Calif. Dep. Fish and Game 1978). Environmental degradation and exotic fishes are again believed responsible for the loss.

CYPRINODONTIDAE—killifish family

Cyprinodon nevadensis calidae Miller—Tecopa Nevada pupfish

This subspecies, originally from north and south Tecopa Hot Springs, Inyo County, has become extinct in recent years (Moyle 1976:256) as a result of activities by man which led to destruction of its habitat.

Cyprinodon nevadensis shoshone Miller—Shoshone Nevada pupfish

This subspecies, from Shoshone Springs, Inyo County, like *C.n. calidae,* has also become extinct in recent years (Moyle 1976:256) as a result of activities by man leading to destruction of its habitat.

Exotic Species—Unsuccessfully Introduced or of Uncertain Status

It is extremely difficult to establish rigid criteria for the inclusion or exclusion of fishes in the list that follows. Some situations are obvious. For example, we have included a species in this list whenever it was introduced as part of a planned program or was known to have had a large escapement of the species, say from a tropical fish farm, even if subsequent investigations have failed to locate it. On the other hand, if only a single specimen or a very few specimens, even if positively identified, were recorded, we have omitted such species from the main list but have tried to mention them below. Obviously, these are judgmental assessments.

The occurrence of a single or a few specimens of tropical or other ornamental fishes probably represents releases by home aquarists. Brittan and Grossman (1979) describe a specimen of pacu, *Colossoma* sp., native to South America, caught by an angler in 1977 from the Sacramento River in Yolo County. Another pacu was reportedly taken from the California Aqueduct in 1979 (Calif. Dep. Fish and Game, Region 5 monthly report for November 1979). Minckley (1973:185) refers to a specimen of walking catfish, *Clarias batrachus,* taken by an angler from the All American Canal in Imperial County west of Yuma, Arizona. Another specimen was taken by an angler from Legg Lake, Los Angeles County (J. A. St. Amant, pers. commun.). A South American aruana, *Osteoglossum bicirrhosum,* was caught by an angler in Lake Berryessa (Calif. Dep. Fish and Game, Region 3 news release for 18 June 1972). Two mature tiger barbs, *Barbus tetrazona,* were collected in 1963 from the small stream flowing from Warm Springs Sanctuary in Owens Valley, Inyo County (Naiman and Pister 1974). None has been taken since then, despite repeated collecting efforts.

Escapements and releases from ornamental fish farms apparently have been the source of a number of established exotics, such as *Misgurnus anguillicaudatus, Poecilia latipinna, P. mexicana,* and *Poeciliopsis gracilis.* Other ornamental species have escaped but in small numbers, and fortunately have not established permanent populations. For example, among the exotics collected by St. Amant and Hoover (1969) from the Westminster flood control channel in Orange County in 1968 were the guppy, *Lebistes reticulatus;* green swordtail, *Xiphophorus hellerii;* southern platyfish, *X. maculatus;* variable platyfish, *X. variatus;* molly, *Poecilia sphenops;* zebra danio, *Brachydanio rerio;* and angelfish, *Pterophyllum* sp. None of these has since been taken in this channel, despite repeated collecting attempts. Mearns (1975) took a specimen of *Xiphophorus hellerii* in 1974 from a drain to the Salton Sea, and G. F. Black (pers. commun.) collected another from the same drain in 1979.

The 1959 supplementary list included 14 species of exotic bait fishes that were being used along the Colorado River (Miller 1952). None of these has become established in California and apparently they are no longer being used as bait in this area, so we have deleted them from the list that follows.

The exotic fishes listed below fall into several groups:

1. Fishes known to have been introduced but which have not survived; e.g., No. 2.
2. Fishes reported, possibly erroneously, to have been introduced, but which have not survived; e.g., No. 9.
3. Fishes which have been reported from this State but whose identification is questioned by the authors; e.g., No. 21.

4. Fishes which have not been recorded from the State for many years; e.g., No. 24.

As will be seen by our annotations, we know of no demonstrable evidence that any of them are successfully established in the fresh waters of California today.

As the general sources for the history and lack of success of most of these introductions are fairly well known, there is little point in listing all the references concerning the status of these fishes. We have alluded to specific literature only when our opinion differs from that of the authors cited, or when such inclusion serves to clarify the exact status of the species.

ANGUILLIDAE—freshwater eel family

1. *Anguilla rostrata* (Lesueur)—American eel

Introduced in 1874, 1879, and 1882. There are no authentic records of survival. However, an occasional eel is collected from various waters in the State. Skinner (1971) reported the capture of two eels from the Sacramento-San Joaquin Delta. The first, taken in 1964, was identified by C. L. Hubbs as an American eel. The second, caught in 1969, was identified as a European eel, *Anguilla anguilla* Linnaeus, by W. I. Follett. Skinner suggested that the most logical explanation for the occurrence of both eels is that they were transported from abroad in the ballast of commercial ships. In 1978 an unidentified species of *Anguilla* was captured in the Los Angeles River (J. A. St. Amant, pers. commun.).

PLECOGLOSSIDAE—ayu family

2. *Plecoglossus altivelis* Temminck and Schlegel—ayu

Large numbers of eggs and fry of this native Japanese food and sport species were stocked in California on the recommendation of Dr. John W. DeWitt, Professor of Fisheries at Humboldt State University, Arcata. Following approval from the Fish and Game Commission, plants of this species were made annually from 1961 through 1965. About 3,845,000 eggs and fry were stocked during this period: 200,000 eggs and fry in Morris Lake, Mendocino County; 395,000 eggs in Ruth Reservoir, Trinity County; and 3,250,000 eggs and fry in the Eel River below Fortuna, Humboldt County (J. W. DeWitt, pers. commun.). No survivors were reported.

COREGONIDAE—whitefish family

3. *Coregonus clupeaformis* (Mitchill)—lake whitefish

3a. *Coregonus clupeaformis clupeaformis* (Mitchill)—Great Lakes whitefish

All introductions of this whitefish were made during the last century. Even the few old reports of recapture (circa 1880) are considered highly dubious.

4. *Prosopium gemmiferum* (Snyder)—Bonneville cisco

In January of 1964, 1965, and 1966, 21,506 spawning Bonneville cisco and about 250,000 cisco eggs were collected from Bear Lake, Utah-Idaho, and transported to Lake Tahoe (Frantz and Cordone 1965, 1967). About 205,000 green eggs, 3,000 eyed eggs and alevins, and 15,888 ripe adults were released in Lake Tahoe over the 3-year span. None is known to have survived.

SALMONIDAE—salmon and trout family

5. *Salmo clarkii* Richardson—cutthroat trout

5a. *Salmo clarkii lewisi* (Girard)—Yellowstone cutthroat trout

Several shipments of cutthroat trout eggs have been brought in from other states, and plants made in California waters. It is probable that most of them were *S. c. lewisi.* There are no records of survival.

6. *Salmo salar* Linnaeus—Atlantic salmon (anadromous form); landlocked Atlantic salmon (freshwater form)

Both forms have been planted several times. The old records of their survival may be dubious; there are no authentic recent records.

7. *Thymallus arcticus* (Pallas)—Arctic grayling

Several early attempts were made to introduce this form, and it apparently met with a brief success in Yosemite National Park following plants made during the 1929–1933 period. However, the last authentic report of its survival there (in Grayling Lake) appears to have been in 1934.

More recently, the California Department of Fish and Game imported large numbers of grayling eggs from Arizona and Wyoming. Resultant fry and fingerlings were stocked in one stream and 57 high mountain lakes scattered from the southern Sierra Nevada into northern California. Approximately 156,000 fish were released during the period 1969 to 1975. Good survival and growth were documented at many of these waters but actual reproduction has not been confirmed.

ESOCIDAE—pike family

8. *Esox americanus* Gmelin—redfin pickerel

8a. *Esox americanus vermiculatus* Lesueur—grass pickerel

9. *Esox lucius* Linnaeus—northern pike

E. lucius was supposedly introduced in 1891, but one of the fish resulting from this shipment was identified in 1896 as *E. vermiculatus* (now *E. a. vermiculatus*). Possibly both species were included. There are no records of capture of either species after 1896.

10. *Esox masquinongy* Mitchill—muskellunge

10a. *Esox masquinongy ohioensis* Kirtland—Ohio muskellunge

Introduced into Lake Merced, San Francisco County, in 1893. None survived.

CHANIDAE—milkfish family

11. *Chanos chanos* (Forsskål)—milkfish

Milkfish from the Hawaiian Islands were planted in a stream in Solano County in 1877. There are no records of their survival there. The species is an ocean fish which occasionally enters fresh water.

CYPRINIDAE—carp or minnow family

12. *Ctenopharyngodon idella* (Valenciennes)—grass carp

Illegal introductions of grass carp into California have been made in the past and may still be continuing. Despite the fact that this species of Chinese carp is officially prohibited in the State, and thus may not be imported, transported, or possessed, some farm pond owners have been importing grass carp from commercial fish farmers in Arkansas and Pennsylvania. The Department has thus far uncovered four instances of grass carp introductions: 12 fingerlings were released in a small pond in Ventura County in 1975, 48 fingerlings were planted in a small pond in El Dorado County in 1975, 2,800 fingerlings and 200 0.34-kg fish were released in seven ponds on a ranch in Napa County in 1975, and 20 grass carp fingerlings were stocked in a small pond in Mendocino County in 1978. The latter plant apparently did not survive the trip from Pennsylvania, but the remaining lots from Arkansas survived and were healthy and growing rapidly until they were removed by the Department.

In May 1980 about 850 hybrids of female grass carp and males of another Chinese carp, the bighead carp, *Aristichthys nobilis*, were released in several man-made waterways in the Coachella Valley. Further releases are anticipated as part of a study to assess the aquatic weed control potential of this hybrid.

ICTALURIDAE—North American freshwater catfish family

13. *Ictalurus platycephalus* (Girard)—flat bullhead

On the basis of a survey made in 1925, Coleman (1930) recorded "The Great Blue, or Forked-Tail Cat—*Ictalurus furcatus*, Cuv. and Vincen.," and "The Brown-Spotted Cat—*Ameirus* [sic.] *platycephalus*, Girard," from Clear Lake, Lake County. Neither has been recorded from the Lake since that time, despite extensive collecting. We believe that Coleman confused *Ictalurus catus* (found in Clear Lake and often called "forked-tail catfish" or "blue cat") with his "*furcatus*". We suspect that his record of *I. platycephalus* is based upon his erroneous interpretation of fishermen's reports.

ORYZIIDAE—tooth-carp family

14. *Oryzias latipes* (Temminck and Schlegel)—medaka

The statements by Snyder (1935), "It has been found in San Francisquito Creek", and Coates (1942:185), ". . . this fish has been turned loose in . . . parts of California, where it is reported to be thriving", are the sole bases for its admission to this list. In a conversation with Snyder on 21 March 1943, he told us (Dill) that some of his students had collected this form in San Francisquito Creek, Santa Clara County. He did not recall the date or other circumstances.

CYPRINODONTIDAE—killifish family

15. *Cynolebias bellottii* Steindachner—Argentine pearlfish

This was the most widely used of the so-called "annual fishes" stocked in several locations in the State, principally in Butte, Kern, and Riverside counties, for mosquito control purposes. Bay (1966) described the first field tests with this species at the University of California, Riverside. Survivors of the tests persisted in the Riverside ponds for 5 years despite repeated floodings and dryings but finally died out (E. F. Legner, Univ. Calif., Riverside, pers. commun.). Additional field tests with the Argentine pearlfish were described by E. C. Bay (pers. commun.). Tests in experimental ponds were conducted in 1966 and 1967 in Kern and Butte counties. The species failed to become established.

Experimental rice plots and ponds on the grounds of the Butte County Mosquito Abatement District were the sites of tests conducted in 1973 and 1974 using the black pearlfish, *Cynolebias nigripinnis,* and White's pearlfish, *Cynolebias whitei* (K. J. Hiscox, Butte County Mosquito Abatement Dist., pers. commun.). The fish did not reproduce and the study was terminated.

POECILIIDAE—livebearer family

16. *Gambusia affinis holbrooki* Girard—eastern mosquitofish

The eastern mosquitofish has been widely distributed in the public waters of California by various mosquito abatement districts (E. F. Legner and K. J. Hiscox, pers. commun.). It is believed to be more tolerant of colder temperatures than the western mosquitofish. The two subspecies hybridize readily and in California collections of pure *G. a. holbrooki* have yet to be made in the wild.

