NOAA/University of Miami Joint Publication
NOAA Technical Memorandum NOS NCCOS CCMA 157 Univ. of Miami RSMAS Tech. Rep. 2002-02

Coastal and Estuarine Data/Document Archaeology and Rescue Program

RESULTS OF A FISH HEALTH SURVEY OF NORTH BISCAYNE BAY
June 1976 - June 1977

(Credit: South Florida Water Management District.)

November 2002

US Department of Commerce
National Oceanic and Atmospheric Administration
Silver Spring, MD

University of Miami
Rosenstiel School of Marine and Atmospheric Science
Miami, FL

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TABLE OF CONTENTS

PREFACE

There is a significant number of documents and data related to the marine environment of Florida that have never been published, and are, therefore, not readily available for use by scientific community and academia. These documents and data are important because they can help define the state of the coastal environment in the past, and can be essential when evaluating the current state of degradation and restoration goals. Due to the nature of the paper and electronic media on which they exist, and, in some cases, the poor conditions in which they are housed, the data and documents are in jeopardy of being irretrievably lost. These materials cannot be located using electronic and manual bibliographic searches because they have not been catalogued or archived in libraries.

One of the objectives of the Coastal and Estuarine Data/Document Archeology and Rescue (CEDAR) Program is to collect unpublished data and documents on the South Florida coastal and estuarine ecosystem; convert and restore those judged valuable to the South Florida restoration effort into electronic and printed form, and distribute them electronically to the scientific community, academia and the public. CEDAR parallels other data and document rescue efforts including the Global Oceanographic Data Archaeology and Rescue (GODAR) of the NOAA National Oceanographic Data Center (NODC)/World Data Center-A for Oceanography (WDC-A). CEDAR, however, is focused on coastal and estuarine data and documents which cover relatively small temporal and spatial scales.

"Data Archaeology" describes the process of seeking out, restoring, evaluating, correcting, and interpreting historical data sets. "Data Rescue" refers to the effort to save data at risk of being lost to the science community. One of the major users of these rescued materials is the South Florida Ecosystem Restoration Task Force.

CEDAR is joint effort between the NOAA Natinal Ocean Service/National Centers for Coastal Ocean Science, and other government and universities in South Florida such as the the NOAA National Marine Fisheries Service, the NOAA Central Library, the University of Miami, Mote Marine Laboratory, and other organizations.

LIST OF TABLES

LIST OF FIGURES

RESULTS OF A FISH HEALTH SURVEY OF NORTH BISCAYNE BAY
June 1976 - June 1977

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ABSTRACT

Fish were collected weekly in Biscayne Bay using a monofilament gill net set from a small skiff during 20-30 minute intervals. Although weekly sampling took place for 2.5 years, only the data from samples collected from June 1976 to June 1977 were used in this document. Abnormal external conditions of fins and body were observed on each fish and recorded. Fish were returned immediately to their habitats. Fish collected in the time period for this study numbered 3,765 and included 32 species. Of these, 16 species, totaling 3,556 fish, were caught in sufficient numbers (20 or more) to warrant data analysis. Only 3 of the 16 species could be considered relatively unafflicted: *Aetobatus narinari* (spotted eagle ray), *Diodon hystrix* (porcupinefish), and *Selene vomer* (lookdown). More than 80% of the examined specimens of these three species were unaffected. Less than 20% of the specimens of *Diapterus plumieri* (striped mojarra), *Micropogonias undulatus* (Atlantic croaker), and *Pogonias cromis* (black drum) displayed normal conditions. The three most afflicted species were *Diapterus plumieri*, striped mojarra; *Micropogonias undulatus*, Atlantic croaker; and *Pogonias cromis*, black drum. Only 7, 3, and 7% respectively showed no external evidence of disease. Data described in this document were originally tabulated in the mid-1970s, remained unpublished, and are no longer available. This document was based on archived unpublished text, a data summary table, and figures. Most of the text and cited references were the ones used in the original manuscript and no attempt was made to update them.

INTRODUCTION

The degradation of fish health can be used as an indicator of the degradation of environmental quality. In particular, fish health can conceivably be an important indicator of the human disease risks in waters such as Biscayne Bay which have prime economic and aesthetic importance as recreational facilities.

Water quality in the northern basin of north Biscayne Bay underwent considerable degradation during the first half of the 20th Century due to physical and chemical alteration by man. The northern Bay is bounded by the Rickenbacker Causeway on the south. It is shallow, averaging 2 m, and warm, seasonal average temperatures range from 17 - 31 °C. Dissolved oxygen levels in Bay seawater are usually at saturation. Salinity decreases near the western shore. Almost all shorelines, which were once bordered by native mangroves, have been filled and vertically bulkheaded. Water exchange with the Atlantic Ocean is hindered by the uninterrupted land mass of Miami Beach, permitting flow only through Baker's Haulover Cut at the north, and

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Government and Norris Cuts to the south. Further restrictions to circulation have been imposed by the land-filled islands and sections of the seven causeways transecting the Bay.

Prior to 1956, raw sewage was discharged directly into the Bay from the Miami River, Arch Creek and several other point sources. The Virginia Key sewage treatment plant was built to rectify this situation. Coliform bacteria counts decreased appreciably (McNulty, 1970; Schmitz, 1973). From 1956 to December 1977, chlorinated secondary treated sewage was pumped to an ocean outfall located 1.5 km east of Virginia Key in approximately 6 m of water.

D'Amato (1973) calculated and then substantiated by fluorescent dye tracers, that the effluent plume from the outfall entered Biscayne Bay through Government, Norris, or Bear Cuts on 80% of the flood tides, depending on wind and current. Moreover, 70 - 80%, of the water flushed from the Bay on an ebb tide was returned on the following flood tide so that effluent polluted waters persisted in the Bay for extended periods of time. These waters were measured and found high in suspended solids, ammonia, phosphate, nitrate, nitrite, silicon and coliform bacteria. Since December of 1977 the outfall has been extended to 5,334 m east of Virginia Key in 30 m of water.

Areas of Miami not serviced by this waste treatment system discharged treated and probably some untreated effluents from numerous sewage treatment plants into the Miami River and other canals which enter the north Bay. Non-point source storm runoff also contributes a significant addition of pollutants such as pesticides and nutrients from lawn fertilizers and sprays.

McNulty (1970) found that benthic flora and fauna in north Biscayne Bay could be used as indicators of sewage pollution, based on coliform counts and sediment particle size. Further, he concluded that sewage produced a harmful-effects zone for 100 - 200 m around some outfalls, as evidenced by an apparent absence of life. Outside of this area was a zone of increased populations showing the fertilizing effects of the sewage.

Fish, being more mobile than most of the benthos, cannot be assessed in the same manner. There is, however, a great difference among fish species as to their tolerance of stressed or polluted environments.

The purpose of this document was to show that fish living within a body of water of known degraded quality exhibited considerable evidence of disease. During the 1970s collections of fish were carried out in Biscayne Bay to assess the type and severity of fish diseases and deformities. Data described here were originally tabulated by Dr. L. Udey at the University of Miami in the mid-1970s and was based on field sampling that involved Walter Kandrashoff. Results of this effort remained unpublished. The original data are no longer available. This document was based on unpublished text, data summary table, and figures prepared by Dr. Udey. Most of the cited references were the ones used in the original manuscript and no attempt was made to update them. The Udey manuscript is archived at the Library of the Rosenstiel School of Marine and Atmospheric Science. Kandrashoff's observations concerning fish diseases in Biscayne Bay fish populations in other years are reported in Skinner and Kandrashoff (1988) and Browder *et al*., (1993).

MATERIALS AND METHODS

Fish were collected weekly using a 274 meter (900 ft) monofilament gill net with 11.4 cm (4.5 inch) mesh, set from a small skiff for 20-30 minute intervals. Although weekly sampling took place for 2.5 yrs, only the data of the samples collected from June 1976 to June 1977 were used in this document.

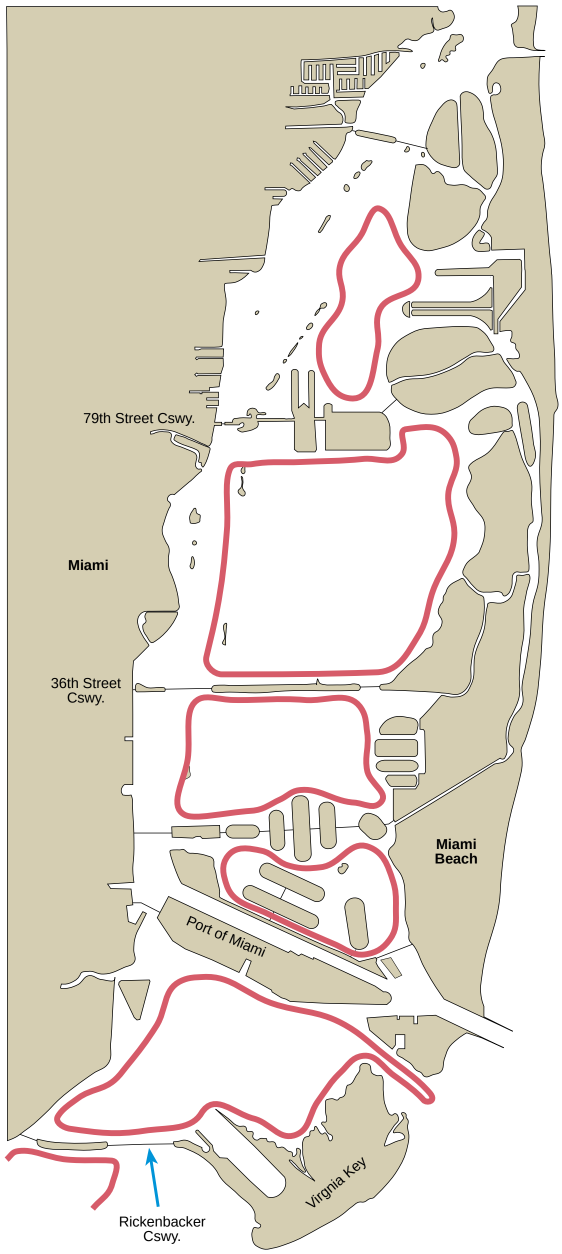

Figure 1. Fish sampling areas in northern Biscayne Bay.

Sampling locations were chosen to represent different habitats and thus allowed a larger variety of species to be sampled. Collection mostly took place north of the Rickenbacker Causeway, particularly between the Rickenbacker Causeway and the Port of Miami, the Port and 36th Street, and the 36th Street and the 79th Street Causeway (Figures 1 and 2). Also sampled were the western shoreline of the Bay between Rickenbacker Causeway and the Snapper Creek Canal; an area near Soldier Key on the east side of the Bay; and the west side of the Bay on the same latitude as Soldier Key.

The feasibility of a thorough internal necropsy was eliminated by the number of fish required to get a significant population of each species. Abnormal external conditions of fins and body were observed on each fish and recorded directly onto standard FORTRAN Coding Forms placed under a separate 36-character field code. Fish were returned immediately to their habitats. In addition to abnormalities, the code included date, fish number, set number; set duration, net length, station location, and species of fish. Information from the field sheets was transferred directly to punched cards, one per fish.

The symptoms of abnormality listed in the field code were chosen because: (1) they were observed on many fish caught in the early part of this study; and (2) they have been referred to in the literature as symptoms of specific diseases of fish. Thus, in this study, a split fin was defined as a separation of the tissue between fin rays that was not freshly caused by net damage. Since this condition was the most frequently observed, differentiation was made between afflicted caudal, pectoral, pelvic, dorsal, or anal fins and also as to the severity of the splits, rates (1) slight: only beginning to split and few in number, (2) moderate: split about halfway to the base and more than a few in number, or (3) severe: many splits to the base of the appendage. Citings of this condition in the literature (Sindermann, 1970; Reichenbache-Klinke and Landolt, 1973; and others) often refer to it as "frayed" fins.

Any reddened fin obviously not due to net damage was recorded as hemorrhaged (Mahoney *et al.*, 1973; Sindermann, 1970; and others). Differentiation was made only between caudal fins and the remaining body fins (coded as "other"). Eroded fins were generally referred to as "fin rot" (Sindermann, 1970; Davis, 1953; Mahoney *et al.*, 1973; and Reichenback-Klinke and

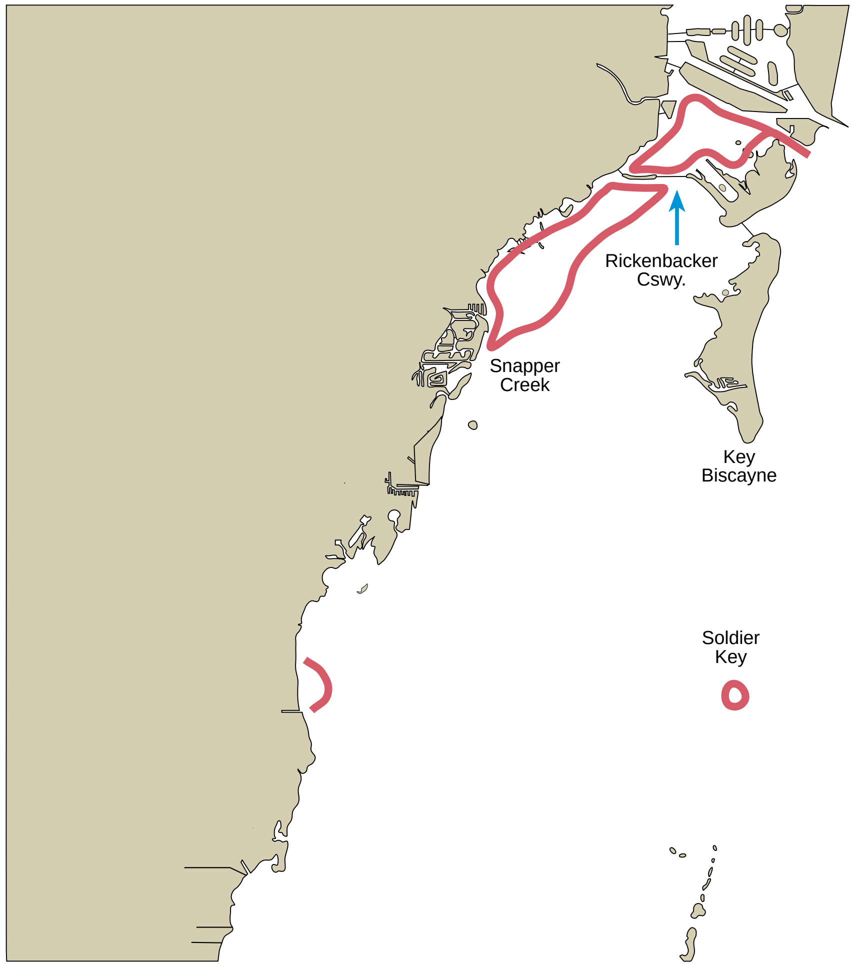

Figure 2. Fish sampling areas in southern Biscayne Bay.

Landolt, 1973). It is one of the most widely mentioned disease signs probably because a necrotic, eroded fin is fairly obvious. Again, distinction was made only between caudal and "other" fin erosion on the field code.

The next four categories of fin conditions were based on field observations which required differentiation. A deformed fin was normal size or larger and complete, but otherwise altered in shape. An incomplete fin was normal size and shape except for a missing portion. A stunted fin was abnormally small, but nor eroded or physically damaged. These usually gave the appearance of a regenerated fin. A missing fin was totally absent.

Body hemorrhages were defined as any unnaturally reddened areas of the skin. Although the incidence of net damage was low, obviously fresh wounds were disregarded. Hemorrhages appeared in several different forms and the number per fish was recorded. Literature citings are fairly numerous.

Any open wound, abscess, or ulceration of the skin was considered a body lesion (also recorded as to number per fish), while proliferative external growths were designated as body tumors.

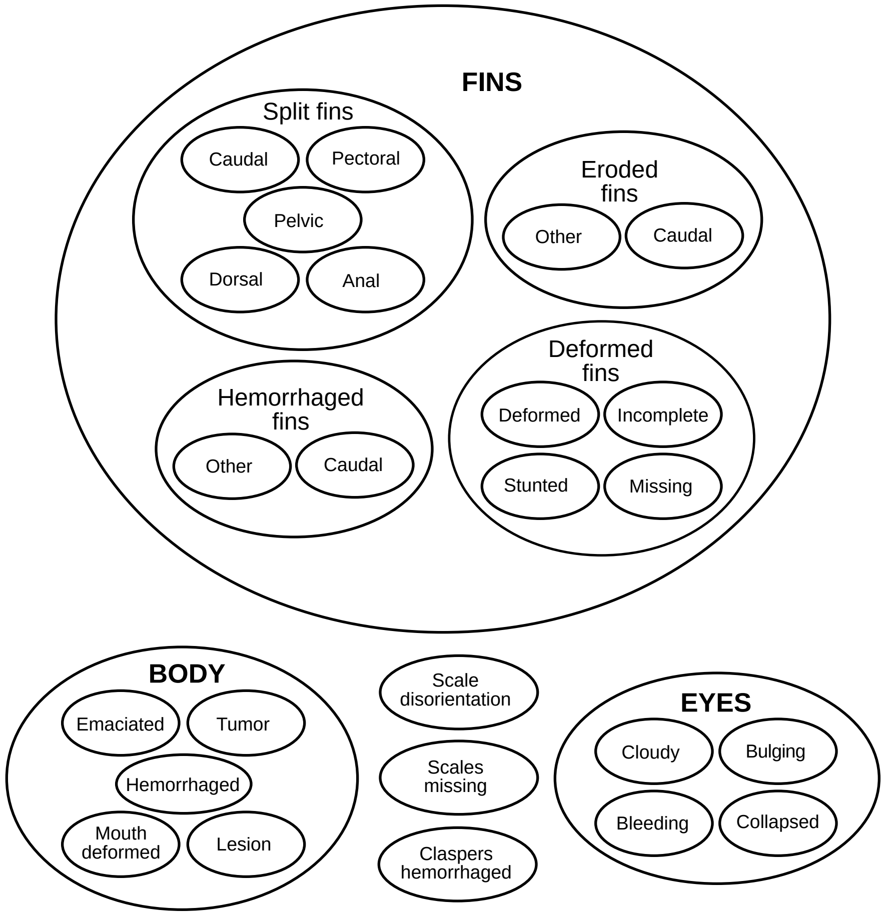

Figure 3. Fish abnormality groups.

Table 1. Scientific and common names of fish used in this study [SOME SPECIES NAMES HAVE CHANGED SINCE ORIGINAL DOCUMENT WAS WRITTEN].

Aetobatus narinari (Euphrasen)	Spotted eagle ray
Albula vulpes (Linnaeus)	Bonefish
Archosargus rhomboidalis (Linnaeus)	Sea bream
Brevoortia tyrannus (Latrobe)	Atlantic menhaden
Caranx hippos (Linnaeus)	Crevalle jack
Dasyatis americana (Hildebrand amd Schroeder)	Southern stingray
Diapterus plumieri (Cuvier)	Striped mojarra
Diodon hystrix (Linnaeus)	Porcupinefish
Elops saurus (Linnaeus)	Ladyfish
Eucinostomus gula (Quoy and Gaimard)	Silver jenny
Gerres cinereus (Walbaum)	Yellowfin mojarra
Lagodon rhomboides (Linnaeus)	Pinfish
Micropogonias undulatus (Linnaeus)	Atlantic croaker
Pogonias cromis (Linnaeus)	Black drum
Selene vomer (Linnaeus)	Lookdown
Trachinotus carolinus (Linnaeus)	Florida pompano

Scale disorientation is a condition first observed by Walter Kandrashoff and brought to the attention of the University of Miami. It is manifested by patches of scales abnormally oriented and obviously visible due to the different reflection of light.

Fish with body emaciation have a hollow, sunken appearance. Collapsed (sunken) eyes were observed, as well as cloudy (showing some opacity of the cornea) and bulging (exophthalmic) eyes.

Discussion of data in this document will be limited to that processed by a program written by F. and M. J. Spencer. Fish abnormality groups were organized according to the circle diagram shown in Figure 3. The graphical presentation of the data is in Appendix I. The following information was extracted:

1. Percent fish of each species afflicted with each condition.

2. Percent fish of each species afflicted with each group of conditions.

3. Percent fish of each species with more than one condition.

4. Percent fish of each species with split fins which have more than one fin involved.

5. Percent fish of each species with hemorrhaged fins

6. Percent fish of each species with eroded fins which have more than one fin involved.

7. Percent fish of each species with (a) deformed, (b) incomplete, (c) stunted, (d) missing fins which have more than one fin involved.

8. Percent fish of each species which have each of three degrees of severity of split fins for each fin group.

9. Percent fish of each species which have fin disorders with more than one group involved.

10. Percent fish of each species which have more than one abnormal fin.

RESULTS

Fish collected in the time period for this study (June 1976 - June 1977) numbered 3,765 and included 32 species. Of these, 16 species, totaling 3,556 fish, were caught in sufficient numbers (20 or more) to warrant data analysis and these results are discussed in this document. These species are listed in Table 1. The percent abnormalities per species found in the 16 major species are listed in Table 2. An additional ~1700 fish were caught by hook and line that were not included in the data since the method of sampling was presumed to be selective for disease-free fish. [Later work in Biscayne Bay and the St. Lucie Estuarine System indicated this was not the case (Browder *et al*., 1993; Gassman *et al*., 1992; and Browder *et al*., (in prep.).]

The percentages of fish of each species which had no observable external symptoms of disease are shown in Figure I.1. Only 3 of the 16 species could be considered relatively unafflicted: *Aetobatus narinari*, *Diodon hystrix*, and *Selene vomer*. More than 80% of the examined specimens of these three species were unaffected. Less than 20% of the specimens of *Diapterus plumieri*, *Micropogonias undulatus* and *Pogonias cromis* displayed normal conditions.

The number of abnormal conditions per fish is shown in Figure I.2, and the percentages of hemorrhaged bodies, scale disorientation and body lesions found in the specimens of the 16 species are shown in Figure I.3. More than 40% of the specimens of *Diapterus plumieri* displayed body hemorrhage.

The prevalence of fin conditions warrants consideration of the four main types. The last, deformed, is a composite of the four minor fin afflictions: stunted, missing, incomplete, and deformed. Figure I.4 shows the frequency of their occurrence in sampled fish while Figure I.5 shows how many fish displayed more than one type of fin symptom. The number of fins per fish involved in each of these groups was disregarded; only the presence of the condition on any fin was counted.

A split caudal fin was the most prevalent of all conditions observed. Figure I.6 shows its severity based on the previously discussed criteria. Figures I.7 - I.9 show the number of fins per fish displaying hemorrhaged, split, or eroded symptoms.

DISCUSSION

The prevalance of external disease signs in north Biscayne Bay is quite high in certain species. Differences among species are the most noticeable feature of the graphed results (Figure I.1 - I.9). Fish species which were found to have a high percentage of one type of affliction generally had a proportionately high prevalance of others. The three most afflicted species are clearly *Diapterus plumieri*, striped mojarra; *Micropogonias undulatus*, Atlantic croaker; and *Pogonias cromis*, black drum. Figure I.1 shows that only 7, 3, and 7% respectively showed no external evidence of disease. Figure I.2 indicates they have the highest multiple occurrence of signs of all fish in the survey, 4% of *Diapterus* exhibiting six concurrent signs, and 67% exhibiting two or more signs. These extreme figures almost overshadow what must, by comparison, be considered to be moderately afflicted species:

Albula vulpes, bonefish; *Archosargus rhomboidalis*, sea bream; *Brevoortia tyrannus*, menhaden; *Dasyatis americana*, southern stingray; *Elops saurus*, ladyfish; *Eucinostomus gula*, silver jenny; *Caranx hippos*, crevalle jack, *Gerres cinereus*, yellowfin mojarra, *Lagodon rhomboides*, pinfish; and *Trachinotus carolinus*, Florida pompano.

Severity of affliction is easily seen by this graph; e.g., although the total percent of afflicted *Eucinostomus* is less than some others, the percent with multiple afflictions is large.

However, this system of gauging severity may be somewhat artificial since it gives equal weight to all conditions. Several sources (Pippy and Hare, 1969; Mahoney, 1970; Akazawa, 1968; and others) suggest that in general there is a certain progression of external symptoms where bacteremias combined with environmental stress are involved. Fins seem to be afflicted first, presumably since they are the most vulnerable part of the fish. Mahoney *et al.* (1973) observed that frayed fin edges and separation of the fin rays preceded fin erosion, and that the caudal fin, except in flounder, was the first afflicted. Gross internal pathology was not evident until moderate fin erosion occurred. Advanced fin necrosis was accompanied by fin and body hemorrhages and body lesions developed with the most severe fin necrosis. Pippy and Hare (1969) followed salmon and suckers through caudal fin erosion, other fin erosion; small body hemorrhages and finally body lesions. Akasawa (1968) also saw body hemorrhages preceding ulcers and finally death. Certainly no hard rule can be made here since each type of disease and each species probably has its own path of progression.