17. *Lebistes reticulatus* (Peters)—guppy

Besides the almost certain release of guppies by tropical fish fanciers, guppies have been stocked on numerous occasions in wastewater treatment ponds throughout the State where access to public waters is possible (K. J. Hiscox, pers. commun.). In 1968 the Fish and Game Commission approved a request by the University of California, Riverside, to stock guppies in dairy and poultry waste lagoons in San Bernardino County (E. C. Bay, pers. commun.). Also in 1968, the Commission permitted the Kings Mosquito Abatement District to release guppies in lower Mill Creek in Tulare and Kings counties. None of the foregoing introductions led to the establishment of permanent populations. However, wild populations can be anticipated in suitable areas with year-round warmwater temperatures.

18. *Rivulus hartii* (Boulenger)—Trinidad rivulus

St. Amant (1970) first observed and collected this species in a small ditch near a tropical fish farm in Imperial County in 1967. It was identified by C. L. Hubbs. Additional specimens were collected in 1968 and both adults and juveniles were taken in 1969. The population has since disappeared.

19. *Xiphophorus variatus* (Meek)—variable platyfish

St. Amant and Sharp (1971) collected approximately 200 adult and juvenile *Xiphophorus variatus,* native to Mexico, from a drain ditch 6.4 km east of Oasis, Riverside County, on 24 December 1969. C. L. Hubbs confirmed the identification. This was the first record of an established population, but it has since died out.

ATHERINIDAE—silverside family

20. *Labidesthes sicculus* (Cope)—brook silverside

The brook silverside was one of five species authorized by the Fish and Game Commission in 1963–64 for introduction into experimental ponds beside Clear Lake. These ponds, plus a deep well, were constructed in 1963 by the Lake County Mosquito Abatement District " . . . for the express purpose of evaluating experimental fishes and their influence on biological productivity" (Cook 1968). The *Labidesthes,* obtained from Ohio, did well in one pond for 3 years and reproduced, but then died out from unknown causes.

CENTRARCHIDAE—sunfish family[4]

21. *Ambloplites rupestris* (Rafinesque)—rock bass

It is recorded in the literature as having been introduced in 1874 and again in 1891, and another record of a plant of "rock bass" in 1917 was furnished by E. H. Glidden of the then California Division of Fish and Game. Brief statements by Neale (1931) and Anon. (1934) as to its limited success in California, and its occasional listing in State fish rescue records up to 1939, are the only bases for belief that this fish ever endured. The terminology used in these rescue records (published in the Biennial Reports of the California Division of Fish and Game) has often been inexact. We have been unable to find a single verifiable record of the occurrence of the rock bass in California.

22. *Enneacanthus gloriosus* (Holbrook)—bluespotted sunfish

This species is listed in the accession list for Steinhart Aquarium as having been collected in March 1931 in the vicinity of Willows, California. The identification was made by Alvin Seale, but the specimens were not saved. We believe this to be a misidentification.

23. *Lepomis macrochirus* Rafinesque—bluegill

23a. *Lepomis macrochirus speciosus* (Baird and Girard)—southwestern bluegill

According to Miller (1952), "The southwestern bluegill . . . is also now evidently established in the Colorado River through introduction . . . (*fide* C. L. Hubbs in letter of 10 May 1951, to R. D. Beland, and letter from Beland of 23 August 1951 to W. A. Dill)." Its current status is unknown.

PERCIDAE—perch family

24. *Stizostedion vitreum* (Mitchill)—walleye

Miller (1967) summarized the history of walleye introductions in California. The first introduction occurred in 1874, when 16 fish from the Missiquoi River in Vermont were stocked in the Sacramento River near Sacramento. One was caught by an angler but nothing further was recorded from the plant.

The second attempt spanned the years 1959 to 1963, when the California Department of Fish and Game, through the cooperation of the Minnesota Conservation Department, secured large numbers of eggs from walleye captured in the Detroit River, Minnesota. About 5,350,000 fry and 34,590 fingerlings were stocked in five southern California warmwater reservoirs in 1959, 1960, 1962, and 1963. These plants were successful in that good survival and growth were experienced, but anticipated angling benefits did not accrue and the program was abandoned. Natural spawning did not take place and the original plants gradually died out.

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[4] "*Lepomis euryorus* McKay". Seale (1930) lists "Sunfish, *Eupomotis euryoris*" in an article entitled, "List of twenty fresh water fishes found in California that may be used in small aquariums or garden pools." The Steinhart Aquarium accession list for 1931 records "*Apomotis euryorus*" as collected near Willows, California. The identification was made by Alvin Seale; the specimens were not saved. Hubbs and Hubbs (1932) have proved that the nominal species "*Lepomis euryorus*" is a hybrid between *Lepomis cyanellus* and *Lepomis gibbosus*. Both of these species are resident in California but *L. gibbosus* has not yet been recorded from near Willows nor do we have any records of its presence in the State as early as 1930 or 1931.

CICHLIDAE—cichlid family

25. *Cichlasoma beani* (Jordan)—green guapote

A well-established population of this species was discovered in 1975 in several small ponds adjacent to Putah Creek in Solano County by A. D. Castro, Aquarist with the California Academy of Sciences (pers. commun.). Identification was made by W. I. Follett. Sampling in 1979 did not uncover any specimens and some of the ponds were dry, so apparently the species did not survive (R. L. Reavis, Calif. Dep. Fish and Game, pers. commun.).

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ELECTROPHORETIC, MORPHOMETRIC, AND MERISTIC STUDIES OF SUBPOPULATIONS OF NORTHERN ANCHOVY, *ENGRAULIS MORDAX*[1]

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We investigated the population structure of northern anchovy found between southern Baja California and Newport, Oregon. We used electrophoretic, morphometric, and meristic methods in our studies, and the results indicate the presence of three distinct anchovy subpopulations.

INTRODUCTION

Hubbs (1925) and McHugh(1951) found subpopulations of the northern anchovy along the west coast of the United States and Mexico. For more effective management of the growing United States and Mexican anchovy fisheries, knowledge of the number of subpopulations and how they are distributed geographically is necessary, as is a feasible method of readily distinguishing the subpopulations. In this study we used electrophoretic methods to distinguish subpopulations and delineate their geographical range; morphometric and meristic comparisons were made between these subpopulations.

Transferrin Electrophoresis

Transferrin is the vertebrate blood serum protein responsible for binding iron. Transferrin polymorphism has been reported in a variety of teleost fishes by several authors including Creyssel et al. (1964), Moller (1966), Moller and Naevdal (1966), Barrett and Tsuyuki (1967), Fujino and Kang (1968), and Utter (1969).

Morphometrics

Hubbs (1925) found small morphometric differences in samples of *Engraulis mordax* collected from San Francisco to southern California. He also described a distinct subspecies, *Engraulis mordax nanus,* which he found inhabiting the brackish waters of San Francisco Bay. We were unable to collect the bay anchovy.

Meristics

McHugh (1951) found three subpopulations of northern anchovy: one off British Columbia to northern California, one off southern California and northern Baja California, and one off central and southern Baja California. He based his conclusion on the mean values he found in five different meristic characters. Hubbs (1925) found a distinct difference in vertebral numbers when he com-

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pared open ocean anchovies with bay anchovies from San Francisco Bay. He also found small differences in vertebral numbers between samples of open ocean anchovies from San Francisco to southern California.

MATERIALS AND METHODS

Transferrin Electrophoresis

Anchovies were collected from Newport, Oregon, to the southern end of Baja California (Table 1). Availability of samples was limited since the anchovies had to be kept alive until the blood samples were taken; dead or preserved fish could not be used. The samples came primarily from commercial live bait vendors and from short-duration surface hauls made with a midwater trawl. We tried to obtain 50 to 100 fish per sample, but this was frequently impossible. In a few cases, two smaller samples taken very closely together in time and space were combined into one; other samples which contained less than 35 readable transferrin types and could not be combined were not used in the population analysis.

TABLE 1. Sampling Data for Northern Anchovy Subpopulation Genetic Testing and Percent Occurence of Transferrin Alleles in the Samples

				Percent transferrin alleles			
Site	*Location*	*Date*	*Number of fish*	*Tf^A*	*Tf^B*	*Tf^C*	*Tf^D*
		Northern subpopulation					
1	Newport, Oregon	July 1969	84	81.6	8.3	5.4	4.8
2	Newport, Oregon	July 1970*	66	78.0	13.6	5.3	3.0
3	Eureka, California	July 1970	38	77.6	14.5	5.3	2.6
4	Salt Point, California	July 1970	54	80.6	13.0	3.7	3.4
5	Monterey, California	November 1969	106	76.9	12.3	5.7	5.2
		Central subpopulation					
6	San Francisco, California	April 1968	48	85.4	7.3	7.3	0
7	San Francisco, California	May 1968	64	72.7	16.4	10.9	0
8	Monterey, California	May 1968	87	76.4	13.8	9.8	0
9	Monterey, California	October 1967	54	82.4	7.4	10.2	0
10	Newport, California	August 1968	94	80.8	10.1	8.0	1.1
11	San Diego, California	July 1968	47	81.9	9.6	7.4	1.1
12	San Diego, California	July 1968	100	80.5	12.0	7.5	0
13	Ensenada, Mexico	May 1968	37	82.4	9.5	8.1	0
14	Ensenada, Mexico	July 1968	94	80.8	11.2	8.0	0
15	Todos Santos Is, Mexico	August 1969	48	83.3	11.5	5.2	0
16	30° 50.5'N	August 1969	43	82.6	11.6	4.7	1.2
17	30° 17'N	January 1969	67	84.3	11.9	3.7	0
18	30° 12'N	January 1969	70	84.3	10.0	5.7	0
19	30° 09'N	March 1968	43	84.9	7.0	7.0	1.2
20	29° 33'N	November 1967	36	80.6	11.1	8.3	0
		Southern subpopulation					
21	28° 33.2'N	November 1967	83	91.1	4.8	4.2	0
22	27° 55.5'N	November 1967	64	90.6	5.5	3.9	0
23	27° 52.5'N	November 1967	87	87.9	6.3	5.8	0
24	27° 06.0'N	November 1967	75	88.7	6.7	4.7	0
25	27° 04.0'N	November 1967	72	87.5	6.9	5.6	0
26	24° 30.0'N	November 1967	72	88.2	6.2	5.6	0

We collected blood samples from live fish by inserting a heparinized capillary tube through the gill opening into the dorsal aorta. The tube was allowed to flow full of blood and then was sealed on the bottom with a bit of clay. Filled capillary tubes were then centrifuged at about 2000 *g* for 5 min. When samples were not electrophoresed immediately, they were frozen with dry ice and stored at 0° C.

When a sample was ready to be electrophoresed, the thawed capillary tube was broken off at the interface of the serum and red cells; the cells were discarded. A piece of absorbent paper was touched to the end of the capillary tube to absorb the serum until a colum of liquid 33 mm long remained; this was equivalent to 25 μl. The 25 μl of serum were mixed with 10 μl of radioactive Fe^{59} and allowed to incubate for at least 10 min. A slot cut in the starch gel was filled with the mixture and electrophoresed for 1 h 40 min at 150 v in a horizontal, thin layer, starch gel apparatus. After electrophoresis was complete, we prepared autoradiographs of the gels using a modification of the method of Giblett, Hickman, and Smithies (1959).

We examined the hypothesis that each band represented a specific transferrin, controlled by a different autosomal allele at a single locus. First, we verified that "artificial heterozygotes" produced by mixing equal parts of sera from the appropriate homozygous types produced electrophoretic patterns indistinguishable from the natural heterozygous types. Secondly, we examined the statistical distributions of phenotypes in populations thought to be in equilibrium with respect to the alleles found.

The frequency of occurrence of the transferrin alleles in anchovy samples was calculated as $1/N\ (0_{ii} + \frac{1}{2}\Sigma 0_{ij})$, where i = A, B, C, D (representing alleles) and $j \neq i$. For examle, O_{AA} is the number of phenotypes AA observed and N is the total number of fish in the sample. Allocation of samples to the subpopulations was determined by cluster analysis (Sneath and Sokal 1973) of the percentage distributions of alleles for each sampling site. The clustering sequence was obtained by identifying the two sites most alike, combine the two and clustering with the next most similar site, etc. The computer program used was BMDP2M written at the Health Sciences Computer Facility, University of California, Los Angeles. Clustering was by Euclidean distance (the square root of the sums of squares of differences between percent alleles).

Morphometrics

Morphometric measurements were made with a vernier caliper on formalin preserved anchovies which had been classified to subpopulation by transferrin gene frequencies. Head length, eye diameter, snout to post-orbital margin, head depth, and body depth were measured. Allometric regressions ($\ln y = a + b \ln x$) were calculated for each of the five morphometric measurements, where x is the standard length (SL).

Meristics

We took all meristic counts from formalin preserved samples which we had classified as northern, central, or southern subpopulation anchovies on the basis of transferrin gene frequencies. Counts were made from x-ray plates with the aid of a binocular dissecting microscope. Vertebrae, anal fin rays, and dorsal fin rays were counted. The vertebral counts did not include the basioccipital nor the hypural.