Split fins, then, which are the most common symptom, are probably not as indicative of disease severity as eroded fins or body conditions. Moreover, since the field code had five columns for split fins and only two for the other fin disorders, this bias was overcome by the grouping of fins in each type (split, hemorrhaged, eroded, or deformed) of symptom to get the picture presented in Figure I.3. Here, if any fin displayed a disorder, the fish was counted.

Besides the three most afflicted species, two other species had over 50% with at least one split fin. *Albula vulpes*, bonefish and *Archosargus rhomboidalis*, sea bream. Hemorrhaged fins are the next most prevalent type of affliction, with incidence in *Diapterus*, *Micropogonias*, and *Pogonias*. Five other species had over 10% of those samples with this condition: *Archosargus, Brevoortia, Caranx, Elops,* and *Lagodon*. Occurrence of fin erosion is highest in *Diapterus* (23%) with *Albula, Elops, Eucinostomus*, and *Micropogonias* all showing over 10%. The highest involvement of deformed fins occurred in Brevoortia and was usually due to a parasitic trematode. Otherwise, only *Micropogonias* and *Diodon*, which is a low-affliction species, had any fin deformities of note.

A third type of assessment of severity is to observe the numbers of fish which exhibit two or more types of fin disorders. Surely a fish with both hemorrhages and eroded fins must be in a more advanced disease state than a fish with split fins only. Figure I.4 shows *Diapterus* to be the most severe in this respect.

Almost 10% of this species had three types of fin conditions and 3% exhibited split, hemorrhaged, eroded and deformed fins. *Micropogonias* and *Pogonias* show 35 and 38% with two types of fin disorder. *Elops* (ladyfish) has a high double incidence and the remaining "moderately afflicted" species show a moderate amount.

When split caudal fins were rated by the collector, 56% of *Pogonias* and 38% of *Micropogonias* had severe and moderate involvement. *Diapterus*, while having a high frequency, seems to show a low degree of severity. *Albula, Archosargus, Elops, Eucinostomus* and *Lagodon*, have high enough incidence of moderate severity to warrant consideration. Even though we suspect that many fish with only split fin affliction are in the earliest stages of disease involvement or not at all, when this split caudal symptom appears with moderate severity, it would appear to indicate health problems in the fish.

A fifth type of severity assessment is seen in Figures I.6 to I.8 which are actual fin counts per fish displaying the different types of fin conditions (excluding deformed fins). If hemorrhaging of the fins occurs, Figure I.7 shows it is more likely to involve a number of fins than either split or eroded-occurrences (Figure I.6 and I.8). *Diapterus*, *Micropogonias*, and *Pogonias* have a high incidence of multiple fin hemorrhaging. When split and eroded fins occur) they usually involve one fin only (generally the caudal).

Scale disorientation is an abnormality whose etiology is unknown. Its relative prevalence among *Archosargus, Lagodon, Brevoortia, Trachinotus*, and *Eucinostomus* is interesting, but inconclusive.

If the previous assumption of disease progression is valid, it follows that there would be a decreasing frequency of signs with increasing severity of disease. Figures I.6 to I.8 show this clearly. It is also probable that the further disease progresses, the more likely the fish will fall to predators.

If the body lesion is a relatively severe condition, and shortly precedes death as observed in Atlantic salmon, one would expect a low prevalence of this as shown in Figure I.9. Body hemorrhage however is common, especially in *Diapterus* (45%). In view of the low prevalence in this vulnerable species of multiple split fins, it may be that disease progresses quickly to advanced states.

Dasyatis, the southern stingray, exhibits 16% body hemorrhages. Being in direct contact with Bay sediments could have an adverse effect, in contrast to *Aetobatus*, the eagle ray, which spends most of its time swimming.

It is not possible, without a complete diagnosis, to state that the external conditions seen in this survey are manifestations of specific diseases mentioned in the literature. We can only note that these named and described diseases produce the same signs seen here. Split fins result from *Icthyophonus*, columnaris disease, (*Myxobacteria*), tuberculosis (*Myobacteria*) and generalized bacteremia as well as from fish bites and other physical damage (Sindermann, 1970; Reichenbache-Klinke and Landolt, 1973; and others). Hemorrhaged fins were observed by Mahoney *et al.* (1973), and Sindermann (1970, 1977) and others to accompany vibriosis and furunculosis.

Eroded fins were associated with bacterial infection by *Vibrio, Pseudomonas, Aeromonas, Haemophilus*, or *Mycobacterum* (Sindermann, 1970; Davis, 1953). Mahoney *et al.* (1973) found internal tissue necrosis and septicemia in weakfish with at least moderate fin erosion, and attributed it to dense bacterial population and the environmental stress of the New York Bight. Sindermann (1970) cites references to support the association of fin rot with degraded habitats such as waste water discharges and suggests that the causes may be chemical stress acting on mucous and epithelium, combined with marginal dissolved oxygen, and secondary bacterial invasion. Mearns and Sherwood (1974) and Ziskowski and Murchelano (1975) histologically observed no bacterial association with fin rot in flounder and sole collected from contaminated sediments of the Palo Verdes shelf in California and the New York Bight. Both attributed it to toxic materials in the sediments. Mahoney *et al.* (1973) induced fin rot in weakfish by rubbing abraded fins with *Vibrio, Pseudomonas*, and *Aeromonas*.

Our laboratory has found an association of *Vibrio parahemolyticus*, *V. alginolyticus*, non-agglutinating cholera vibrios and *V. anguillarum* with fin erosion. Fin rot, like most of the other external disease conditions, is probably not confined to a specific etiology.

Body hemorrhage is also associated with internal and external *Aeromonas* and with invasion by *Vibrio, Pseudomonas*, and *Aeromonas* and with environmental damage (Sindermann 1970, 1977; Reichenbache-Klinke and Landolt, 1973; and others).

Body lesions can be caused by *Haemophilus piscium* (Davis, 1953; and others). Sindermann (1970 and 1977) associates them with *Vibrio, Pseudomonas, Corynebacterium* (kidney disease), *Chondrococcus columnaris*, (myxobacteria) *myxosporidians*, and *Icthyophonus*. Ulcer disease caused by *Vibrios* is common in Japanese waters during the warmer months (Akazawa, 1968). Young (1964) induced lesions in killifish using seawater-diluted sewage. Overstreet and Howse (1977) report lesions from *Epistylus* protozoan and *Anilocra* (isopod) in low-salinity waters.

Tumors in fish are often caused by protozoan parasites (Overstreet and Howse, 1977). Several sources imply a relationship between a high incidence of neoplasms (malignant and benign) and polluted habitats (Edwards and Overstreet 1976; Young, 1964; Overstreet and Howse, 1977). Tumors were rare on north Biscayne Bay fish.

Body emaciation, found only infrequently in *Micropogonias* and *Diapterus*, can result from tuberculosis (*Mycobacteria marinum*) (Reichenbache-Klinke and Landolt, 1973) or fish suffering from starvation.

Collapsed eyes are reported by Reichenbache-Klinke and Landolt (1973) in fish with severe internal illness, metabolic disturbances, starvation, or chlorine poisoning. Bulging eyes occurs when fluid accumulates in the eye socket because of viral or bacterial infection, or parasitic invasion (Reichenbache-Klinke and Landolt, 1973; Sindermann, 1977). Young (1964) found it in fish from sewage polluted waters of southern California. Cloudy eyes can also result from bacterial or parasitic origin, or can be due to physical or chemical abrasion (Reichenbache-Klinke and Landolt, 1973) or metal poisoning (Sindermann, 1976). Mouth deformities can result from acute bacterial erosion (mouth rot) or skeletal abnormalities (Reichenbache-Klinke and Landolt, 1973; and others).

An arbitrary index of fish health is as follows. The different fin and body conditions have been numerically weighted according to observed and suspected severity and thus the index invites criticism. It gives, however, a rough, overall evaluation of each species according to data collected.

FISH HEALTH INDEX

A. Split fins: 1. [% with 1 fin + 2(% with 2 fins) + 3(% with 3 fins), etc.]
plus:
B. Hem. fins: 2. [% with 1 fin + 2(% with 2 fins) + 3(% with 3 fins), etc.]
plus:
C. Eroded fin: 3. [% with 1 fin + 2(% with 2 fins) + 3(% with 3 fins), etc.]
plus:
D. Hem. body: 4. [%]
plus:
E. Body lesions: 5. [%]
plus:
F. Figure I.4: [1(% with 2 types) + 2(% with 3 types) + 3(% with 4 types), etc.]
plus:
G. Figure I.5: [% with moderate split caudal + 2(% with severe split caudal)]

Diapterus:

A		1	[0.62 + 3(0.03)] = 0.62 + 0.09	0.71
B	+	2	[0.24 + 2(0.19) + 3(0.05) + 4(0.06)]	2.02
C	+	3	[0.22 + 4(0.01)]	0.78
D	+	4	[0.45]	1.80
E	+	5	[0]	0.00
F	+	1	[0.24 + 2(0.10) + 3(0.03)]	0.53
G	+	1	[0.07 + 2(0.14)]	0.35
				6.19

Micropogonias:

A		1	[0.77 + 2(0.01) + 3(0.01)]	0.82
B	+	2	[0.15 + 2(0.11) + 3(0.01) + 4(0.03)]	1.16
C	+	3	[0.10 + 2(0.01)]	0.36
D	+	4	(0.13)	0.52
E	+	5	(0.02)	0.10
F	+	1	(0.35) + 2(0.02)	0.39
G	+	1	(0.30) + 2(0.06)	0.42
				3.77

We can therefore presume that several species of fish in northern Biscayne Bay display a high incidence of disease. Other studies of the same nature have not recorded external symptoms in such detail but still serve as a comparison for certain conditions of fish from degraded habitats.

"Fin rot syndrome" was estimated to occur in 10% of spot and southern flounder and 5% of spotted sea trout, Atlantic croaker, and pinfish during the summer month ((5% and 1% per annum) in Mississippi estuaries (Overstreet and Howse, 1977). Sherwood and Mearns (1974) report 30% fin erosion in Dover sole and 13% and 14% in rex sole and green striped rockfish from southern California over a 4-year period. During the 1967 epizootic in New York Bight, Mahoney *et al.* (1973) found 70% of bluefish afflicted with fin rot syndrome, 40% of summer flounder, 25% of winter flounder, and 35% of adult weakfish. The following year, less bluefish (25%) and weakfish (15%) were afflicted (free-swimming species) but more demersal fish (45% of summer flounder and 55% of winter flounder). (Had the causative agents been incorporated into the sediments?). Couch and Nimmo (1974). Our own results of eroded fins (*Diapterus* 24%, *Brevoortia* 16%, *Elops* 15%, *Eucinostomus* 13%, *Micropogonias* 11%, *Albula* 13%) seem comparable with other degraded habitats.

Controversy exists over the use of marine and aquatic organisms as indicators of pollution and over the use of the word pollution (Doudoroff, 1957). Some claim that reduction of the diversity of species will destroy balance of life and so this condition constitutes the pollution. Doudoroff (1957) maintains that only impairment of waters for beneficial human use, actual or potential, is pollution, the two main criteria of this being destruction of fishing and human health hazard. While north Biscayne Bay certainly maintains large numbers of a wide variety of species, fishermen [W. Kandrashoff (pers. communication); D. de Sylva (University of Miami, pers. communication)] claim that "clean water species" which were once caught in great numbers are now absent from north Bay. In at least one example it would appear that a highly afflicted species (*Pogonias cromis*) continues to inhabit the Bay (these results) but will no longer take fishing bait perhaps because of its disease state.

In order to use fish as pollution-indicator species, a thorough investigation of population dynamics would be necessary (Doudoroff, 1957). The fish in the survey were caught only because they were of a certain size (adult) to be trapped in the 4.5 inch gill net and were somewhat free swimming. Among these are valuable sport fishing species (pompano, bonefish, Atlantic croaker). Primarily bottom dwellers (flounders), or rock dwellers (mangrove snapper) escaped detection. Adult mullet, which abound in north Bay, were never caught because of their size. Superficial sampling, with a smaller mesh gill net showed that juveniles of the same species caught as adults do exist in north Bay, indicating that complete life cycles are possible.

The question here, then, is not whether north Biscayne Bay is polluted enough to kill fish, but whether the enrichment effect, which appears to induce growth and fecundity of certain species, in combination with certain environmental stresses (bacteria, pesticides, metals, turbidity) which may contribute to fish disease, can increase the human health hazard from fish harboring human pathogen.