RESULTS AND DISCUSSION

Transferrin Electrophoresis

We found that transferrin polymorphism in the northern anchovy orginates in a genetic system of four co-dominant autosomal alleles, each controlling the formation of a single protein with a specific anodal migration rate when electrophoresed in starch gel. The four iron-binding protein bands were designated A, B, C, and D. The migration distance in a standard run was 23.4 mm for band A, 21.1 mm for band B, 19.0 mm for band C, and 16.2 mm for band D (Figure 1).

Northern (sites 1–5) and southern (sites 21–16) groups were clearly distinguished by cluster analysis (Figure 2) of the transferrin alleles' percentage of occurrence (Table 1). A central group (site 6 and sites 9–20) was also evident. However, samples taken at sites 7 (San Francisco) and 8 (Monterey) during May of 1968 were distinct from all groups. These samples were anomalous in that they were not intermediate between the major groupings but rather represented extreme levels for all alleles; thus a mixture of populations or interbreeding does not suffice as a rational explanation. These anomalies are believed to be due to occasional indistinct separation of the first three bands within the gel. The absence of the D allele separates these samples from the northern group and the relative frequencies of the B and C alleles separates them from the southern group; thus we included them within the central subpopulation. There is an overlap in the geographical range of samples attributed to the northern and central subpopulations; the southernmost sample from the northern subpopulation was taken in Monterey in November 1969, and the northernmost samples from the central subpopulation were taken from San Francisco Bay in April and May 1968, an overlap of about 70 nautical miles. This does not mean that the two subpopulations were necessarily present in these areas at the same time; instead, both subpopulations may tend to move north in the spring and summer and return toward the south in the fall and winter. Anchovy tagging studies conducted by California Department of Fish and Game support the north and south movements (Haugen, Messersmith, and Wickwire 1969).

The northern subpopulation was distinguished from the other two by the Tf^D allele which was not found in the southern subpopulation, was rare in the central subpopulation (0.2%), but occurred at a rate of 4.02% in the northern subpopulation (Table 2). The central subpopulation was distinguished from the southern one by the frequency of occurrence of Tf^A and Tf^B alleles. Tf^A occurred at a rate of 88.96% in the southern subpopulation compared to 81.17% in the central one; Tf^B occurred at 11.0% in the central subpopulation and only 6.07% in the southern one. Chi-square goodness of fit tests on observed numbers of phenotypes for the three subpopulations versus the expected numbers calculated from the Hardy-Weinberg equilibrium formula (Table 2) support the four-allele hypothesis.

Similarity or dissimilarity of the subpopulations was judged on the basis of the observed phenotypic distributions with northern-central and central-southern differences treated separately. We found the rare allele to be important in discriminating the northern subpopulation, whereas the predominant alleles provided the discriminatory power for the central and southern subpopulations (Table 3). To avoid difficulties with expectations in the statistical tests, all combinations of the Tf^D allele were grouped for the chi-square tests. The results of the chi-square tests for independence $[\Sigma(O-E)^2/E]$ are as follows:

North-central $X^2 = 61.99$, d.f. $= 6$; $P < .005$
Central-southern $X^2 = 27.88$; d.f. $= 6$; $P < .005$

Both indicate highly significant differences between subpopulations.

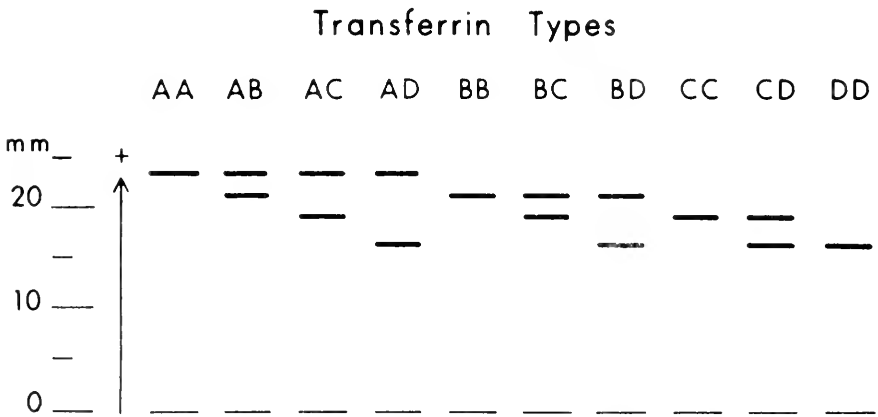

FIGURE 1. Transferrin pattern types found in northern anchovy.

TABLE 2. Gene Frequencies in the Three Northern Anchovy Subpopulations and the Observed and Expected Number of Phenotypes. The Expected Numbers were Calculated from the Hardy-Weinberg Equilibrium Formula

Allele	*Northern (N)*		*Central (C)*		*Southern (S)*	
Tf^A	78.88%		81.17%		88.96%	
Tf^B	11.92		11.00		6.07	
TF^C	5.17		7.56		4 97	
Tf^D	4.02		0.27		0.00	
Phenotype	*Expected*	*Observed*	*Expected*	*Observed*	*Expected*	*Observed*
AA	216.52	215	614.05	619	358.51	360
AB	65.47	67	166.40	161	48.93	47
AC	28.39	30	114.44	111	40.03	39
AD	22.09	22	4.05	3	0.00	0
BB	4.95	4	11.27	13	1.67	2
BC	4.29	4	15.50	17	2.73	4
BD	3.34	4	0.55	1	0.00	0
CC	0.93	0	5.33	6	1.12	1
CD	1.45	2	0.38	1	0.00	0
DD	0.56	0	0.01	0	0.00	0

$X^2_N = 0.36$; d.f. $= 5$; $P > 0.995$
$X^2_C = 1.38$; d.f. $= 4$; $P > 0.750$
$X^2_S = 0.78$; d.f. $= 3$; $P > 0.750$

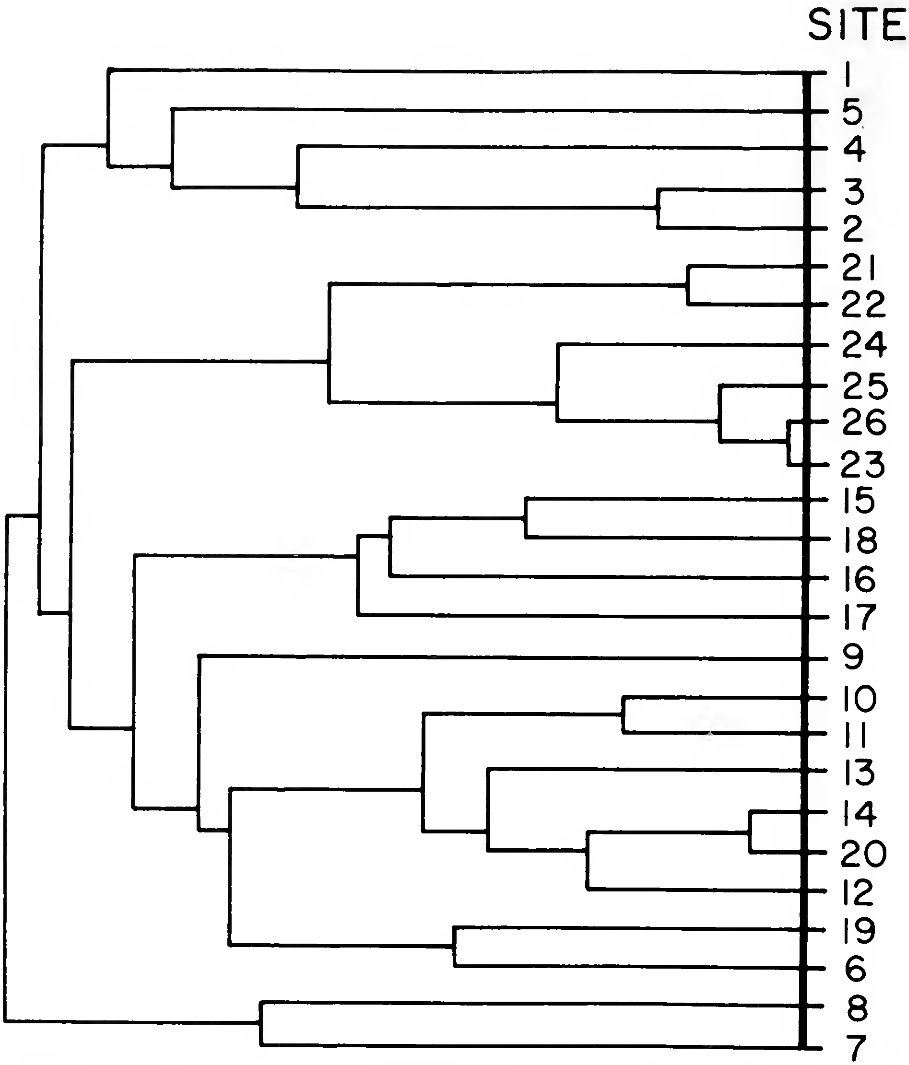

FIGURE 2. Cluster tree diagram of sample sites by proportion of transferrin alleles. Clustering sequence is determined by the distance of the vertical bars from the solid vertical line. Example: 23 and 26 are most similar, then 14 and 20, etc. Subpopulations identified are northern (1–5), southern (21–26) and central (6–20).

Thus, the transferrin data support the conclusion of McHugh (1951) that there are three subpopulations of northern anchovies in the area. The close agreement in numbers of transferrin types observed with the expected numbers (Table 2) calculated from the Hardy-Weinberg equilibrium formula indicates three genetically distinct subpopulations with little or no interbreeding; a northern one from about Monterey north, a central one from San Francisco to about 29° N lat, and a southern one south of 29° N (Figure 3).

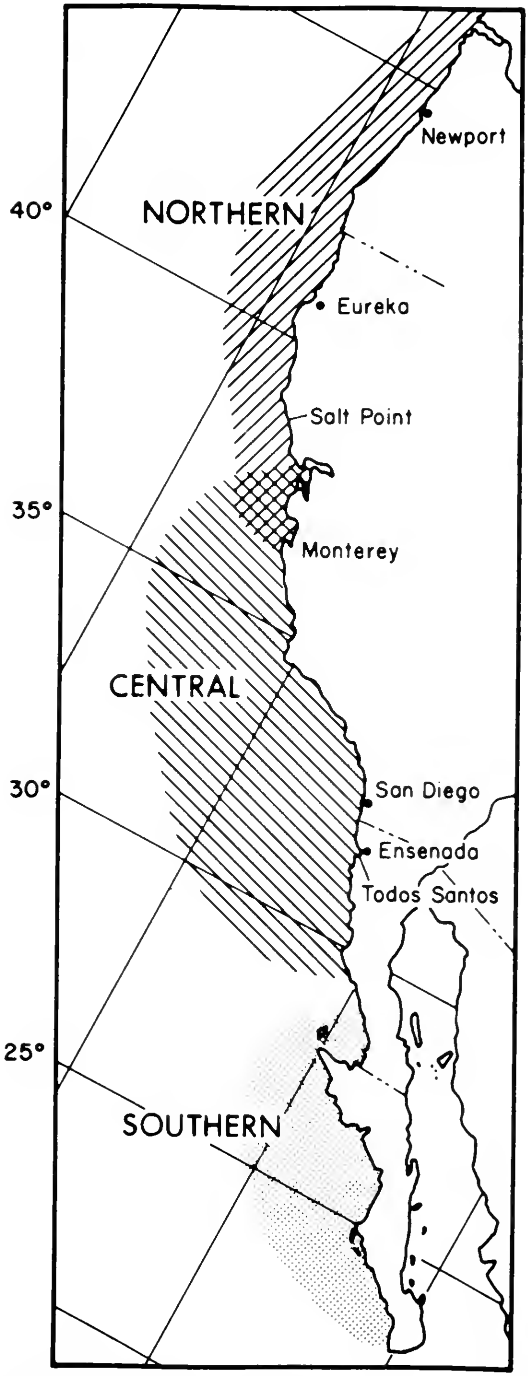

FIGURE 3. Distribution of three northern anchovy subpopulations based on transferrin allele frequencies.