Since population dynamics are poorly known, we do not know if perhaps important predators (barracuda) are eliminated by the stresses, thus increasing high populations of mature diseased fish. Nor do we know if disease itself is responsible for the elimination of important food fishes or organisms necessary to their life cycles. We do not know to what degree these stresses

Table 2. Percent of abnormalities per species (June 1976 - June 1977).

Species	Split caudal fin	Split pectoral fin	Split pelvic fin	Split dorsal fin	Split anal and/ or misc. fin
Aetobatus narinari	0.0	0.0	0.0	0.0	0.0
Albula vulpes	65.3	2.8	2.8	1.4	0.0
Archosargus rhomboidalis	57.2	1.7	0.3	0.4	0.2
Brevoortia tyrannus	19.2	0.0	0.3	1.0	0.3
Caranx hippos	15.5	0.0	0.0	1.7	0.0
Dasyatis americana	0.0	0.0	0.0	0.0	0.0
Diapterus plumieri	64.5	0.0	2.6	0.0	0.0
Diodon hystrix	0.0	0.0	0.0	0.0	0.0
Elops saurus	40.0	0.0	0.0	0.0	0.0
Eucinostomus gula	23.1	1.1	1.6	0.5	0.5
Gerres cinereus	11.6	1.6	1.4	0.0	0.2
Lagodon rhomboides	40.7	0.9	0.0	0.0	0.0
Micropogonias undulatus	78.9	1.4	1.4	0.0	0.0
Pogonias cromis	86.7	10.6	3.5	4.4	0.0
Selene vomer	8.5	0.0	0.0	0.0	0.0
Trachinotus carolinus	25.0	0.0	0.0	0.0	0.0

Species	Hemorrhaged caudal fin	Hemorrhaged other fin	Hemorrhaged claspers
Aetobatus narinari	0.0	0.0	0.0
Albula vulpes	2.8	1.4	0.0
Archosargus rhomboidalis	7.0	6.2	0.0
Brevoortia tyrannus	14.8	5.7	0.0
Caranx hippos	10.3	6.9	0.0
Dasyatis americana	0.5	5.3	45.5
Diapterus plumieri	34.2	38.2	0.0
Diodon hystrix	0.0	4.8	0.0
Elops saurus	25.0	0.0	0.0
Eucinostomus gula	5.5	2.7	0.0
Gerres cinereus	2.2	3.0	0.0
Lagodon rhomboides	10.6	1.8	0.0
Micropogonias undulatus	16.9	22.5	0.0
Pogonias cromis	21.2	44.2	0.0
Selene vomer	0.8	0.0	0.0
Trachinotus carolinus	4.2	4.2	0.0

Table 2. Percent of abnormalities per species (cont.).

Species	Eroded caudal fin	Eroded other fin	Deformed fin	Incomplete fin	Stunted fin	Missing fin
Aetobatus narinari	0.0	0.0	0.0	0.0	0.0	0.0
Albula vulpes	11.1	1.4	0.0	0.0	0.0	0.0
Archosargus rhomboidalis	1.9	0.7	3.1	1.0	0.5	0.0
Brevoortia tyrannus	2.6	0.3	14.0	0.5	2.6	0.5
Caranx hippos	3.4	3.4	0.0	0.0	0.0	0.0
Dasyatis americana	0.0	0.5	0.0	1.1	0.0	1.1
Diapterus plumieri	19.7	5.3	6.6	0.0	0.0	0.0
Diodon hystrix	0.0	0.0	9.5	0.0	0.0	0.0
Elops saurus	5.0	10.0	0.0	0.0	0.0	5.0
Eucinostomus gula	12.1	3.8	3.8	0.5	0.5	0.0
Gerres cinereus	4.3	1.0	1.6	1.2	0.2	0.2
Lagodon rhomboides	3.5	0.0	2.7	0.0	0.9	0.0
Micropogonias undulatus	11.3	1.4	8.5	0.0	1.4	0.0
Pogonias cromis	2.7	0.9	1.8	0.0	0.0	0.0
Selene vomer	0.0	0.0	2.3	1.6	0.0	0.0
Trachinotus carolinus	4.2	0.0	0.1	0.0	4.2	0.0

Species	Hemorrhaged body	Body lesion	Body tumor	Scale disorientation	Scales missing	Emaciated body
Aetobatus narinari	0.0	0.0	0.0	0.0	0.8	0.0
Albula vulpes	11.1	0.0	0.0	1.4	0.0	0.0
Archosargus rhomboidalis	3.8	0.7	0.1	11.2	0.3	0.2
Brevoortia tyrannus	4.4	0.0	0.5	6.5	0.3	0.0
Caranx hippos	3.4	1.7	0.0	1.7	0.0	0.0
Dasyatis americana	15.9	2.6	0.0	0.0	0.0	0.0
Diapterus plumieri	44.7	0.0	0.0	2.6	0.0	2.6
Diodon hystrix	4.8	0.0	0.0	0.0	0.0	0.0
Elops saurus	0.0	0.0	0.0	0.0	0.0	0.0
Eucinostomus gula	9.3	1.6	0.0	4.9	0.0	0.0
Gerres cinereus	13.8	1.2	0.0	2.6	0.0	0.0
Lagodon rhomboides	0.9	0.0	0.0	16.8	0.0	0.0
Micropogonias undulatus	12.7	1.4	0.0	2.8	0.0	1.4
Pogonias cromis	11.5	0.0	0.0	0.0	0.0	0.0
Selene vomer	3.1	0.0	0.0	0.0	0.0	0.0
Trachinotus carolinus	0.0	0.0	0.0	12.5	0.0	0.0

Table 2. Percent of abnormalities per species (cont.).

Species	Cloudy Eyes	Collapsed Eyes	Bulging Eyes	Bleeding Eyes	Deformed Mouth
Aetobatus narinari	0.0	0.0	0.0	0.0	0.0
Albula vulpes	1.4	0.0	0.0	1.4	0.0
Archosargus rhomboidalis	0.4	0.1	0.1	0.5	0.2
Brevoortia tyrannus	0.3	0.0	0.0	0.0	0.0
Caranx hippos	0.0	0.0	0.0	1.7	0.0
Dasyatis americana	0.0	0.0	0.0	0.0	0.0
Diapterus plumieri	1.3	0.0	1.3	0.0	0.0
Diodon hystrix	0.0	0.0	0.0	0.0	0.0
Elops saurus	0.0	0.0	0.0	0.0	0.0
Eucinostomus gula	0.5	0.0	0.0	0.5	0.0
Gerres cinereus	0.6	0.2	0.2	0.2	0.0
Lagodon rhomboides	0.0	0.0	0.0	0.0	0.0
Micropogonias undulatus	4.2	0.0	0.0	1.4	0.0
Pogonias cromis	0.0	0.0	0.0	0.0	0.0
Selene vomer	0.8	0.0	0.0	0.0	0.0
Trachinotus carolinus	0.0	0.0	0.0	0.0	0.0

select for certain species. The most frequently caught fish in our survey (*Archosargus*) is also the one most often trapped directly in a raw sewage outfall. Is it replacing a more valuable species? Is *Diapterus* to be considered a "pollution resistant" species that can survive in spite of displayed stress symptoms, or is it the most vulnerable since it was the most afflicted, on the verge of elimination from the Bay. Doudoroff (1957) has pointed out the complexities of this type of speculation. A fish health index could seemingly make a contribution to the solution of these and other problems in the management of our waterways.

ACKNOWLEDGMENTS

This report is based on the initial data reduction and manuscript of L. R. Udey. The authors wish to thank C. Sindermann, J. Hameedi and S. Baker for their reviews and helpful suggestions; E. Collins (NOAA Central Library) and M. J. Bello (NOAA Miami Regional Library) for assistance in the location of literature citations; K. Hale (University of Miami, retired) for archiving the manuscript; and all those who participated in this study.

This work was funded through a grant of the South Florida Ecosystem Restoration Prediction and Modeling Program (SFERPM) - a competitive program conducted by the Center for Sponsored Coastal Ocean Research (CSCOR), in association with the South Florida Living Marine Resources Program (SFLMR) - for Coastal and Estuarine Data/Document Archeology and Rescue (CEDAR) for South Florida.

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APPENDIX I

Graphic presentation of abnormalities data for fish collected June 1976 - June 1977

[Values used to generate figures were estimated from unpublished graphical data and are thus subject to estimation errors. Questionable estimates are noted with a question mark.]

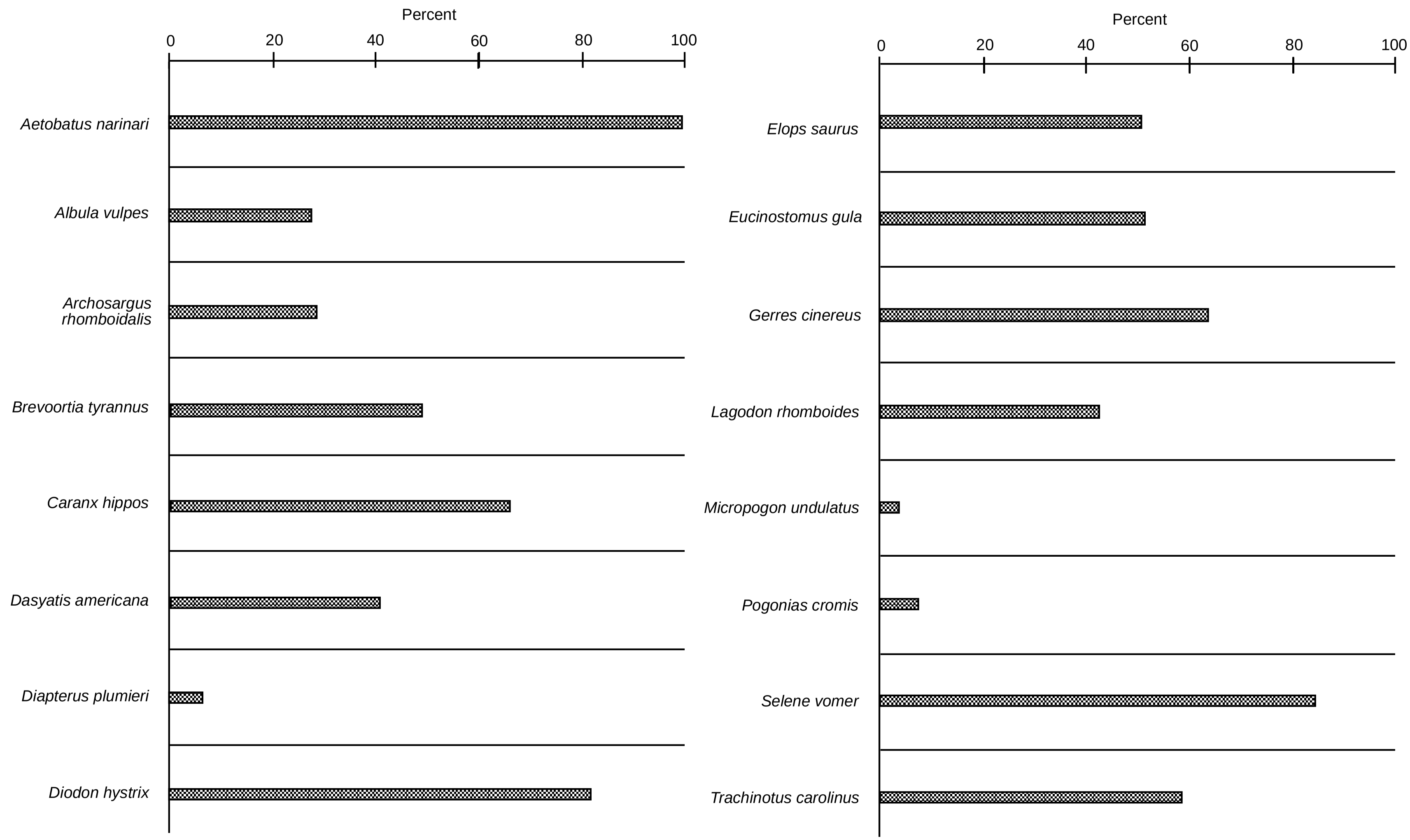

Figure I.1. Percent of normal fish.