TABLE 3. Observed and Expected Numbers of Phenotypes Assuming No Differences Between Subpopulations

		AA	*AB*	*AC*	*BB*	*BC*	*CC*	*AD+BD+CD+DD*	*Total*
Northern	O	215	67	30	4	4	0	28	348
	E	226.7	62.0	38.3	4.6	5.7	1.6	9.0	
Central	O	619	161	111	13	17	6	5	932
	E	607.2	166.0	102.7	12.4	15.3	4.4	24.0	
TOTAL		834	228	141	17	21	6	33	1280

		AA	*AB*	*AC*	*BB*	*BC*	*CC*	*AD+BD+CD+DD*	*Total*
Central	O	619	161	111	13	17	6	5	932
	E	658.8	140	100.9	10.1	14.1	4.73	3.4	
Southern	O	360	47	39	2	4	1	0	453
	E	320.2	68	49.1	4.9	6.9	2.3	1.6	
TOTAL		979	208	150	15	21	7	5	1385

Morphometrics

Morphometric measurements were taken on 613 fish (Table 4). Except for eye diameter, there was no evidence that the slope coefficients b differed among the subpopulations (Table 5) test for parallel lines. The slope for eye diameter in the northern group differed from those of the southern and central, but the latter two showed no statistical difference. Only body depth indicated direct proportionality, i.e., b was not significantly different from unity.

TABLE 4. Sampling Data for Northern Anchovy Morphometric and Meristic Testing

Subpopulation	*N*	*Mean standard length (mm)*	*Range*	*Standard deviation*
Northern	206	97.20	77–135	10.01
Central	225	104.47	70–136	15.39
Southern	182	90.11	50–116	13.65

Because the slope coefficients for eye diameter differed among subpopulations, no test for a common regression line was performed for eye diameter. All other tests for a common regression line, i.e., the same slope and intercept, were highly significant ($P < 0.01$). In each instance, the more similar of the two subpopulations were also tested for a common relationship. Body depth indicated no difference between the southern and central subpopulations. Otherwise all differences between subpopulations were significant at $P < 0.05$. The analysis of covariance is not entirely appropriate for morphometric data since both variates are subject to error, especially for field sampling where the size range of the samples is rarely the same and cannot be controlled. It is well to insist on a conservative level of statistical significance; therefore, we calculated the estimated morphometric measurements for a 70-, 100-, and 130-mm anchovy from each subpopulation (Table 6). Southern subpopulation anchovies showed a distinctly longer head, larger eye, and longer snout to post-orbit than did either central or northern ones. Northern subpopulation anchovies exhibited a deeper body, and northern and southern subpopulation anchovies showed a slightly deeper head than did those of the central stock. Average morphometric measurements calculated for 10-mm intervals from 70 to 120 mm show the consistent pattern of differences between the subpopulations at all sizes (Table 7).

TABLE 5. Covariance Analysis for the Three Northern Anchovy Subpopulations: SL = Standard Length

Subpopulation		*Test for common regression line*	*Test for parallel lines*
	Head depth (hd)		
Southern	$\ln L_{hd} = -1.637 + .967 \ln L_{SL}$		
Central	$\ln L_{hd} = -1.661 + .968 \ln L_{SL}$	$F_{4,607} = 12.79$*	$F_{2,607} = 0.10$**
Northern	$\ln L_{hd} = -1.570 + .955 \ln L_{SL}$		
	Body depth (bd)		
Southern	$\ln L_{bd} = -1.982 + 1.052 \ln L_{SL}$		
Central	$\ln L_{bd} = -1.928 + 1{,}039 \ln L_{SL}$	$F_{4,607} = 16.00$*	$F_{2,607} = .54$**
Northern	$\ln L_{bd} = -1.770 + 1.012 \ln L_{SL}$		
	Eye diameter (ed)		
Southern	$\ln L_{ed} = -1{,}551 + .753 \ln L_{SL}$		
Central	$\ln L_{ed} = -1.366 + .692 \ln L_{SL}$		$F_{2,607} = 8.37$*
Northern	$\ln L_{ed} = -2.235 + .882 \ln L_{SL}$		
	Snout to post-orbit (po)		
Southern	$\ln L_{po} = -1.273 + .823 \ln L_{SL}$		
Central	$\ln L_{po} = -1.313 + .816 \ln L_{SL}$	$F_{4,607} = 125.04$ *	$F_{2,607} = 2.76$**
Northern	$\ln L_{po} = -1.042 + .755 \ln L_{SL}$		
	Head length (hl)		
Southern	$\ln L_{hl} = -0.850 + .932 \ln L_{SL}$		
Central	$\ln L_{hl} = -1.027 + .955 \ln L_{SL}$	$F_{4,607} = 158.92$*	$F_{2,607} = 2.56$**
Northern	$\ln L_{hl} = -0.784 + .900 \ln L_{SL}$		

* Significant $P \leq .01$
** Not significant

TABLE 6. Estimated Morphometric Measurements of 70, 100, and 130 mm Standard Length Northern Anchovies Expressed as Percent of Standard Length

Length	*Subpopulation*	*Head length*	*Eye diameter*	*Snout to post-orbit*	*Head depth*	*Body depth*
	Northern	29.8	6.5	12.4	17.2	17.9
70	Central	29.6	6.9	12.3	16.6 *	17.2
	Southern	31.9 *	7.4 *	13.2 *	16.9	17.2
	Northern	28.8	6.2	11.4	16.9	18.0 *
100	Central	29.1	6.2	11.5	16.4 *	17.4
	Southern	31.1 *	6.8 *	12.4 *	16.7	17.5
	Northern	28.1	6.0	10.7	16.7	18.0 *
130	Central	28.8	5.7	11.0	16.2 *	17.6
	Southern	30.6 *	6.4 *	11.8 *	16.6	17.7

* Significant difference ($P \leq 0.01$) between subpopulations within length group.

Hubbs (1925) also reported longer head length (31.9% SL) for a San Francisco Bay subspecies *Engraulis mordax nanus* which also had a greater body depth (19.7% SL) than did the open ocean anchovies (18.1% SL).

Mais (1974) reported that southern subpopulation anchovies are much smaller than central stock anchovies. Of the 2,332 fish he measured from 96 samples collected in more than 5½ yr south of lat 28°30′ N, less than 10% exceeded 106 mm total length (the minimum legal limit of the California anchovy reduction fishery), while 79% of the central stock anchovies were 106 mm or greater. Southern anchovies were significantly smaller than central ones at all ages and nearly attained their maximum length by age 3, while central subpopulation anchovies continued to grow for at least 3 more years.

TABLE 7. Average Morphometric Measurements (mm) in Three Northern Anchovy Subpopulations in 10 mm Intervals of Standard Length; N = Northern; C = Central; S = Southern Subpopulations.

Interval		*Standard length*	*Body depth*	*Head depth*	*Head length*	*Snout-postorbital*	*Eye diameter*	*Number of observations*
	N							0
70– 79	C	75.5	12.8	12.4	22.4	9.2	5.2	24
	S	75.6	13.0	13.0	24.9	10.3	5.9	34
	N	86.2	15.9	15.0	25.2	10.3	5.5	42
80– 89	C	84.0	14.9	14.6	24.9	10.1	5.5	3
	S	83.7	14.4	14.0	26.7	10.9	6.1	36
	N	92.9	16.4	15.5	27.0	10.8	5.8	91
90– 99	C	95.4	16.7	15.8	27.7	11.1	5.9	62
	S	95.0	16.5	15.8	29.4	11.8	6.4	51
100–109	N	105.1	18.9	17.7	30.0	11.8	6.4	33
	C	103.6	18.2	16.8	29.7	11.6	6.3	51
	S	103.5	18.3	17.3	31.7	12.6	6.8	42
110–119	N	112.1	20.5	19.1	31.9	12.5	6.9	37
	C	114.2	20.1	18.9	33.1	12.9	6.8	37
	S	111.6	19.8	18.6	33.9	13.4	7.3	10

Meristics

Vertebrae

Northern subpopulation anchovies had the greatest mean number of vertebral centra (Table 8). The mean for the central subpopulation was significantly less than that of the northern subpopulation ($d = 0.46$; $F_{1,404} = 41.83$; $p < 0.001$). This was also the case for the southern subpopulation with regard to the northern one ($d = 0.43$; $F_{1,386} = 49.44$; $p < 0.001$). There was no significant difference between central and southern subpopulation mean number of vertebrae ($d = 0.03$; $F_{1,380} = 0.16$; $p < 0.25$).

Hubbs (1925) reported a mean number of 44.73 vertebrae for offshore northern anchovies off San Francisco, which is very close to the 44.75 we found for the northern subpopulation. When we partitioned McHugh's (1951, Tables 2 and 3) vertebral data into probable subpopulations (northern, central, or southern) merely on the basis of location of capture, we calculated his northern subpopulation samples to have a mean of 44.74 vertebrae, again in good agreement with ours. His southern subpopulation samples had a mean of 44.32 vertebrae, identical to ours.

TABLE 8. Meristic Analysis of the Three Subpopulations of Northern Anchovies: $\bar{x}$ = Mean, S = Standard Deviation, and S = Standard Error of Mean

	No.	Range	$\bar{x}$	S	$S_{\bar{x}}$
Vertebrae					
Northern subpopulation	206	43–46	44.75	0.6325	0.0441
Central subpopulation	200	42–46	44.29	0.7994	0.0565
Southern subpopulation	182	42–45	44.32	0.5734	0.0425
Anal fin rays					
Northern subpopulation					
Male	136	20–24	22.18	0.9043	0.0775
Female	70	20–25	22.20	0.9869	0.1180
TOTAL	206	20–25	22.19	0.9308	0.0649
Central subpopulation					
Male	94	19–25	22.43	1.1499	0.1186
Female	106	19–25	22.36	0.9481	0.0921
TOTAL	200	19–25	22.39	1.0456	0.0739
Southern subpopulation					
Male	109	20–25	22.53	1.0850	0.1039
Female	64	20–25	22.64	1.0445	0.1306
TOTAL	173	20–25	22.58	1.0686	0.0808
Dorsal fin rays					
Northern subpopulation					
Male	136	15–18	16.26	0.5962	0.0511
Female	70	15–17	16.43	0.6272	0.0750
TOTAL	206	15–18	16.32	0.6108	0.0426
Central subpopulation					
Male	94	15–18	16.46	0.6336	0.0654
Female	106	15–18	16.37	0.6666	0.0647
TOTAL	200	15–18	16.41	0.6512	0.0460
Southern subpopulation					
Male	110	15–18	16.35	0.6146	0.0586
Female	65	15–17	16.43	0.6116	0.0759
TOTAL	180 *	15–18	16.37	0.6075	0.0453

* Includes five juveniles.

When we compared the central subpopulations, however, we calculated a mean of 44.88 vertebrae for his samples, which is 0.59 greater than ours. His data indicated a high degree of variability from month to month and year to year. For instance, his data for the mean number of vertebral centra in anchovy post-larvae off southern California (McHugh 1951, Table 4) was 44.21 in 1945, 44.69 in 1947, 44.84 in 1948, and 44.65 in 1949.

Anal Fin Rays

McHugh (1951) reported strong evidence for sexual dimorphism in the number of anal fin rays, with those of males exceeding those of females by 0.13 rays. Our data did not indicate such dimorphism. When all of our samples were combined according to sex, fin rays of females exceeded those of males by only 0.02 rays. When each subpopulation was tested separately for sexual dimorphism, the greatest difference found (Table 8) was in the southern subpopulation where females exceeded males by 0.11 anal fin rays, which was not significant ($F_{1,171} = 0.43$; $p > 0.25$).

When we compared both males and females combined for each of the three subpopulations, we found that the northern subpopulation had a mean anal fin ray count 0.20 less than that of the central subpopulation; the difference was significant ($F_{1,404} = 4.18$; $p < 0.05$). The mean number of anal rays for the northern subpopulation was 0.39 fewer than that for the southern subpopulation, which was highly significant ($F_{1,379} = 14.33$; $p < 0.001$). Central and southern subpopulations differed by 0.19 rays, which was not significant ($F_{1,373} = 2.93$; $p < 0.10$).

When we partitioned McHugh's (1951) anal fin ray data into their probable subpopulations on the basis of locality, we found his mean anal fin ray count for the combined northern subpopulation samples to be only 0.03 fewer than ours. His southern subpopulation mean ray count was only 0.16 fewer than ours, but, as with vertebrae, there was a large difference in the central subpopulation, with his mean count being 0.36 greater than ours (Table 9).

TABLE 9. Mean Numbers of Anal Fin Rays From McHugh (1951, Table 11, 12 and 13) Compared with Those of This Study: N = Number, $\bar{x}$ = Mean

		McHugh (1951)				*This study*
		Adult males	*Adult females*	*Young*	*Combined total*	*Combined total*
Northern subpopulation						
	N	105	87	105	297	206
	$\bar{x}$	22.21	21.94	22.28	22.16	22.19
Central subpopulation						
	N	284	418	404	1,106	200
	$\bar{x}$	22.81	22.66	22.79	22.75	22.39
Southern subpopulation						
	N	41	49	100	190	175
	$\bar{x}$	22.83	22.55	22.18	22.42	22.58

Dorsal Fin Rays

McHugh (1951) noted a probable sexual dimorphism in mean dorsal fin ray counts; males had a grand mean difference of 0.12 count greater than that of females. Males in our samples averaged fewer dorsal rays that did females in both northern and southern subpopulations but more rays than did females in the central subpopulation (Table 8). Since the differences between the sexes were not significant and were not consistent in direction, we concluded that the variations were random and we might combine the data for males and females when comparing the three subpopulations.