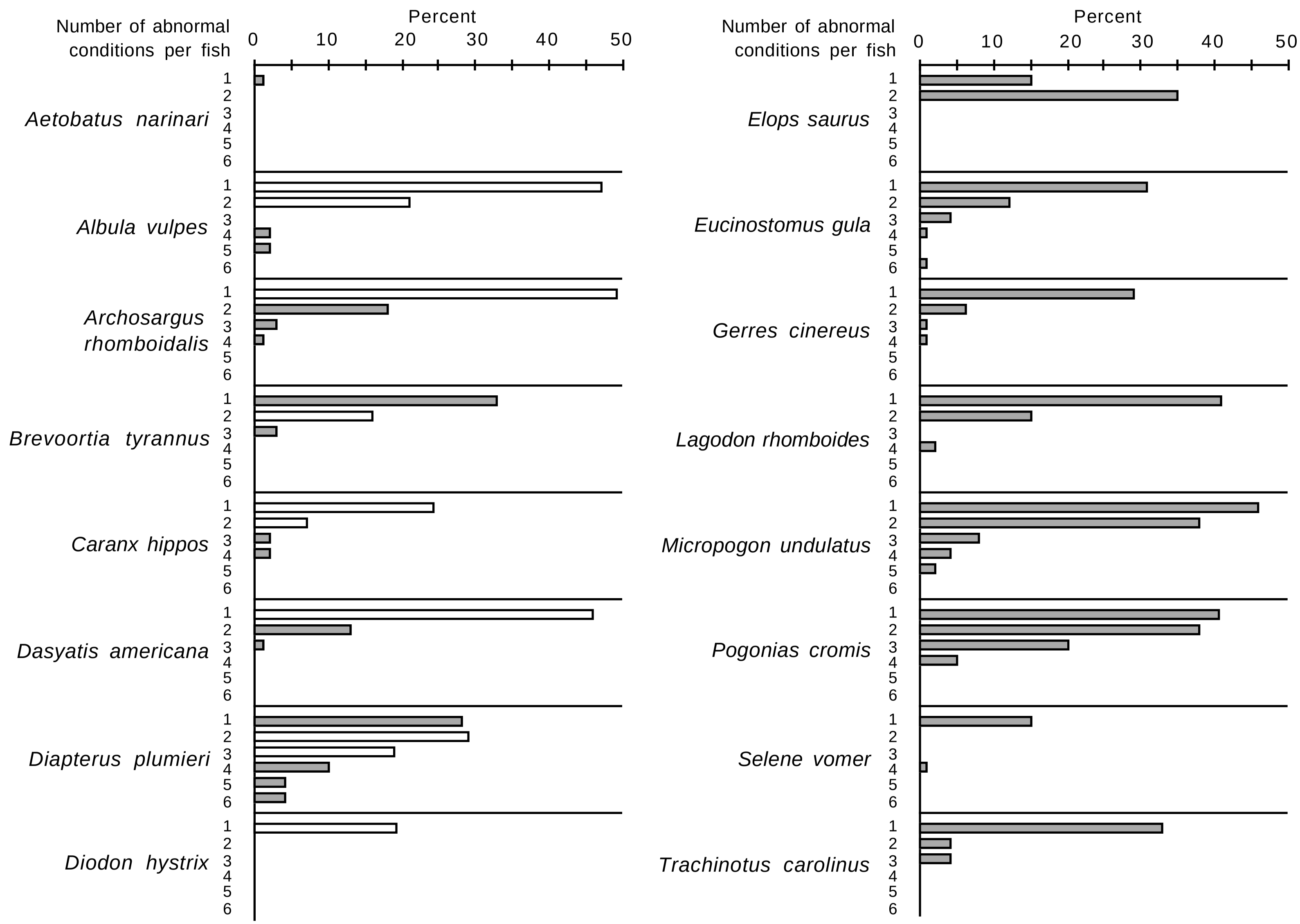

Figure I.2. Percent of fish with one or more abnormal condition.

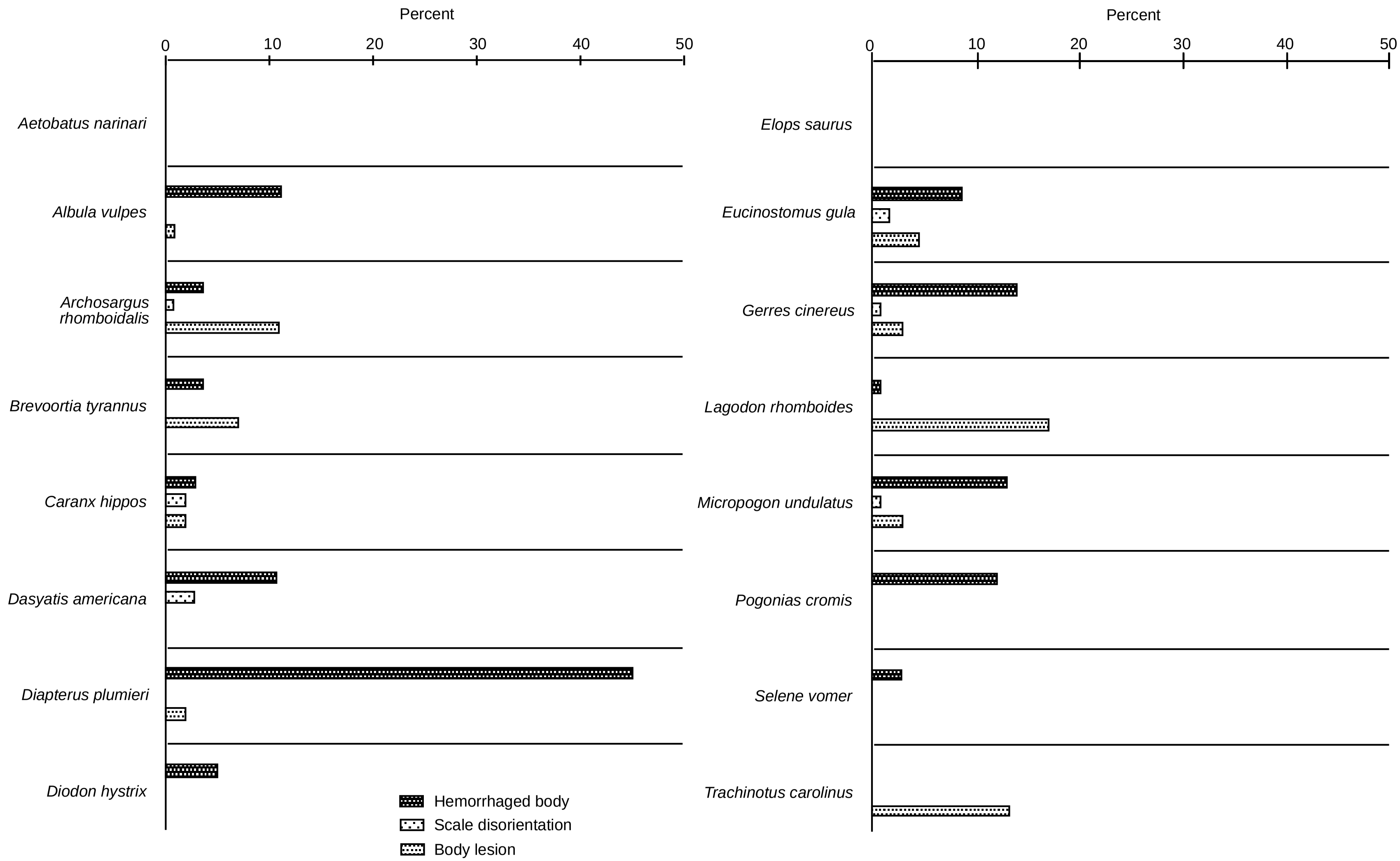

Figure I.3. Percent of fish with body abnormalities.

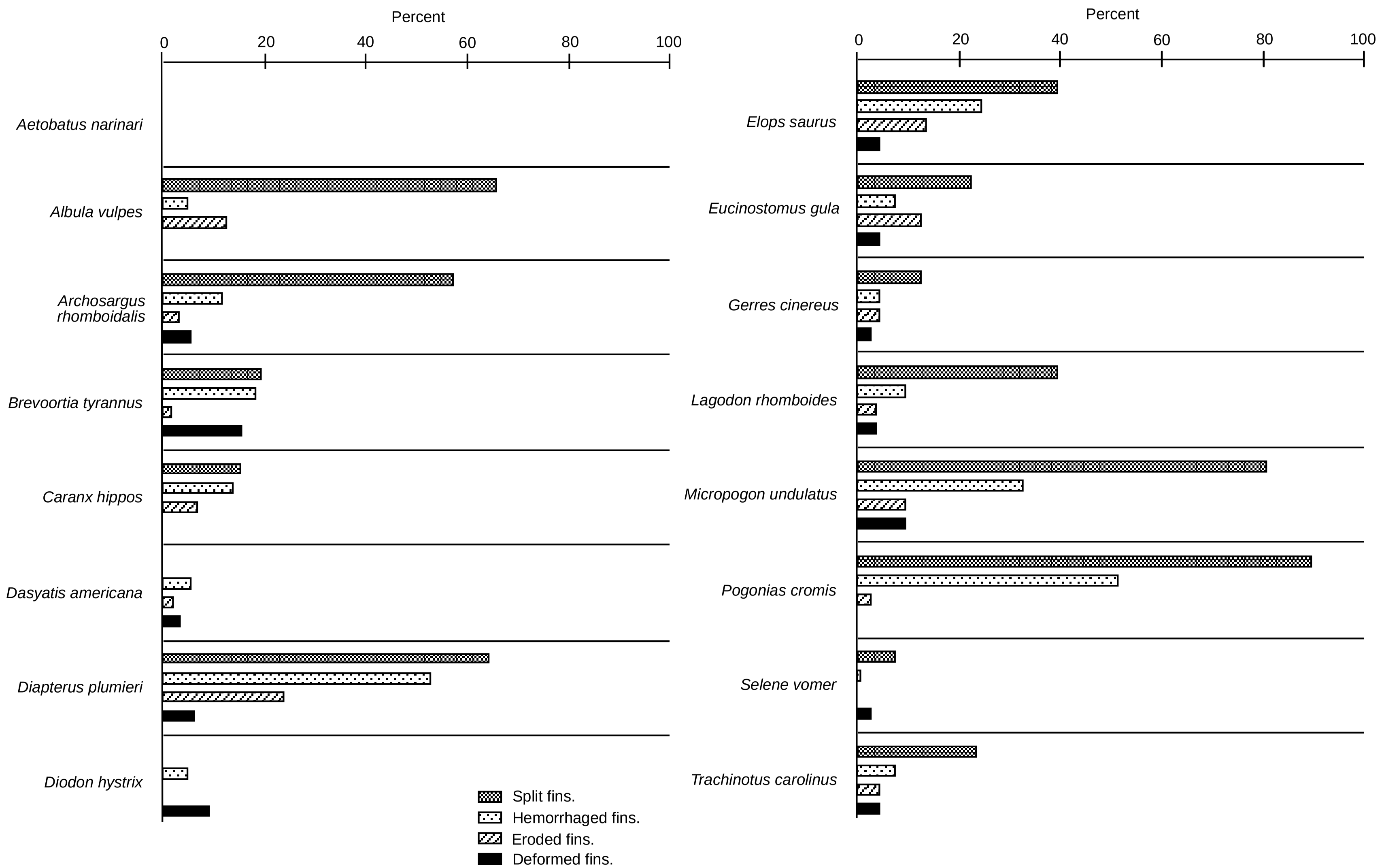

Figure I.4. Percent frequency of each group of fin disorders.

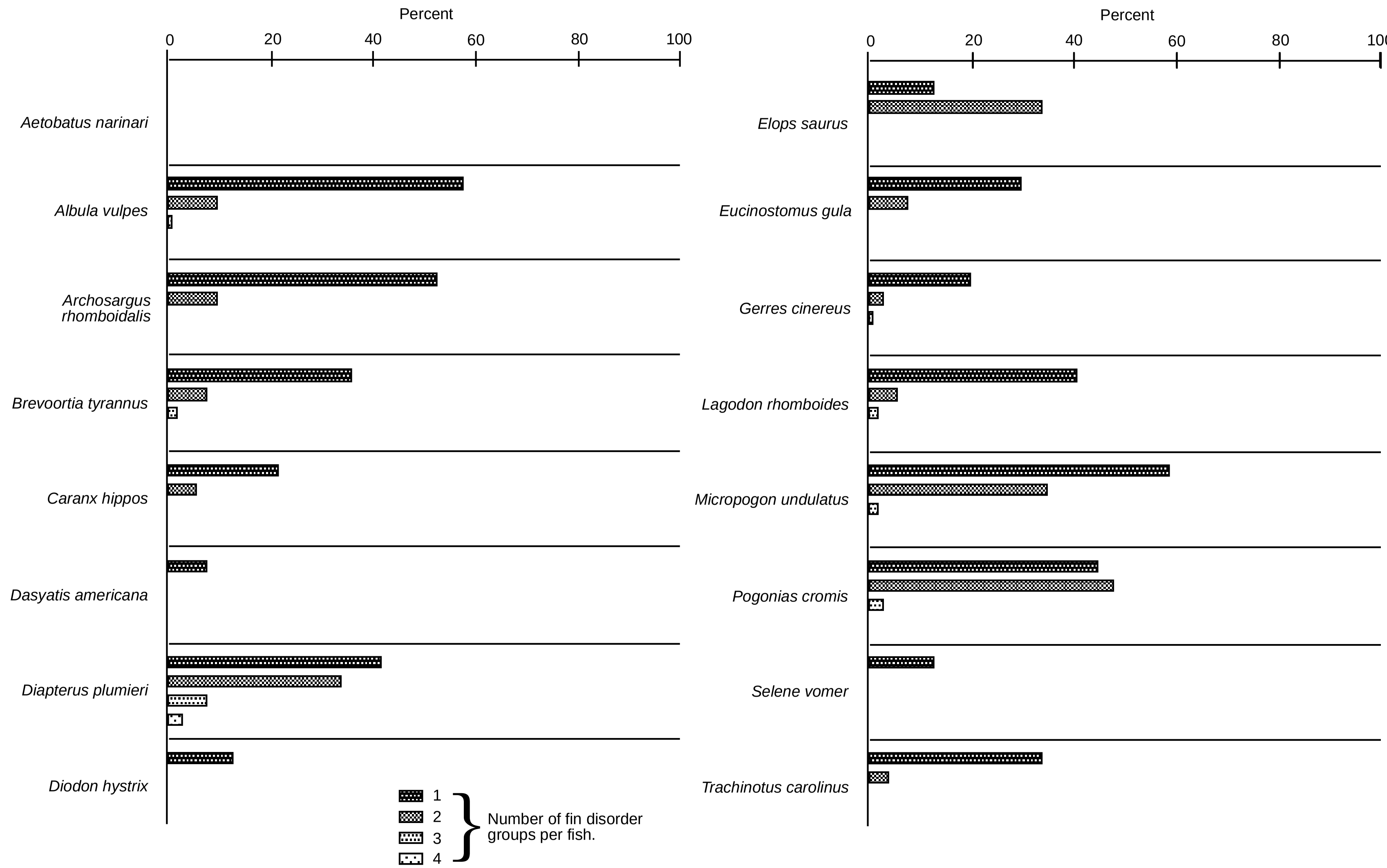

Figure I.5. Percent of fish with one or more groups of fin disorders.

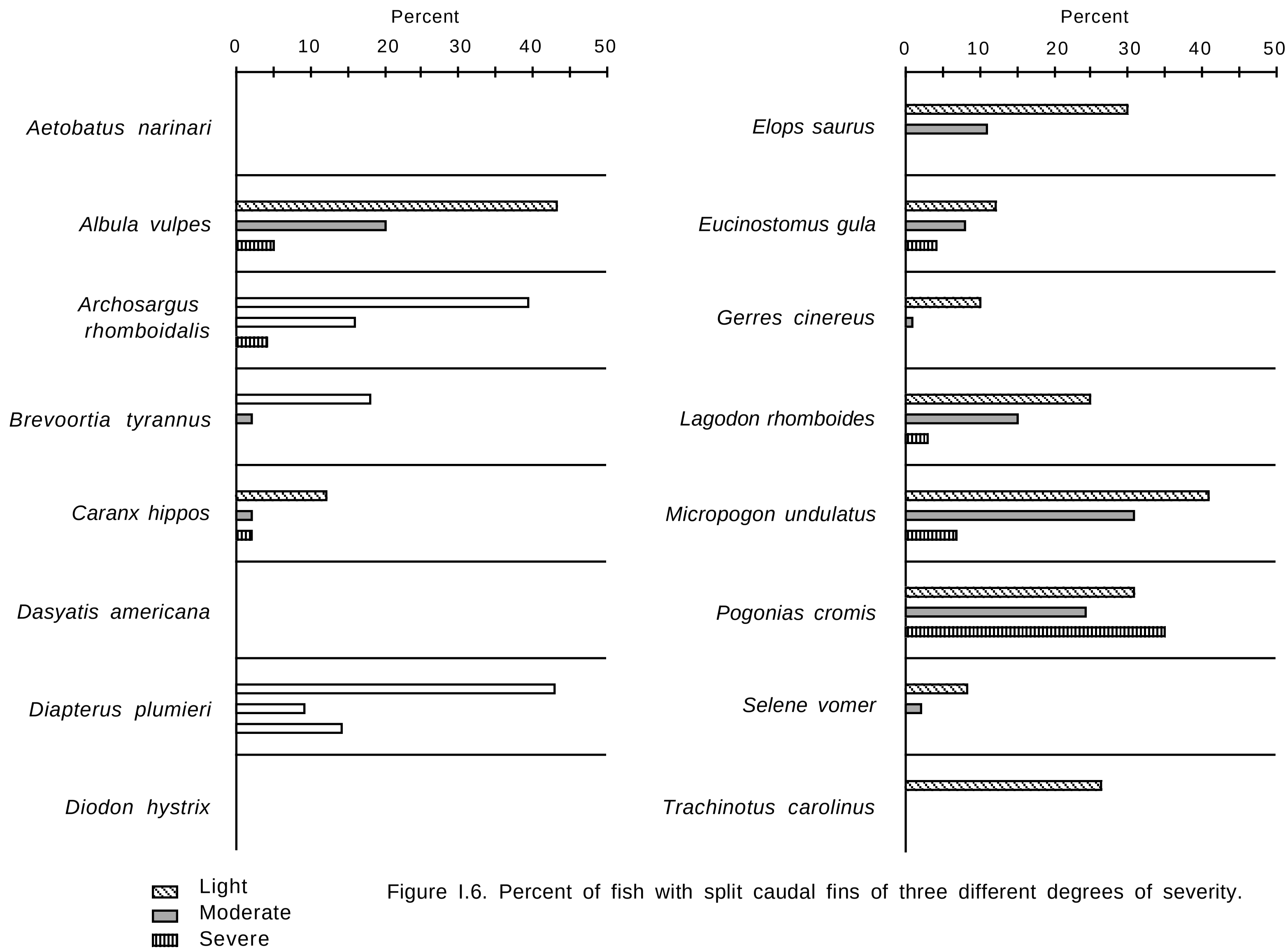

Figure I.6. Percent of fish with split caudal fins of three different degrees of severity.

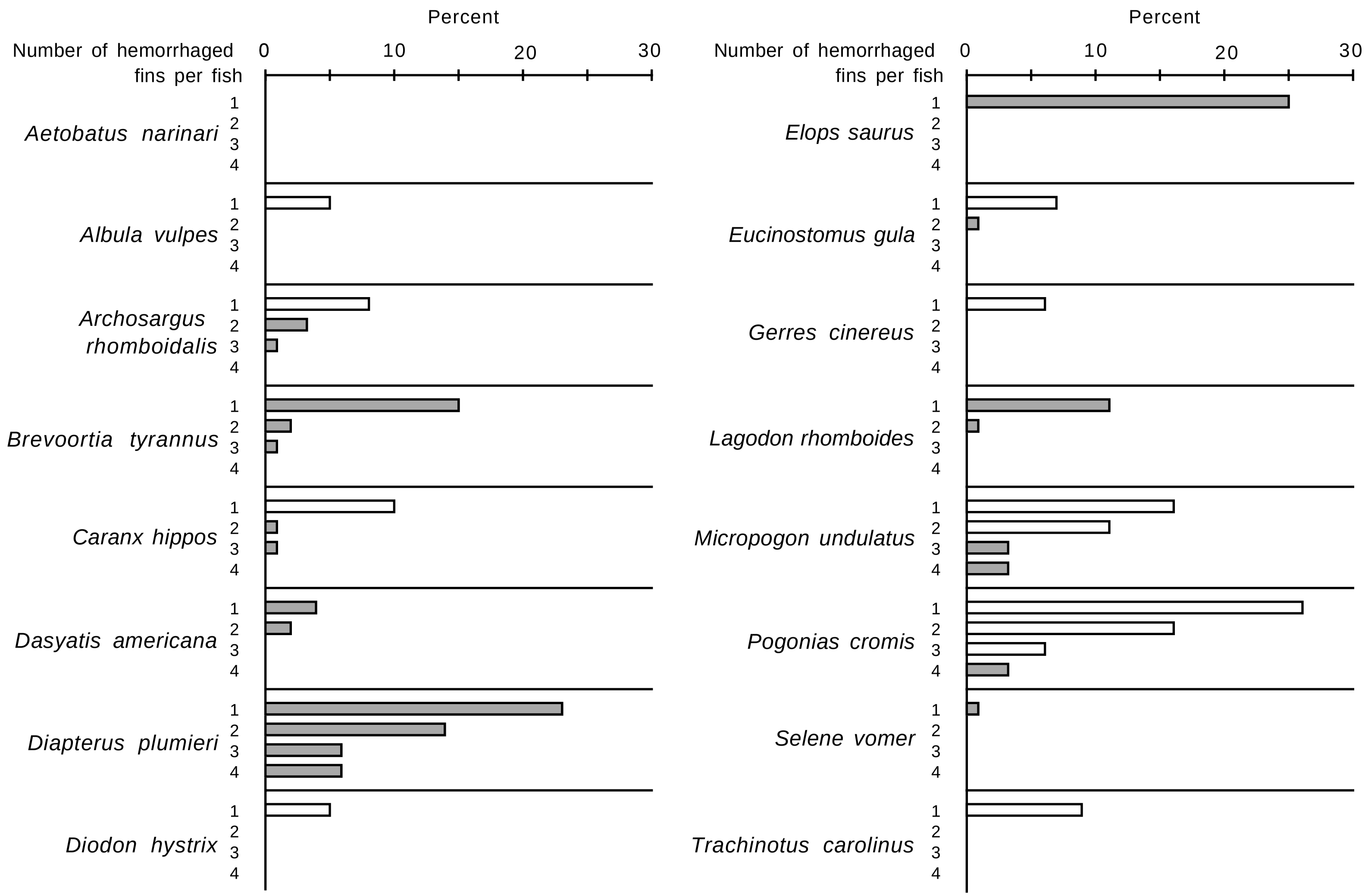

Figure I.7. Percent of fish with one or more hemorrhaged fins.

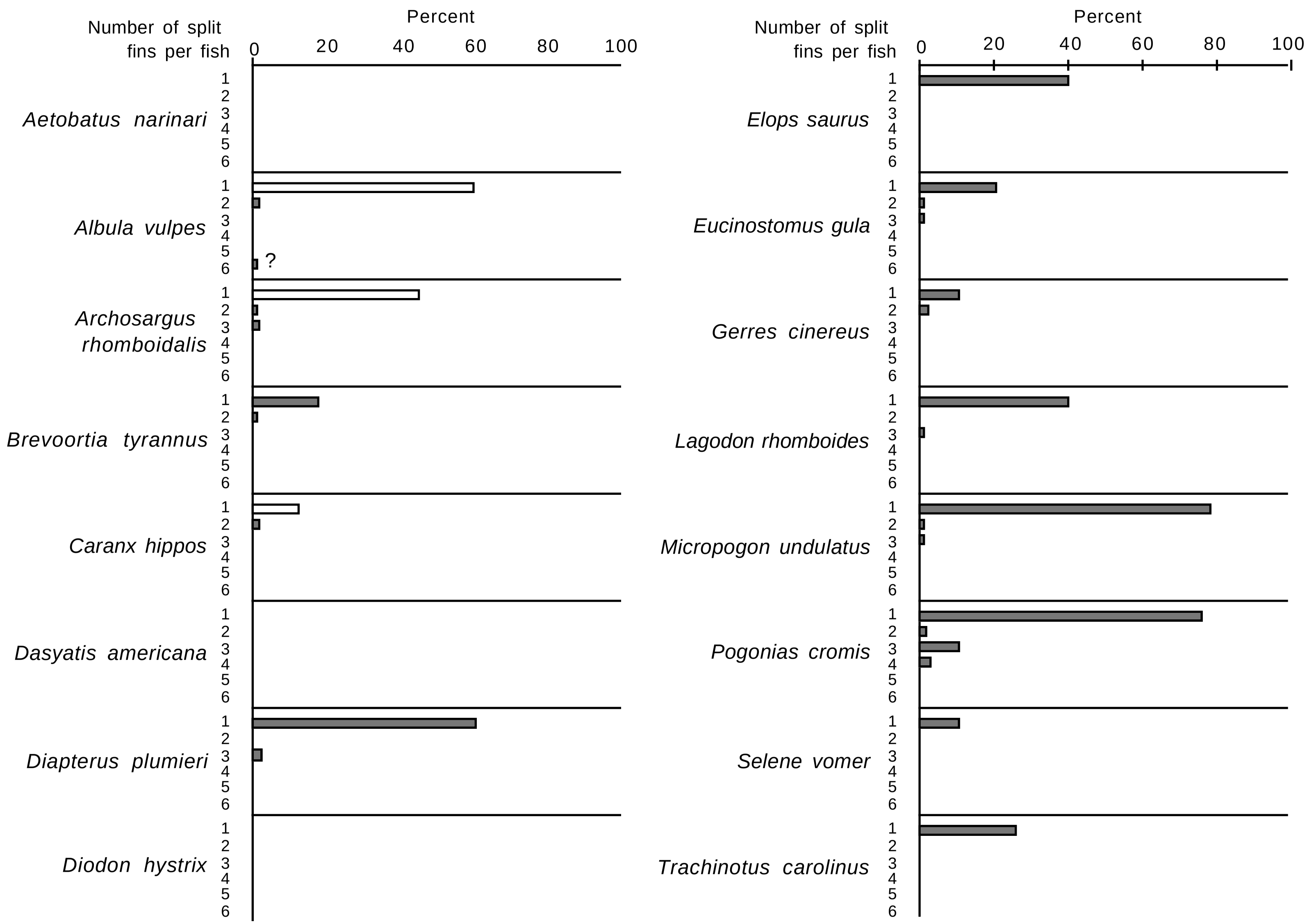

Figure I.8. Percent of fish with one or more split fins.