Central subpopulation anchovies had the largest mean number of dorsal fin rays, 0.09 greater than that of the northern stock and 0.04 greater than that of the southern stock, but these differences are not significant (northern vs. central: $F_{1,904} = 2.27$, $p > 0.10$; northern vs. southern: $F_{1,384} = 0.83$, $p > 0.25$; central vs. southern: $F_{1,378} = 0.33$, $p > 0.25$).

SUMMARY AND CONCLUSION

We found three distinct subpopulations of northern anchovies inhabiting the coastal waters between Newport, Oregon and the southern end of Baja California, Mexico: northern, between Newport and Monterey; central, between San Francisco and lat 29° N and southern, south of; lat 29° N. There was an overlap of about 70 nautical miles for the northern and central subpopulations (Figure 3). Our conclusion was based on our transferrin electrophoresis study, and supports McHugh's (1951) conclusion of three subpopulations. Our morphometric and meristic work also supports our genetic findings.

Given a sample of anchovies from the southern subpopulation range, our studies showed that it could be identified as such if the mean head length, snout length, and eye diameter were greater than those of the northern and central subpopulations, and if the mean standard length of the sample (at all ages) were signficantly less than that of the other two subpopulations. A sample of anchovies from the northern subpopulation range could be identified as such if it had i) a greater mean number of vertebrae and fewer anal fin rays than either central or southern subpopulation anchovies, and ii) if the mean head depth were greater than that of central subpopulation anchovies. However, any conclusion on subpopulations involving meristic counts should take into consideration McHugh's (1951) work showing a high degree of variability in these parameters from year to year and even from month to month.

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DENNING CHARACTERISTICS OF BLACK BEARS, *URSUS AMERICANUS,* IN THE SAN BERNARDINO MOUNTAINS OF SOUTHERN CALIFORNIA [1]

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Denning information was obtained from field studies of nine black bears during two winters. Seven dens were examined. They were located in areas of steep terrain and minimal human disturbance. All of these dens were dug under large boulders or beneath the bases of trees. Six were located in areas where the Canyon Oak Series was dominant or co-dominant; the other was located in the Ponderosa Pine Series. The mean denning period of seven males was from mid-December to mid-March. The range of denning periods of all bears was late October to early April. Bears denned significantly longer and emerged later in the wet winter of 1977–78 than in the relatively dry winter of 1976–77. The cumulative effects of weather probably caused these differences.

INTRODUCTION

Throughout their geographic range, black bears vary greatly in denning habits and habitat preferences. The majority of investigations have been done in regions with moderate to severe winters. Some recent studies (Poelker and Hartwell 1973; Lindzey and Meslow 1976; Hamilton and Marchinton, 1980; LeCount 1980) have reported on areas with relatively mild winters. Many researchers, including Erickson (1965); Jonkel and Cowan (1971); Craighead and Craighead (1972); Lindzey and Meslow (1976); LeCount (1980); and Reynolds and Beecham (1980), have determined the length and dates of denning. Various factors responsible for wide variations in denning habits have been documented, including food availability, physical condition of bears, and cumulative effects of weather. Only one study (LeCount, 1980) has described denning times and den site selection in the climatically mild Southwest.

Black bears were introduced into southern California in 1933 (Burghduff 1935). However, no information concerning the ecology of these bears had been gathered until 1974, when we began a long-term study of the San Bernardino Mountain population. That study's primary objectives were to determine food habits (Boyer 1976), habitat utilization (Novick 1979), and physical characteristics (Siperek 1979) of the bears. Concurrently, we conducted a 3-year investigation of denning characteristics of bears in this population. The purposes of this study, reported here, were to determine den site characteristics and time and duration of denning.

STUDY AREA

The study area encompasses approximately 170 km ^{2} of the Banning Canyon and Mill Creek drainages and lies in the southeastern portion of the San Bernardino Mountains (Figure 1). Topography is characterized by deep, rocky can-

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yons and steep ridges, with many slopes exceeding 45 degrees. Elevations range from 1,200 to over 2,750 m. A Mediterranean climate of infrequent winter rains and pronounced summer drought is characteristic. Annual precipitation in the form of rain or snow at the Mill Creek Ranger Station ranges between 21 and 104 cm and averages 49 cm. Snow cover is common at the higher elevations from about late December to mid-March. However, at lower elevations it does not remain long, especially on southern exposures. Average temperatures range from 3°C during midwinter to over 35°C in summer.

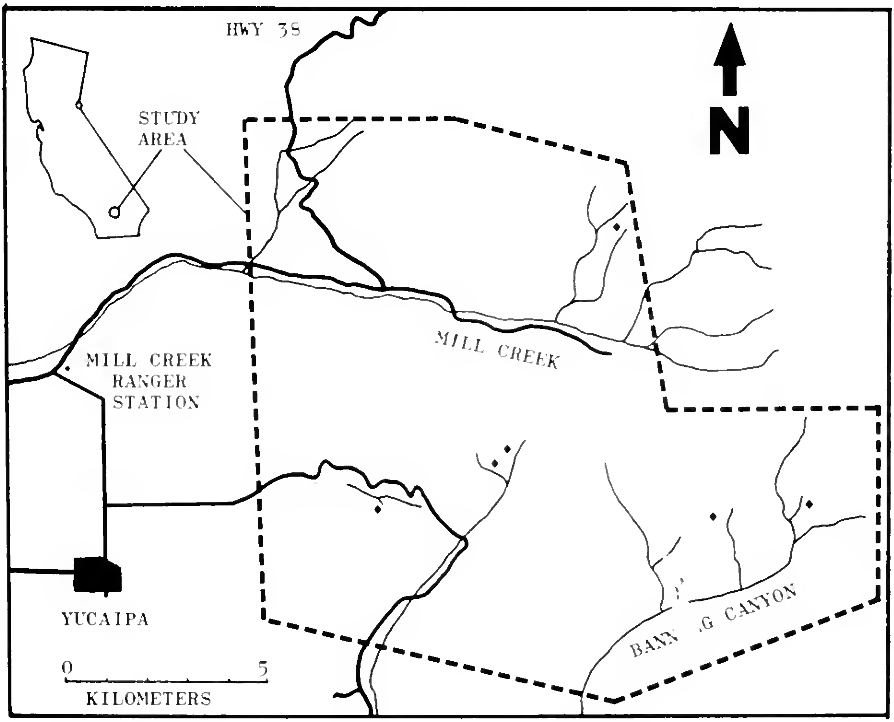

FIGURE 1. Geographic location of the study area in the San Bernardino Mountains, California. Den locations are indicated by ◆.

Climate, topography, and fire history influence the type, distribution and abundance of plant communities present. The area has a heterogeneous mixture of Conifer Forest, Woodland, and Chaparral Formations (Derby et al. 1978). The relative amounts of these formations within the study area are approximately 38%, 24%, and 29%, respectively. Other habitats occupying the remaining 9% are Barren, Grassland, Agriculture, and Riparian Series.

The Conifer Forest Formation is found from 1,600 to over 2,750 m elevation. Lodgepole Pine, *Pinus murrayana;* Sugar Pine, *P. lambertiana;* and White Fir, *Abies concolor,* Series are found in the higher elevations; Mixed Conifer, Coulter Pine, *P. coulteri,* and Bigcone Douglas Fir, *Pseudotsuga macrocarpa,* Series at the lower elevations.

In the Woodland Formation, Canyon Oak, *Quercus chrysolepis,* Series is found from 1,600 to 2,450 m elevation on southern exposures and from 1,200 to 1,700 m on northern exposures. This series occupies the broad interface between the Chaparral and Conifer Forest Formations. It contains a heterogeneous mixture of canyon oak; interior live oak, *Q. wislizenii;* California black oak, *Q. kelloggii;* and a few scattered conifers. The Black Oak Series is found in more mesic conditions from 1,450 to 2,100 m elevation. The Interior Live Oak Series occurs in more xeric, lower elevations, usually below or in association with canyon oak. Key black bear foods, such as acorns *Quercus* spp.; western chokecherry, *Prunus virginiana;* coffeeberry, *Rhamnus californica;* holly-leaved cherry, *Prunus ilicifolia;* and manzanita, *Arctostaphylos* spp., are present in the Woodland Formation.

The Chaparral Formation is found below 1,650 m and includes the Ceanothus, *Ceanothus* spp./Manzanita Series and the Chamise, *Adenostoma fasciculatum,* Series. The latter is generally below 1,400 m.

METHODS AND MATERIALS

Bears were captured in a culvert trap or in Aldrich foot snares (Novick 1979, Siperek 1979) and immobilized with CI-744, an experimental drug (Stewart, Siperek, and Wheeler 1980). Upon successful immobilization of each bear, pertinent information was collected, including weight, measurements, and health. A third premolar was extracted for age determination (Stoneberg and Jonkel 1966). Radio telemetry collars (Telonics of Mesa, Arizona) were attached to nine bears between May 1976 and December 1977. Surveillance of bears was achieved by ground and fixed-wing aircraft monitoring. Dens were located in early winter and again in the spring. Information was recorded on slope, aspect, elevation, percent cover, and habitat type. Monitoring was conducted primarily from the fall 1976 to the spring 1978, but a female bear was monitored in winter 1978–79, also.

Entrance and emergence of bears were carefully monitored. However, periods ranging from 3 to 16 days elapsed between monitoring days, and the exact dates of entrance and emergence were not known in most cases. Thus, arbitrary dates were assigned, the day having the lowest maximum temperature and highest precipitation being selected for the entrance date and the day having the highest maximum temperature being selected for the emergence date. This procedure is based on Lindzey and Meslow's (1976) correlation of pre- and post-denning behavior with daily weather, principally temperature and precipitation.

All temperature and precipitation data presented here are those recorded by the U.S. Forest Service's ranger station at Mill Creek (Figure 1; elevation: 762 m). Student's t-test was used for statistical comparisons (Zar 1974).

RESULTS

Denning information was obtained from nine bears. During the winter of 1976–77, three den sites were located, and an additional five sites were discovered the following winter. One den was occupied by the same bear (880) both winters. Throughout the winter of 1976–77, a 3-year-old male (A483) moved several times and apparently did not have a permanent den. This bear fled upon a close approach, and a search of the immediate area revealed only several day beds.

Denning Periods

Most bears denned from December until March, with a range for all bears of late October to early April (Table 1). The mean denning period of seven males in the two winters was 93 days, and mean entrance and emergence dates were 15 December and 15 March, respectively.

TABLE 1. Age, Sex, and Denning Dates of Black Bears in the San Bernardino Mountains

Bear No.	*Sex*	*Age (1976)*	*Year (winter of)*	*Denning dates* Entrance	*Denning dates* Emergence	*Denning period (days)*
880	M	5	1976–77	24 Dec.	1 Mar.	68
			1977–78	30 Nov.	9 Mar.	100
882	M	2 (est.)	1977–78	20 Dec.	6 Apr.	108
883	M	8	1976–77 [3]	10 Dec.	1 Mar	82
884	M	10	1976–77	24 Dec.	8 Mar.	75
885	M	1	1977–78	20 Dec.	24 Mar.	95
886	F	5	1976–77 [1]	31 Oct.	7 Apr.	159
			1977–78 [2, 3]	9 Dec.	24 Mar.	106
890	M	3 (est.)	1977–78	20 Dec.	28 Mar.	99
A483	M	3	1976–77 [3]	unknown	unknown	—
A489	M	3	1976–77 [3]	unknown	1 Mar.	—
			1977–78	30 Nov.	24 Mar.	115

[1] Pregnant
[2] Denned with cub/yearlings
[3] Den site not precisely located

During the winter of 1976–77, a pregnant female (886) entered her den much earlier and emerged much later than did the three males monitored the same winter (Table 1). The following winter, the same female was not pregnant but had two cubs/yearlings. Her denning times were similar to those of five males monitored. Due to the variation in the denning behavior of bear 886, data collected on her were omitted from calculations of denning period averages.

During the winter of 1976–77, males entered their dens between 10 and 24 December ($n = 3$, $\bar{x} = 19$ December). During the winter of 1977–78, denning by males commenced from 30 November to 20 December ($n = 5$, $\bar{x} = 12$ December). The mean duration of denning varied from 75 ($n = 3$, range 68–82) to 103 days ($n = 5$, range 95–115) for the winters of 1976–77 and 1977–78 respectively. This difference is significant ($P < 0.01$). Emergence dates ranged from 1 to 8 March ($n = 4$, $\bar{x} = 3$ March) and 9 March to 6 April ($n = 5$, $\bar{x} = 24$ March) for the same winters.

Den Characteristics

Seven den sites were precisely located (Table 2). Heavy snows during the winter of 1977–78 hampered efforts to find the exact den site of the female bear; nevertheless, aerial and close range ground tracking confined the site to within 400 m.[2]

TABLE 2. Den Characteristics of Black Bears in the San Bernardino Mountains

Bear	Year (winter of)	Den site	Habitat-type (Series)	Elevation (m)	Estimated slope	Slope aspect	Estimated percent cover: Den	Estimated percent cover: Slope
880	1976–77	Under base of dead white fir	Ponderosa Pine	2,469	30°	SE	5	30
	1977–78	Same as previous year	Same	Same	Same	Same	Same	Same
882	1977–78	Under huge boulder	Canyon Oak	2,256	45°	SE	10	50
884	1976–77	Under huge boulder	Canyon Oak/Mixed Conifer	1,981	45°	S	95	60
885	1977–78	Under base of living canyon oak	Canyon Oak	1,920	60°	S	90	20
886	1976–77 [1]	Under base of partially living black oak	Black Oak/Canyon Oak	1,554	40°	NW	10	60
	1977–78	Not precisely located	Mixed Conifer/Canyon Oak	2,438	50°	S	Unk.	20
890	1977–78	Under huge boulder	Canyon Oak	2,316	60°	SE	45	65
A489	1977–78	Under huge boulder	Canyon Oak/Coulter Pine	2,134	60°	S	75	40

[1] This den also was used by this bear in 1978–79.

All bears constructed dens in areas with minimal human disturbance. These sites had southern or southeastern exposures at elevations from 1,920 to 2,469 m ($\bar{x}$ = 2,248 m). In the winter of 1976–77, the female utilized a den having a northern exposure at an elevation of 1,554 m, only 40 m below an infrequently used fire road. The average estimated slope for all dens was 49 deg (range: 30–60 deg).

Dens were excavated under standing trees or huge granite boulders. The den of bear 880 was the only one with the entrance on the uphill side of the tree. Den dimensions recorded at three sites, along with visual observations at other sites, indicate that the size of a den is just large enough to accommodate the bear. In these three cases, entrance height averaged 50% less than shoulder height. Our observations on den dimensions relative to bear size are similar to those of Craighead and Craighead (1972). Small amounts of nesting material found in dens consisted of shredded twigs, bark, leaves, or needles.

The most common habitat type for den sites was the Canyon Oak Series, or this series co-dominant with a conifer series. Six of the seven den sites at least partially contained the Canyon Oak Series. Understory vegetation in the immediate vicinity of the dens was not dense and had a sparse, brushy appearance. It was composed primarily of young canyon oak, mountain mahogany, *Cercocarpus betuloides,* coffeeberry, and to a lesser extent, ceanothus and manzanita.

Overstory cover at den sites usually was either dense (75%–95%) or sparse (5%–10%). Overstory cover for the surrounding areas was more uniform, ranging from 20–65%. Dens at lower elevations usually had very dense cover, which in part is due to their location near canyon bottoms, but also is due to the nature of the Canyon Oak Series. The Canyon Oak Series typically has a dense overstory cover at lower elevations, where it is dominant. At higher elevations the canopy cover is more open due to the increased slope, elevation, and the presence of conifer co-dominants.

DISCUSSION

Winter dormancy allows black bears to survive in regions having severe climatic conditions and associated food scarcity. Still, bears den in regions with mild winters and available food sources (LeCount 1980). Internal mechanisms controlling this phenomenon probably are inherent.

Comparisons With Other Studies

For denning dates of black bears in other states, most reports give approximate ranges and a few give mean denning dates; a direct comparison with our study results is difficult. In addition, monitoring techniques available to us are more refined than techniques used by earlier researchers, so we were able to obtain more precise information. Despite these differences, it is evident that denning periods in regions with moderate or severe winters differ from those in regions having mild winters (Table 3). Also, bears denned later and for a shorter period in our study area than in all other regions except North Carolina. Even in areas of the West having relatively mild winters, such as Arizona and the coast of Washington, bears have earlier and longer denning periods than we recorded. Bears in this study had an average denning period of 3 months, while investigators in other regions report dormancy lasting from 4 to 6 months. The correspondence between denning dates in our area and North Carolina is most likely due to similar climatic conditions. North Carolina is reported to have mild winters with infrequent snowfall (Hamilton and Marchinton 1980). Southern California has only slightly more harsh winters, suggesting that black bears maintain a minimum denning period. Although factors governing denning behavior are not fully understood, data obtained during this investigation support those of Lindzey and Meslow (1976). These researchers believe that cumulative effects of weather, principally precipitation and daily maximum temperatures (rather than food availability), are the most influential factors affecting the timing of denning.

TABLE 3. Comparison of Approximate Denning Dates for Black Bears

State	*Entrance dates*	*Emergence dates*	*Reference*
Alaska	Late October	April or later	Erickson (1965)
Arizona	Early Nov. to Dec.	Late March to early April	LeCount (1980)
Colorado	Early to mid-Nov.	Mid-March to mid-April	Gilbert (1952)
Idaho	Late Oct. to early Nov.	Mid to late April	Amstrup and Beecham (1976)
Maine	Early December	Early April	Spencer (1955)
Montana	Late October	Mid-April to mid-May	Jonkel and Cowan (1971)
North Carolina	Early to late Dec.	Late March	Hamilton and Marchinton (1980)
Washington	Late October to Nov.	Mid to late March	Lindzey and Meslow (1976)
California	Mid-December (Range: late Oct.* to late December)	Mid-March (Range: early March to early April)	This study.

* Represented by one pregnant female.

Yearly Differences in Denning

Even in the same area, yearly differences in denning behavior were noted. The winters of 1976–77 and 1977–78 differed considerably. In 1976–77 California was in the midst of a drought, with low precipitation (30 cm in the study area) and mild temperatures. Prior to the first major storm of the year (on 30 December), daily maximum temperatures at Mill Creek fluctuated slightly (15–23°C) and dropped slowly during a 1-month period. During this period, all males denned 6 to 20 days before the storm arrived. At the beginning of the severe winter of 1977–78, which had unusually heavy precipitation (87 cm), daily maximum temperatures were erratic (13–31°C) and dropped relatively fast during the month before the first storm arrived. All bears denned 17 days before to 3 days after the start of the first snowfall on 17 December. Although these two winters were remarkably different, the onset of denning did not differ significantly ($P > 0.05$). However, storm activity appeared to initiate denning slightly earlier in 1977.

It appears that duration of denning is merely a function of the time of emergence. We found that emergence from denning is slightly earlier than other studies report. These differences are probably influenced by the warm Mediterranean climate, which characterizes southern California. During this study, the time of emergence was significantly different for the two springs ($P < 0.01$). The first spring of monitoring had little precipitation and all bears came out during a warm trend, when daily maximum temperatures were fluctuating between

12–22°C. The following spring had erratic temperatures (daily maxima 9–28°C) and weekly storms during emergence. This weather pattern, characterized by an appreciable amount of precipitation in late February and March, probably delayed emergence of most bears in 1978. Lindzey and Meslow (1976) state that emergence of bears from dens is a response to a general warming trend during a period of increased day length. In regions with mild climates, we believe the severity of the winter also influences the time of emergence and the duration, but not the onset, of denning.

Age and Sex Differences in Denning Patterns

It is notable that in the exceptionally mild winter of 1976–77, one subadult male (A483) either did not den or did not have prolonged denning. This is not surprising, however, because Hamilton and Marchinton (1980) found in North Carolina that an adult male had the shortest period of inactivity and two immature males remained active throughout midwinter. It is unclear whether this behavior is related to a specific sex or age class. The time and duration of denning for two yearling/subadult bears was not significantly different ($P > 0.05$) from adult male bears, a characteristic also described by LIndzey and Meslow (1976). Still, most bears den regardless of the mildness of the winter.

The behavior of the one female bear monitored throughout this study provides some interesting comparisons with the behavior of other bears. When this bear was pregnant in the winter of 1976–77, she entered her den in late October. This early denning was not influenced by stormy weather. During this winter, she denned approximately 2 months longer than male bears. Her denning times with cubs/yearlings at a different location the following winter was not significantly different ($P > 0.05$) from those of five adult males monitored. When pregnant again in the winter of 1978–79, this female reoccupied the den she had used in 1976–77. She entered at about the same time as did the males, but emerged later as in 1976–77. Several researchers have reported that pregnant female bears enter dens earlier and emerge later than non-pregnant females and males. Craighead and Craighead 1972; Amstrup and Beecham 1976; Lindzey and Meslow 1976; LeCount 1980; and Reynolds and Beecham 1980. However, Amstrup and Beecham (1976) also felt that females with yearlings were last to emerge from dens. These reports and our observations suggest that denning behavior of females is quite variable.

Den Site Characteristics

Many authors have reported dens to be under large boulders, fallen logs, dense vegetation, bases of dead and living trees, in excavations on hillsides, and in tree cavities several meters above the ground (Jonkel and Cowan 1971; Erickson 1965; Hamilton and Marchinton 1980; and LeCount 1980; and Pelton, Beeman, and Eagar 1980). In our study area, dens were most frequently dug beneath large boulders. The ease of digging in loose granitic soil and the abundance of large boulders in most canyons contribute to making this type of den readily available. Also, the stable micro-climate to be expected in these dens could make them preferable to other types of dens.

Dens were generally located in remote areas with steep terrain, where there was little human disturbance. Most dens were located within 100 m of a creek bottom. This is probably due to a number of factors. For example, there are many den sites (i.e., large boulders) near canyon bottoms. Also, the Canyon Oak Series provides thermal and escape cover, and the availability of water may be important to bears upon emergence from their dens.

Importance of the Canyon Oak Series

The Canyon Oak Series, while occupying only 16% of the study area, was the habitat chosen for most dens. This series supplies most fall food items. In response to the phenological progression of coffeeberry and various acorn crops during the fall months, bears often were found from middle to high elevations in their normal home ranges. Coffeeberry and acorns are the most important fall foods (Boyer 1976). Most bears denned at significantly ($P < 0.001$) higher elevation ($\bar{x} = 2{,}248$ m) than where they were active in previous seasonal ranges (Novick 1979).

We suggest that the moderate to dense overstory cover provided by the Canyon Oak Series keeps the den site cooler than it would be in more exposed locations. On southern exposures below 2,400 m, snow does not accumulate. A well-developed canopy may help compensate for warm winter temperatures, particularly at lower denning elevations, thus meeting thermal requirements for denning.

Factors influencing den site preferences of black bears are complicated. There appears to be a complex relationship between available den sites which meet their thermal requirements (high elevation or moderate to dense overstory cover), areas with minimal human disturbance (remote areas with steep terrain), and the location of fall food items (coffeeberry and acorns) within their home ranges. The Canyon Oak Series meets these conditions and probably is the most important habitat type for black bear den locations in the San Bernardino Mountains.

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NOTES

UPDATE OF THE ESTIMATED MORTALITY RATE OF *ENGRAULIS MORDAX* IN SOUTHERN CALIFORNIA

INTRODUCTION

The central subpopulation of northern anchovy, *Engraulis mordax,* found along the west coast of North America from 0° N to 38° N and concentrated in Southern California Bight, is subject to an extensive reduction and bait fishery. The management plan for the U.S. anchovy fishery (Pacific Fishery Management Council 1978) required by the Fishery Conservation and Management Act of 1976 (Public Law 94-265) is based on existing knowledge of population parameters. Annual mortality (*a*) and instantaneous total mortality (Z) are two of the parameters used in the plan and are based on estimates of MacCall (1974). Using the catch curve analysis method developed by Chapman and Robson (Chapman and Robson 1960; Robson and Chapman 1961), MacCall arrived at an average Z of 1.09 and an average *a* of 66.5% for the central subpopulation. I have updated the estimate of Z by including more recent data and have examined the time series for any recent changes or long-term trends in the parameter values.

MATERIALS AND METHODS

The analysis is based on data reports of the California Department of Fish and Game, Pelagic Fish Investigations Sea Survey Project, from October 1966 to November 1979 (Mais 1969*a, b*; 1971 *a, b, c*; 1972, 1973, 1974, 1975, 1976, 1977, 1978, 1979, 1980). Also included are data from one cruise in 1980 (K. Mais, Marine Biologist, Calif. Dept. Fish and Game, pers. commun.). Catch curves are derived from year-class frequencies of anchovies in the midwater trawl stations. Annual mortality rates and the corresponding instantaneous total mortality rates are calculated for each cruise using the Chapman-Robson method as applied by MacCall (1974). The best estimate of Z is then the mean value over all the cruises and *a* is determined from that mean value (Table 1).