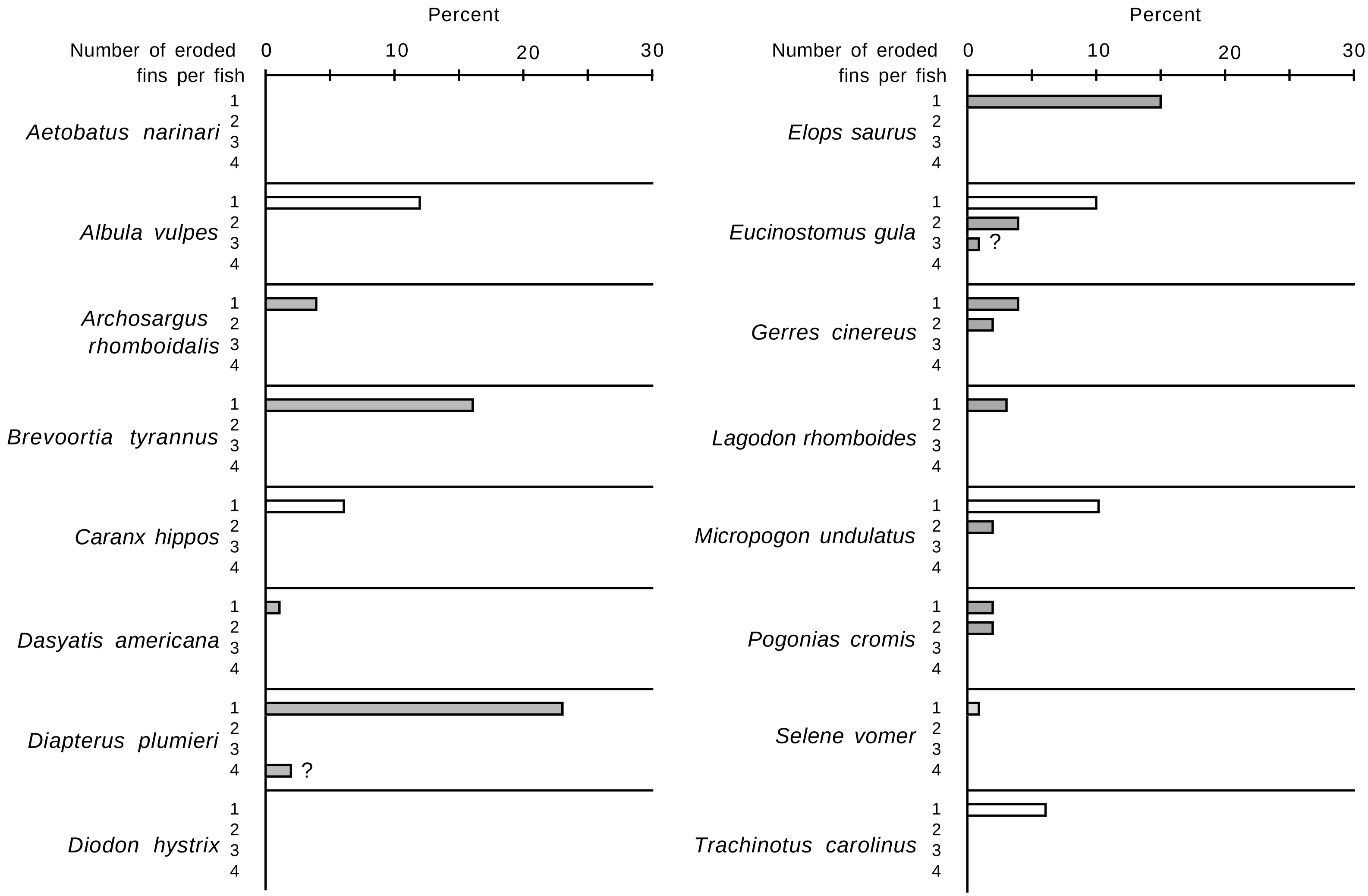

Figure I.9. Percent of fish with one or more eroded fins.

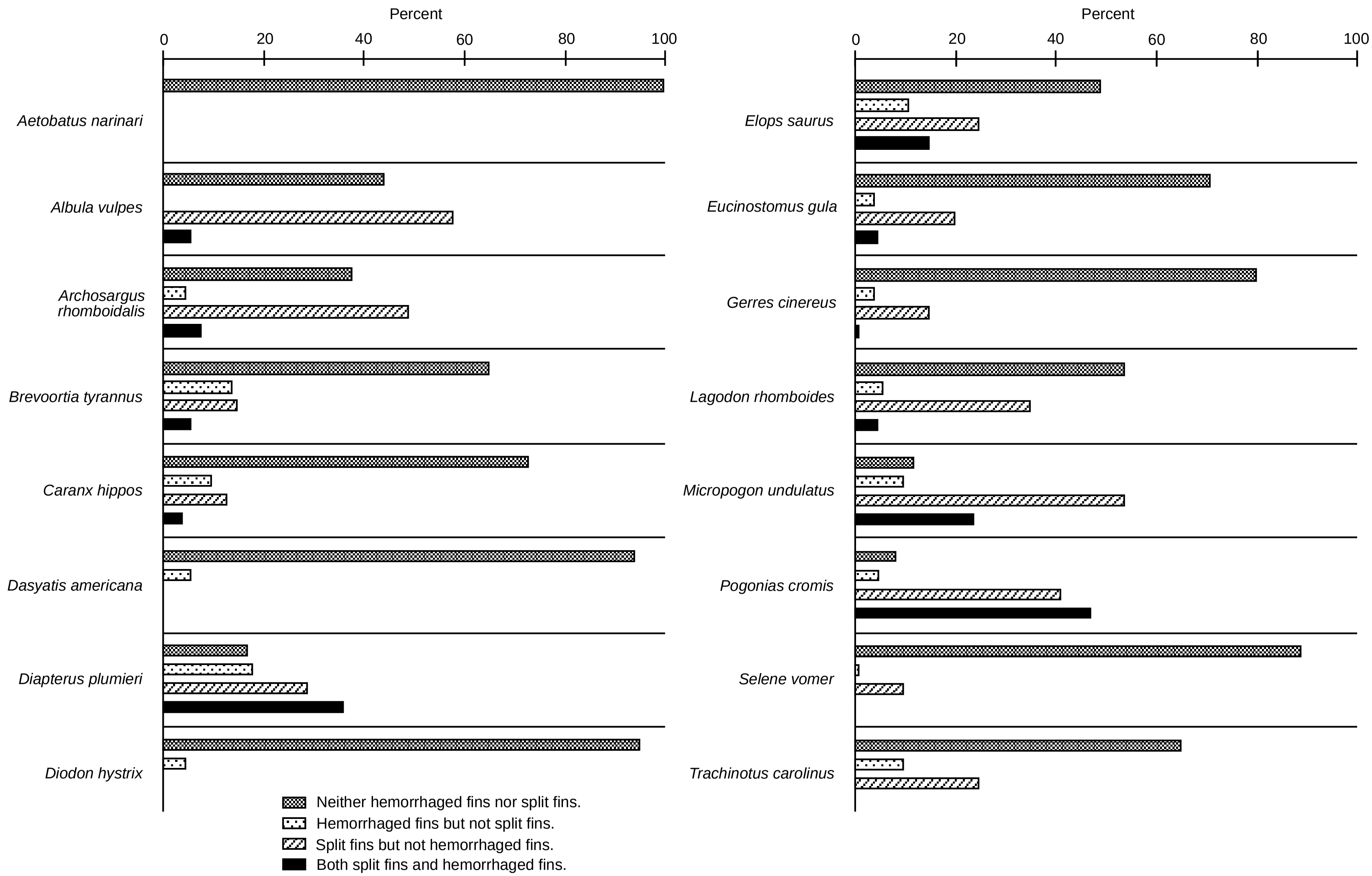

Figure I.10. Percent of fish with hemorrhaged fins and/or split fins.

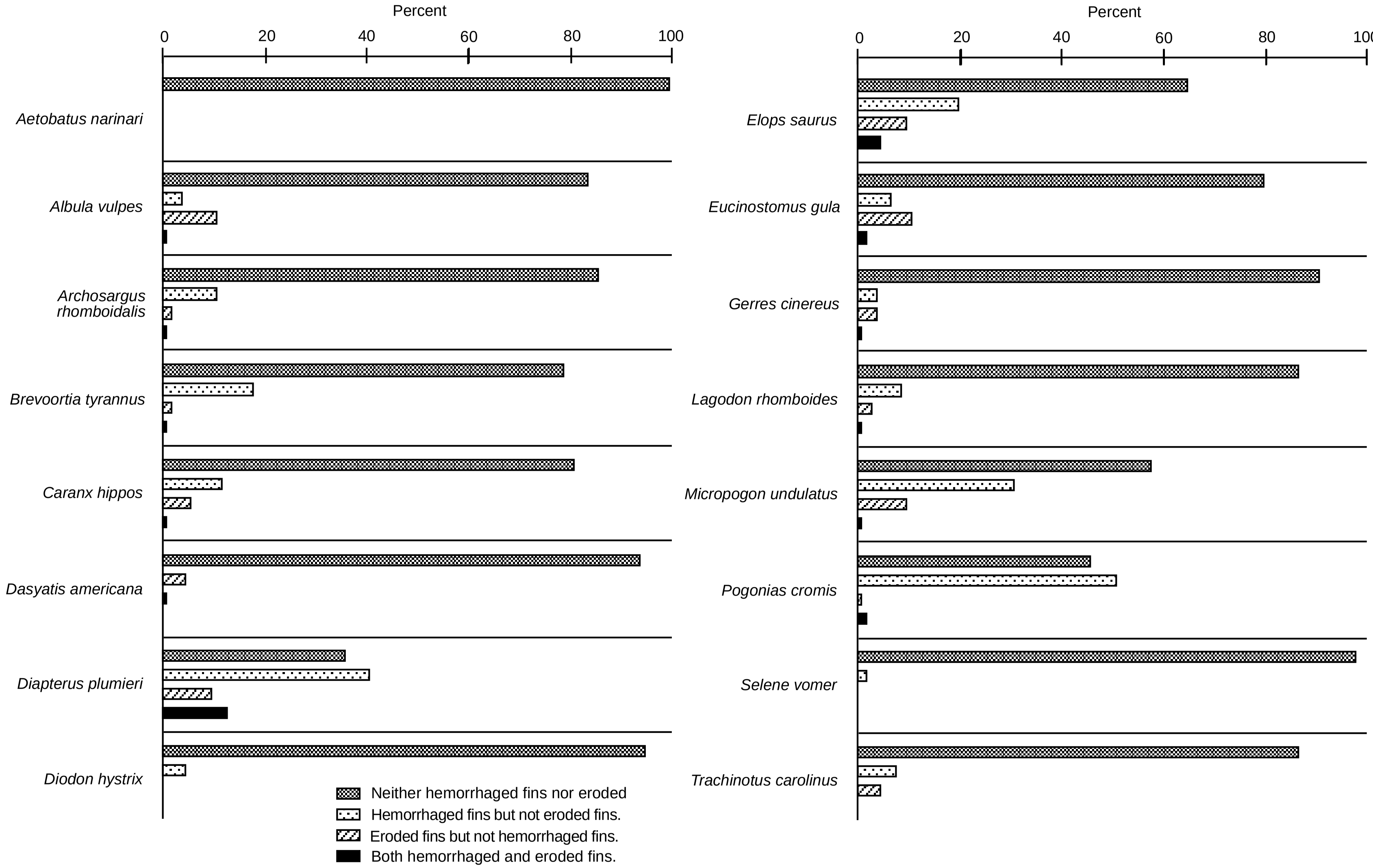

Figure I.11. Percent of fish with hemorrhaged and/or eroded fins.