RESULTS AND DISCUSSION

The estimate of Z is calculated to be 0.97 ($s = 0.38$) which corresponds to a 62.1% annual mortality. Although the assumptions necessary to use the Chapman-Robson analysis are poorly satisified due to large fluctuation in recruitment and the likelihood of increasing mortality with age, these deficiencies are offset by averaging the values of Z over the 14-year period.

When the values of Z from each cruise are plotted against time (Figure 1), the between sample variance becomes apparent and may be due to high variability in recruitment of year classes or relative year class strengths. A 10-year decreasing trend in the values of Z is dramatically reversed after 1976 (Figure 1). This 4-year increase in Z since 1976 is concerning, since it coincides with a sharp decrease of older anchovies in the commercial catch (J. Sunada, Marine Biologist, Calif. Dept. Fish and Game, pers. commun.) and a decline in the total U.S. catch. Studies have not shown, however, if the manifestations are natural fluctuations in the anchovy population or responses to outside stimuli such as environmental change, predators, or competitors.

TABLE 1. Mortality Rate Estimates Based on Sea Survey Data for Southern California.

Cruise	*Number sampled* *	*Annual mortality rate (a)*	*Instantaneous mortality rate (Z)*
66A8	106	.60	.90
67A2	60	.66	1.07
68A4	145	.53	.75
68A8	128	.69	1.17
68A9	55	.62	.95
69A6	105	.66	1.07
69A8	146	.68	1.13
69A11	127	.72	1.26
70A1	92	.75	1.35
70A4	145	.73	1.30
70A7	111	.67	1.11
71A1	85	.71	1.20
71A3	92	.61	.94
71A7	162	.66	1.06
72A3	98	.60	.90
72A9	115	.84	1.79
73A2	169	.75	1.36
73A3	156	.56	.82

Cruise	*Number sampled* *	*Annual mortality rate (a)*	*Instantaneous mortality rate (Z)*
73A8	236	.59	.90
74A3	246	.55	.79
74A9	240	.57	.84
75A1	243	.55	.80
75A2	90	.54	.76
75A5	73	.63	.98
75A6	289	.52	.73
76A3	307	.41	.53
76A4B	155	.48	.64
76A7	123	.45	.60
76A9	216	.40	.50
77A3	277	.44	.58
77A6	81	.55	.79
77A13	167	.47	.64
78A2	57	.62	.94
78A3	174	.46	.61
79A1	133	.72	1.26
79A2	91	.64	1.07
80A1	100	.84	1.83

	Instantaneous mortality rate (Z)	*Standard deviation*	*Annual mortality rate (a)*
1966–1976	0.97	0.28	0.621
1976–1980	0.97	0.42	0.621
1966–1980	0.97	0.31	0.621

* Number of fish 2 years old or older.

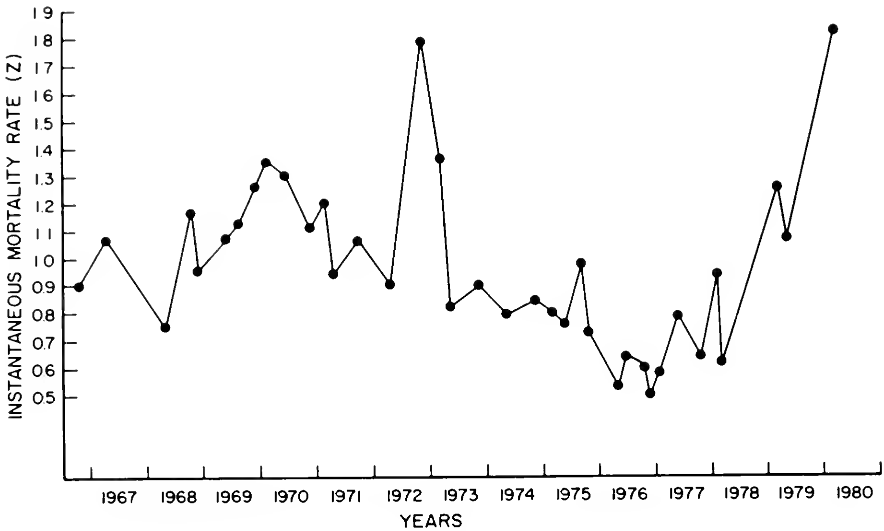

FIGURE 1. The values of instantaneous mortality rate are plotted for each of the sea survey cruises for the period October 1966 to February 1980.

ACKNOWLEDGMENTS

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FIRST RECORD OF DEXTRALITY IN THE CALIFORNIA TONGUEFISH *SYMPHURUS ATRICAUDA*, WITH A SECOND REPORT OF AMBICOLORATION.

The California tonguefish, *Symphurus atricauda* (Jordan and Gilbert), is a member of the family Cynoglossidae, which are characteristically sinistral (left-eyed). A dextral (right-eyed) California tonguefish was captured during a trawling study near Long Beach, California (lat 33° 43′ 16″ N, long 118° 09′ 09″ W). The specimen was collected at 10 fathoms using an 8-ft otter trawl while aboard the NAUTILUS. The trawl was taken between 1750 and 1810 hours on 28 January 1979. The specimen had a standard length of 117 mm, as measured from the tip of the snout to the end of the fleshy portion of the tail. It had a damp weight of 25.09 g and a displaced volume of 18.5 ml. Radiographs indicated no unusual skeletal features other than that of an apparent mirror image of normal, left-eyed specimens (Figure 1 top). Fin formulas for this specimen were: D98, A80, with 13 caudal and 4 pelvic fin rays. Caudal fin ray count was determined using the method described by Menon (1977). There were 120 scales in a longitudinal series from the head to the tail, and 49 scales in a maximum dorsal to ventral diagonal cross series. All counts were within normal limits for the species (Jordan and Evermann 1896). The liver was on the left side of the abdominal cavity, and the intestine was on the right. Therefore, the viscera retained the typical orientation for the family Cynoglossidae. The specimen is now in the California State University Long Beach fish collection (collection # 790128).

Developmental anomalies in the California tonguefish are apparently rare. The only previous record of an anomaly was that of a partially ambicolored specimen (Haaker 1973). I received a California tonguefish which also shows partial ambicoloration. The specimen had pigment on less than half of the posterior blind side (Figure 1 bottom). The pigment was continuous and of the same density as that of the eyed side. This specimen was trawled off the Dume Canyon number 1 station of the Southern California Coastal Water Research Project (lat 33° 59′ 30″ W, long 118° 49′ 30″ N), on 15 November 1979. The only other reports of ambicoloration in tonguefishes are for *S. plagiusa* (Dawson 1962, Dahlberg 1970*a*), and *S. diomedianus* (Moe 1968).

A dextral *S. atricauda* was briefly mentioned by Mahadeva (1956 unpubl.), but the specimen was undescribed and no data provided. Therefore, I feel that this is the first documented report of reversal for the California tonguefish. Reversal in the Cynglossidae is not common. The first incidence of reversal reported was for *S. plagiusa* (Linneaus) trapped off Louisiana by Chabanaud (1948). A second reversed *S. plagiusa* was trawled from Duplin River, Georgia

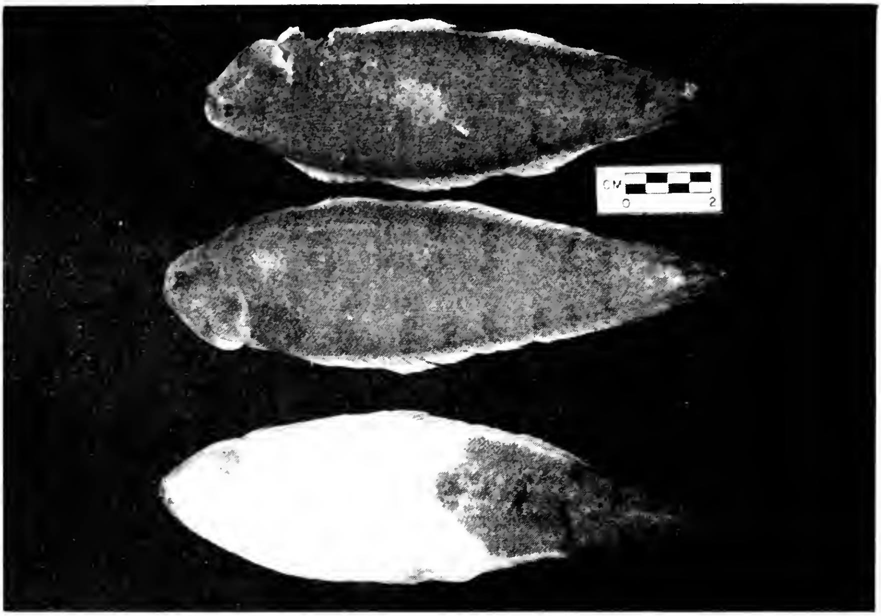

FIGURE 1. The specimen of *Symphurus atricauda* at the top of the photograph is the first reported instance of reversal for the species. The center individual shows the normal sinistral condition. The bottom individual is the second reported incidence of ambicoloration for the species.

(Dahlberg 1979*b*). The only other record of reversal in the tonguefishes was a reversed and partially ambicolorate *S. diomedianus* (Goode and Bean), from the Gulf coast of Florida (Moe 1968). Because both Chabanaud's and Moe's specimens lacked pelvic fins, they hypothesized that reversal may inhibit the development of pelvic fins (Chabanaud 1948, Moe 1968). However, Dahlberg (1970*b*) reported that, "The presence of reversed, but otherwise normal pelvic fins in my specimen does not support their conclusion." Normal California tonguefish have only one pelvic fin, and it is found on the left (-eyed) side. In this reversed specimen the pelvic fin was on the right (-eyed) side; the fin was otherwise normal. This also does not support the pelvic fin inhibition theory. There is insufficient evidence at this time to indicate any true connection with the inhibition of pelvic fin development and reversal.

Norman (1934) and Dawson (1962) both suggested that the Cynoglossids and Soleids are highly specialized. Work by Dawson (1962), and Haaker and Lane (1973) suggested that the more primitive groups of flatfishes show a higher occurrence of anomalies than those groups which are more specialized. If this were true, Cynoglossids and Soleids would show a lower incidence of anomalies than the more primitive flatfishes, such as the Bothids. This trend was supported by Dawson (1962), who found a higher incidence of anomalies for Bothids than for Cynoglossids and Soleids. Haaker and Lane (1973) reported a higher occurrence of anomalies for the bothid, *Paralichthys californicus,* than for the pleuronectid, *Hypsopsetta quttulata,* and cited this as evidence that the Pleuronectids are more specialized than Bothids. The rarity of reported anomalies in the tonguefishes appear to further support the suggestion that Cynoglossids are indeed highly specialized.

ACKNOWLEDGMENTS

My thanks to R. Bray for his help and advice during this study. Also, may appreciation to the Southern California Coastal Water Research Project for the donation of the ambicolored specimen.

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BOOK REVIEWS

The George Reserve Deer Herd

By Dale R. McCullough; University of Michigan Press, Ann Arbor, MI; 1979; 271 p.; $16.00.

Seldom are wildlife managers and other applied ecologists offered such a detailed data set, analysis, and evaluation as that provided in this volume by Dr. McCullough. The book is prefaced by the author as a progress report synthesizing investigations conducted on a southern Michigan white-tailed deer population since the 1930's. Despite the continuing nature of experiments on the study area, results and conclusions discussed in the book provide an innovative approach to management concepts for large ungulate through detailed analysis of empirical data. This book is clearly not intended for the layman, but, as stated by the author, "there is no reason why any intelligent person could not comprehend the material."

The basis for the research reported on by McCullough involves combining white-tailed deer ecology with a conceptual ecosystem model to demonstrate model function and describe the George Reserve population. Specifically, deer population dynamics are illustrated through the use of models for production, recruitment, mortality, and yield. Although data were obtained from white-tailed deer, the ecosystem hypothesis tested produced conclusions applicable to other subclimax ungulate species. The author presents an excellent discussion of the theory of carrying capacity and problems associated with usages of the term in wildlife management.

The George Reserve Deer Herd emphasizes sport hunting as the primary management tool for K-selected ungulate species. McCullough presents challenges to a number of intuitive beliefs related to manipulating sex and age structure and effects on population yield and stability. An excellent analysis of the integration of social and biological factors influencing sport hunting is presented in the chapter dealing with management concepts. The technically sound, thorough evaluation of the subject matter makes this book a valuable contribution in the field of large mammal ecology and management.—*Terry M. Mansfield*

How to Build a Freshwater Artificial Reef—Second Edition

By Eric D. Prince, O. Eugene Moughan, and Paul Brouha; Sea Grant at Virginia Tech, Extension Division, Virginia Polytechnic and State University, Blacksburg, VA 24061; 14 pp; illustrated; $1.00.

This concisely written pamphlet decribes some of the problems which might be encountered during the emplacement of artificial freshwater reefs. It offers guidelines for various construction phases and summarizes the state-of-the-art literature on the subject. The authors touch on such pertinent topics as the physical and biological need for reefs, various legal considerations and how they apply to various levels of government, and benefits, costs, and longevity of various reef types.

Photographs and illustrations of reefs made from scrap tires, brush, wooden stakes, vitrified clay pipe, and other materials clearly demonstrate the practical applications of these materials.

Although artificial reefs are admittedly not a panacea to every fisheries management problem, this publication will prove useful to private farm pond owners and professional fisheries biologists alike.—*Larry E. Week*

The Black Bear in Modern North America

By Dale Burk; Boone and Crockett Club and the Amwell Press, Clinton, New Jersey; 1979; 300 p.

Black bear management in the last 2 decades has gone from solving local pest problems to concerned international cooperation in the interest of the species. This book is the proceedings of a workshop on bear status and management attended by bear biologists from the United States, Canada, and Mexico. Workshop chairman Alan Stoken cites a threefold purpose: to review the status of the bear, to develop policy statements, and to publish the transcripts. The result is a reference for the desk of bear researchers, laymen, and professionals.

In the first portion of the book, Editor Dale Burk has put together an orderly geopolitical arrangement of regional statements on the bear's status. The entertaining comparative discussion of brown and black bears is followed by the most important and final section. Resource managers are led regionally into the complex environmental interrelationships within which the species must be managed. Workshop participants suggest management action based on range environmental conditions rather than on isolated political districts.

As with their earlier bighorn sheep publication, the sponsoring Boone and Crockett Club has done wildlife a service.—*Larry Sitton*

Estimation of Density from Line Transect Sampling of Biological Populations

By Kenneth P. Burnham, David R. Anderson, and Jeffrey L. Lake; The Wildlife Society, Inc., Washington, D.C.; 202 pp.; $4.00.

The difficulty of accurately estimating the density of animals has led to the development of a variety of estimators. This Wildlife Monograph proposes line transect sampling with a Fourier series estimator providing the probability density function.

The authors have the commendable goals of combining theory with practice; providing statisticians with the underlying theory of the methods presented and biologists with reliable, practical procedures for design, execution, and analysis of field studies. Unfortunately the task of including material at a level meaningful to each discipline has forced the structure of the Monograph into numerous parts and appendixes and necessitated the inclusion of a Reader's Guide which recommends which parts to read for practitioners of the different levels of the appropriate professions. Perhaps it is time to acknowledge that most individuals trained or employed as biologists are not, as the authors assumed in their preface, ". . . familiar with such concepts as random variables, estimators, sampling variance, confidence intervals, bias, and chi-square test statistics". As moral philosophers have pointed out, "you can't make an is from an ought".

Nevertheless, the Monograph is a particularly comprehensive reference on line transect sampling and with the guidance provided by this treatise, biologists seeking to estimate the density of objects in a sampled area should be able to make conceptually sound and explicitly accurate density estimates.

There are occasional lapses in this generally lucid work which are confusing, such as the paragraphs on page 14 under the hearing "Assumptions" which are promptly followed by the disclaimer, "These are not to be considered as assumptions." Also the choice of print styles and parameter names might have been better coordinated. This reviewer found it extremely slow going when trying to read a paragraph in which the parameter "a" was discussed, because the article "a" occurred equally often and was only distinguishable by careful attention to context.

These quibbles aside, this Monograph is going to be extremely useful to biologists who are increasingly dealing with nongame and endangered species for which the change-in-ratio methods which depend on harvest are difficult to apply.—*Earle W. Cummings*

Salmon Fishers of the Columbia

By Courtland L. Smith; Oregon State University Press, Corvallis, OR; 128 pp; illustrated; $15.00.

At times, trying to read *Salmon Fishers of the Columbia* was as difficult as staying awake during a post-lunch lecture in a warm hall. Dullness aside, this fairly short book provides a good overview of the history of the Columbia River salmon fishery, from aboriginal times to the early 1970's.

Drawing on the historical record, anthropologist-author Courtland Smith has documented the rise and decline of the canned salmon industry, with special emphasis on the competition within and between different user groups that has existed from almost the beginning of the industry. The numerous catch and pack statistics, while not the highlight of the book, are necessary for understanding of the history of this fishery. These are balanced with frequent interesting recitations from old newspapers, legislative records, association minutes, and even a couple of native American legends.

One minor irritant, to me, was the author's predominant use of the current, awkward-sounding, terms, "fisher" and "native American." They seemed contrived, especially when "fisherman" and "Indian" slipped in occasionally.

To my knowledge, *Salmon Fishers of the Columbia* is the most comprehensive book on the subject. As such, it would be valuable reading for those interested in Pacific Coast salmon fisheries or history.—*David A. Hoopaugh*

Sampling Design and Statistical Methods for Environmental Biologists

By Roger H. Green; John Wiley & Sons, Inc. New York, 1979; 257 p. $19.95.

The author's stated purpose "is to provide biologists with a compact guide to the principles and options for sampling and statistical analysis methods in environmental studies," and "tie together a methodology that already exists but is widely scattered throughout many books and journals." Dr. Green has avoided reproducing that literature except where it is not widely available. Biologists, particularly those with ready access to consulting statisticians, would prefer that the book be made more compact.

This book will be valuable to anyone responsible for the design or supervision of research or monitoring projects, and not already thoroughly familiar with sampling design. Those responsible for advising biologists will get ideas for more efficient communication with biologists. It is the author's goal to bridge the gap between statisticians and biologists. His own research has been in aquatic biology, as is much Fish and Game work. He has, however, advised students of terrestrial systems, and found the problems and questions to be the same regardless of the species.

Biologists long skeptical of statistical methods will appreciate Dr. Green's warning that ". . . the biologically defined objective should dominate and utilize the statistics rather than the reverse." Because the book's organization parallels the chronology of project design, I'm sure biologists with weak math backgrounds will be tempted to use this book to cookbook their way through projects. Many past projects would have benefited from such an approach. Dr. Green does not recommend that, but rather an understanding and application of principles. Psychologists have found that philosophical changes occur after, not before, behavioral changes. Biologists can therefore develop an understanding of statistical principles while cookbooking their way through a project. This use of the book is not likely to result in great harm because Dr. Green warns the reader of critical points at which a statistician must be consulted. Consulting time will be reduced, made more valuable, and be less frustrating if biologists will follow the methods outlined in this book to develop an understanding of what they want to do before consulting a statistician.—*James E. Hardwick*

The Hawaiian Goose

By Janet Kear and A. J. Berger; Buteo Books, P. O. Box 481, Vermillion, South Dakota 57069. 1980; 154 pps.; $30.00.

A comprehensive treatise covering three timely subjects: 1. Life history and biology of the Nene Goose, 2. Captive rearing of endangered waterfowl, and 3. Success and problems associated with artificial propagation as a method for augmenting endangered wildlife populations.

I have never read a more detailed account of a propagation effort for waterfowl. Due to the endangered status of the Nene, the worldwide interest of aviculturalists and the progressive individuals involved in the propagation program, of which Peter Scott of the Wildfowl Trust is the most noted, meticulous record keeping accounts were made for virtually every egg and individual in the propagation program. Sections include Historical Background, Morphology, Ecology, Causes for Decline, and Behavior.

The price of $30.00 and the specific nature of this book might put it beyond reach or interest for most biologists as a general reference book. It does, however, serve as an excellent high quality reference book dealing with rehabilitation and research needs of endangered wildlife, as well as comprehensive work on the Nene.—*Dan Connolly*

Population Dynamics—Alternative Models

By Bertram G. Murray Jr.; Published by Academic Press, Inc., 111 5th Ave., New York, N.Y. 1979; 212 p; $24.00.

This book attempts to present a new paradigm of population dynamics, one which rejects the linearly density dependent assumptions of the logistic model. Murray proposes a class of "density independent" models, wherein *per capita* rate of increase is constant and independent of density up to a population size above which this rate declines due to limiting factors. His thesis is that these limiting factors need not invoke "density dependence," which he has interpreted in the very narrow sense of linear changes in *per capita* rate of increase. Some of his proposed limiting mechanisms are reasonable; others appear to beg the question, expecially in the case of food limitation (p. 68).

The logistic model, which Murray rejects, assumes that maximum population growth rate or net productivity occurs at one-half of the maximum equilibrium abundance. His alternative models characteristically result in maximum population growth at greater than one-half of the maximum equilibrium abundance. This is consistent with current, independent thought regarding population dynamics and management of large mammals. On the other hand, numerous small organisms, such as fish, have shown maximum net productivity to occur at less than one-half maximum equilibrium abundance. The proposed alternative models are unable (nor is the logistic model) to produce this property because their *per capita* growth rates curve in the wrong direction: Murray's curves are necessarily convex. Unfortunately, Murray does not discuss this fundamental limitation of his models.

This is a provocative book and is enjoyable reading, although annoyingly pedantic in places. It forces the reader to re-examine his views on mechanisms regulating the abundance of animals, which is a valuable exercise whether or not those views are modified as a result. I particularly enjoyed the criticism of "r-selection and K-selection" wherein Murray shows the the circularity and disutility of this concept. The book approaches population dynamics from a life-table viewpoint, and demonstrates the strength of the method even when used in a qualitative rather than quantitative application. I recommend that this book be read by biologists with a background in population dynamics, against which it can be evaluated. I do not recommend it as a text for a person seeking an introduction to the subject, because of the book's polemical nature.—*Alec D. MacCall*

The Freshwater Fishes of Alaska

By James E. Morrow; Alaska Northwest Publishing Co., Anchorage AK: 1980; xv + 248 p., $24.95.

Dr. Morrow has done an excellent job of summarizing the current knowledge of the freshwater fishes of Alaska. The 56 species described include the known freshwater, anadromous, and euryhaline species that have been collected in the freshwaters of Alaska. This a straight forward, no frills book that covers the basic information for each of the species described.

The book begins with a key to the families of fishes, which refers the reader to the appropriate chapter for the family. Each chapter covers a separate family (subfamilies in the case of the Salmonidae) with a key to the species within it. Particularly useful is an illustrated key for identifying juvenile salmonids.

Each chapter has a brief description of the family, then detailed descriptions for each of the species. An identical format is followed for each species: a brief paragraph of distinctive characters, followed by a detailed taxonomic description of the species; a section on range and abundance, covering the total range and distribution as well as that for Alaska; a detailed description of the species habits and finally, its importance to man. Each chapter ends with one or more black and white locator maps covering Alaska and the adjacent area of Canada, on which are crosshatched the areas of distribution of the species. The same base map is used in all cases, which simplifies comparison between species.

Probably the greatest feature of this book is the illustrations. There are 63 pages of outstanding photographs and paintings, including 30 plates of watercolor and carbon dust illustrations by Marion J. Dalen. The details in Mrs. Dalen's illustrations have to be seen to be appreciated. Line drawings are used in each of the species sections.

One feature that will be appreciated by the more mature reader is the printing—it is clear and sharp, even the finest is easily read.

The only drawback that I could find with the book is the lack of a hard cover. The present day cost of printing, especially the many color illustrations, no doubt precluded this.—*Don A. LaFrance*

Inland Fishes of Washington

By Richard S. Wydoski and Richard R. Whitney; University of Washington Press, Seattle and London; 1979; xxxii + 220 p; illustrated; $8.95 paper, $17.50 cloth.

This ranks with the best of the state or regional ichthyology books. It was designed as ". . . a handbook for everyone interested in fish", and I believe it admirably achieves this goal. All the basic subjects are covered in concise, clear language. Included are sections on the drainages, geology, and topography of Washington with emphasis on how they influence fish distribution; conservation and management; family and species keys; life history accounts, which include distinguishing characteristics, distribution, habits and habitat, age and growth, reproduction, and food habits; and references. The appendix consists of a checklist of Washington rivers, and checklists of Idaho and Oregon fishes not included in the text. An extensive reference section and a detailed index complete the book.

One of the outstanding features of this book is the excellent color plates for 75 of the species described in the text. With four exceptions, the photographs are of fresh specimens taken soon after capture. The very effective methods and materials are described in the appendix. Numerous nicely executed line drawings also enhance this volume.

I take exception to some of the statements. For example, the authors maintain that compared with other species of trout, brown trout survive and thrive in warmer waters and are more tolerant of turbid waters and lower oxygen levels. This certainly isn't the case in California, where rainbow trout replace brown trout in marginal waters.

The flaws, however, are few and are dwarfed by the overall excellence of this book. I recommend it to anyone sincerely interested in freshwater fishes—*Almo J. Cordone*

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