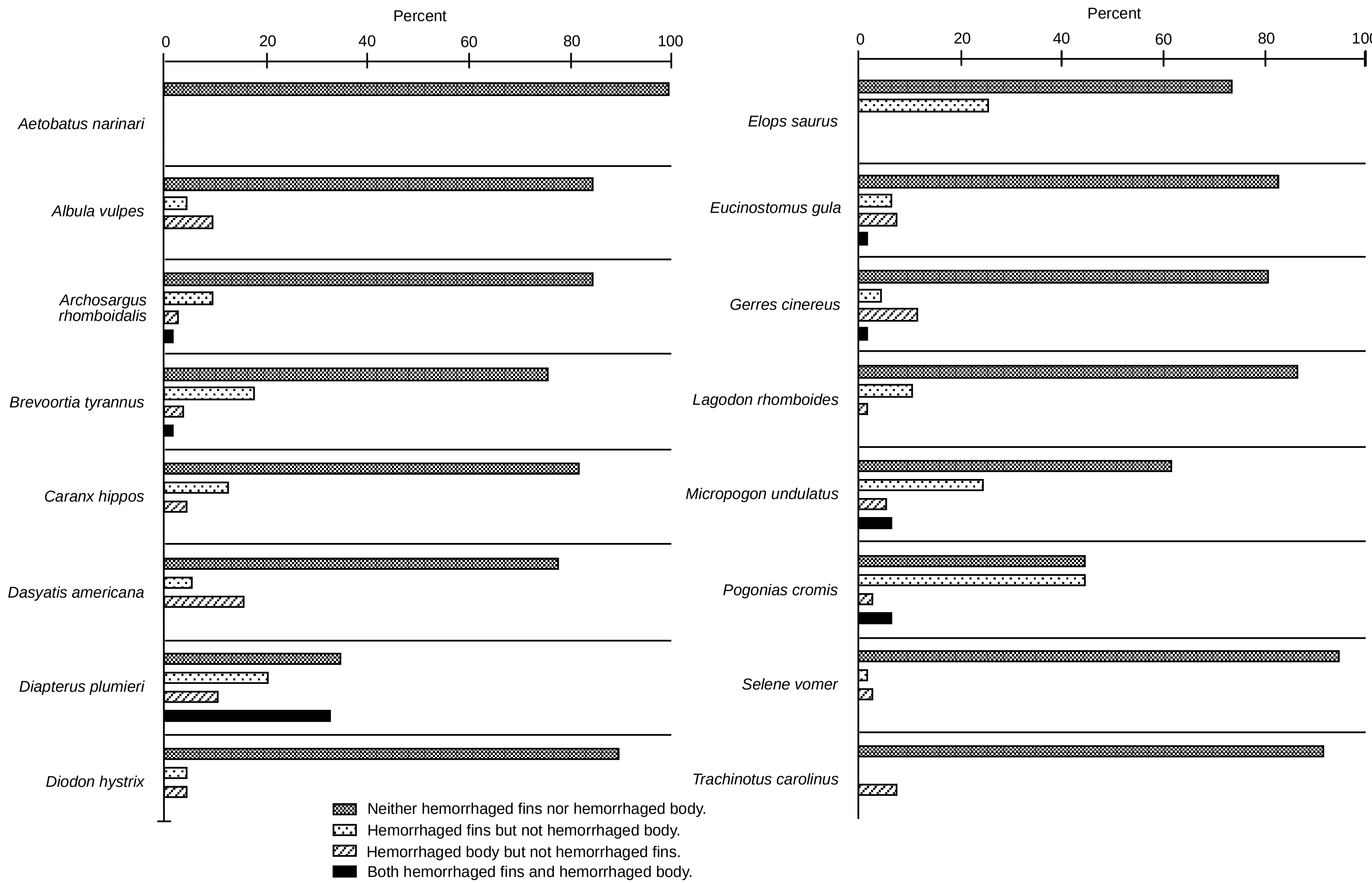

Figure I.12. Percent of fish with hemorrhaged fins and/or hemorrhaged body.

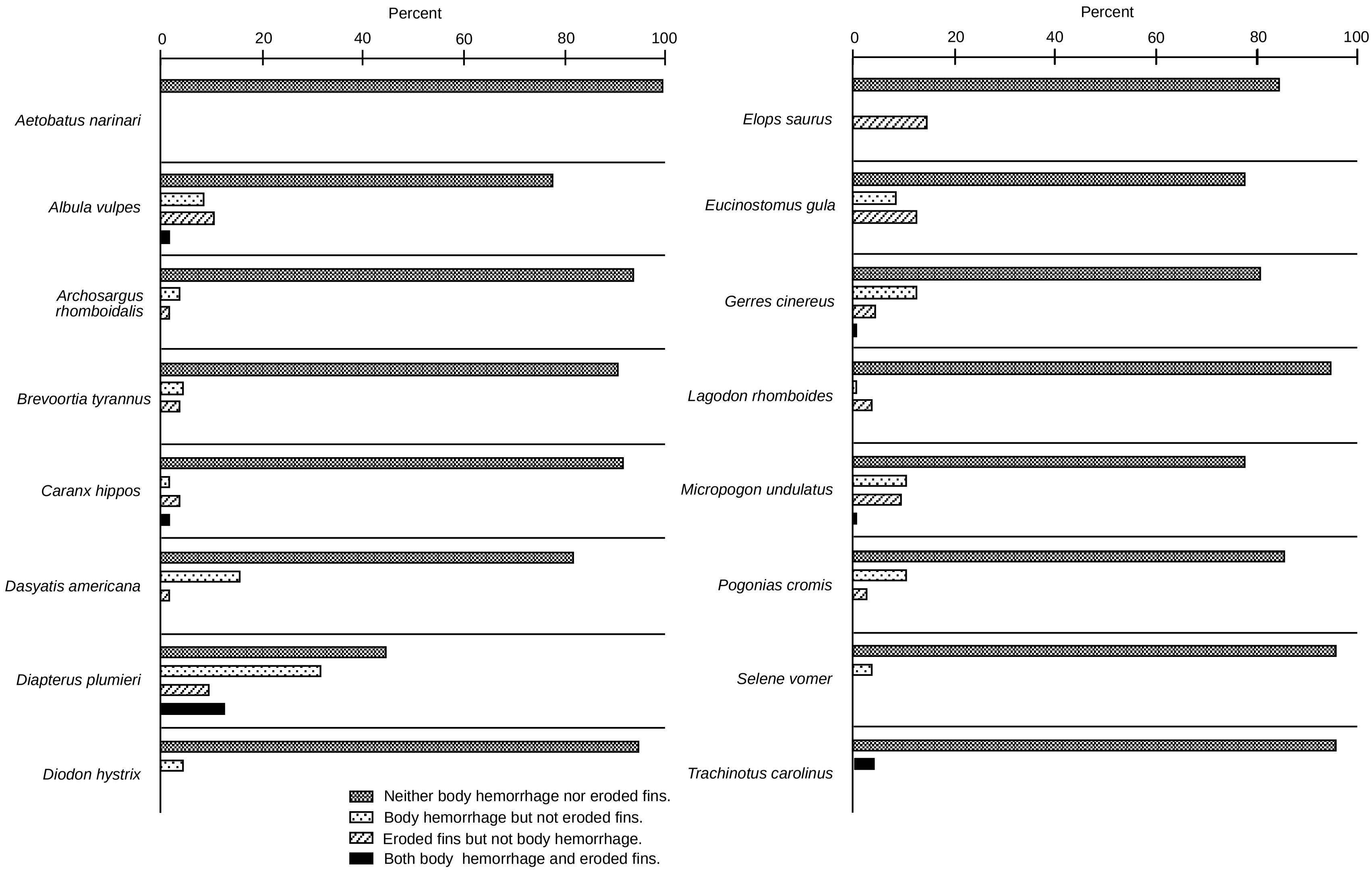

Figure I.13. Percent of fish with body hemorrhage and/or eroded fins.

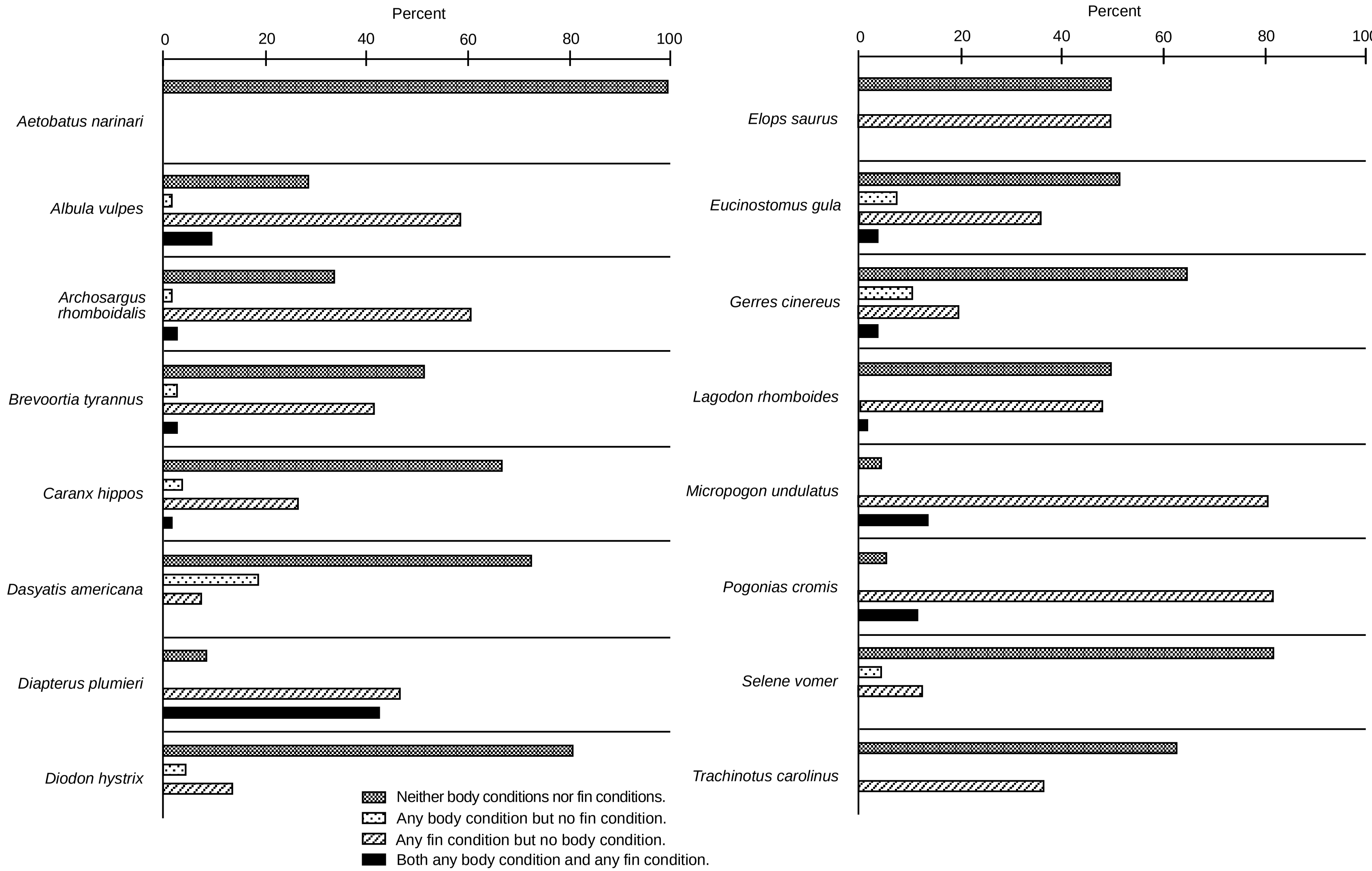

Figure I.14. Percent of fish with any body condition and/or any fin condition.