# Collections and Submarine Observations of Deep Benthic Fishes and Decapod Crustacea in Hawaii[1]

THOMAS A. CLARKE[2]

ABSTRACT: Depths between 150 and 400 m off Oahu, Hawaii, were surveyed by submarine, gill nets, and traps. Depth of capture or observations and other data are given for 47 species of fishes and 20 species of decapod Crustacea. Of these species, 10 fishes and five crustaceans are either undescribed or new records for Hawaii. Four other fishes collected and several others observed from the submarine are probably undescribed or unrecorded species. A large proportion of both the total number of species collected and of the new forms were taken by gill net. The gill nets are able to sample steep, rocky bottoms and obtain types of organisms inaccessible to other types of gear, particularly bottom trawls.

THE DEEP WATER BENTHIC FAUNA of the Hawaiian Islands is known mainly from results of deep bottom trawling by the *Albatross* near the turn of the century (Gilbert, 1905) and from a few subsequent trawling-dredging collections. Such collections have undoubtedly missed some forms and, as Gosline (1965) has noted, data on depth distribution are inadequate. Brock and Chamberlain (1968) and Strasburg, Jones, and Iverson (1969) have reported on submersible observations down to about 200 m. These data have extended depth ranges and provided interesting observations on many organisms, but, because of the depth limits of the submersible, have included few deep-water species. The only other sources of deep-water specimens have been fishermen who have collected occasional individuals by handline, and volcanic eruptions during which specimens have floated to the surface following lava flows into deep water (Gosline, Moore, and Yamaguchi, 1954).

This paper presents results of a survey during which a submersible and several types of fishing gear were utilized. The efforts were concentrated on steep, rocky bottoms between 150 and 400 m depths. The investigation was restricted to fishes and decapod Crustacea. The results provide records of several species new to Hawaii, depth ranges of these and many others, information on the habits of some species, and a basis for comparing the effectiveness of different survey methods.

## METHODS

The submersible used was the *Naia,* operated by Pacific Submersibles, Inc. *Naia*'s maximum depth is about 400 m. She carries a pilot and two observers (fore and aft). Four dives were made (9, 12, 14, and 22 September 1968). All were during the daytime, between 0945 and 1600. Only cursory observations were made above 150 m. The maximum depths attained ranged from 255 to 380 m. Time per dive below 150 m averaged about 150 minutes. All observations were recorded on a tape recorder. Fish poison was released on most dives. Unfortunately, the submarine's collecting arm did not function properly and only two fish were recovered from the bottom. (Three more were found floating on the surface after a poisoning at 155 m).

Traps and gill nets were usually set in the evening and retrieved the following morning. Traps were of 2.5, 1.2, and 0.6 cm wire mesh and were baited with fish and/or squid. Most were about 1.0 × 0.5 × 0.5 $m^3$ in

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[2] University of Hawaii: Department of Oceanography Honolulu, Hawii 96822, and Hawaii Institute of Marine Biology, P. O. Box 1067, Kaneohe, Oahu, Hawaii.

dimensions, but one large trap about 2 × 2 × 3 $m^3$ was used on one cruise. Gill nets of 12.5, 7.5, and 3.7 cm stretch mesh multifilament nylon were used. Each set included several mesh sizes in a string about 200 m long with anchors and float lines at each end.

Standard length of the fishes, and carapace length of Crustacea were in most cases measured to the nearest mm; occasionally, with larger specimens, less precise measurements were made in the field. The identifications used here are mostly from Gosline and Brock (1965) and Rathbun (1906). Where these proved inadequate, specialists were consulted. All names used here which are either tentative or uncertain are discussed briefly in the appendix. Representatives of rare, unrecorded, and new species that are not currently in the hands of taxonomists have been deposited in the Bernice P. Bishop Museum, Honolulu, Hawaii.

## STUDY AREAS

The submarine dives were all made off Barbers Point at the southwest corner of the island of Oahu. Most of the gillnet fishing was done near the sites of the sub's dives; depth coverage and dates are shown in Table 1. A total of 22 traps was set between about 170 and 365 m in this area on the same dates. Trapping effort was about evenly distributed through the depth zone.

The bottom near Barbers Point dropped steeply from about 100–120 m to about 300 m. The slope angle ranged from 60° to 90°. In many places the cliff face was smooth rock with little or no sediment covering. The only relief was small ledges or canyons in the face of the cliff. Below 300 m, the bottom was coarse sand with estimated slopes of 5° to 20°. There were occasional rocks, 0.5 to 2.0 m in diameter, on the sandy areas. Temperatures taken from the submarine in September 1968 dropped from 25° C at 100 m to 22°, 18°, and 13° C at 150, 200, and 300 m, respectively. Temperatures taken by bathythermograph in April 1969 were 20.5°, 18°, 14.5°, and 9° C, for the same depths.

TABLE 1

DATES AND DEPTHS OF GILLNET SETS MADE OFF BARBERS POINT, OAHU, NEAR THE AREA WHERE SUBMARINE DIVES WERE MADE

| DATE | DEPTH (m) |
|---|---|
| 14–15 Dec 1968 | 185–220 |
| 15–16 Dec 1968 | 185–245 |
| 9–10 Apr 1969 | 165–200 |
| 9–10 Apr 1969 | 225–310 |
| 10–11 Apr 1969 | 275–310 |
| 10–11 Apr 1969 | 200–275 |
| 28–29 Oct 1969 | 365 |
| 28–29 Oct 1969 | 275 |
| 28–29 Oct 1969 | 185 |
| 19–20 Jun 1971 | 39–41 |
| 19–20 Jun 1971 | 85–95 |
| 19–20 Jun 1971 | 115–130 |

Traps and a few gill nets were also set off Kaneohe and Haleiwa, Oahu. The bottom off Kaneohe is steep but, judging from the types of organisms collected and the frequent presence of mud on the anchors, it is covered mostly with sediment. The bottom off Haleiwa is, in contrast to that of the other two areas, much gentler in slope. Except for occasional low outcrops, the bottom at Haleiwa is sediment-covered. About 160 traps were set between 110 and 450 m off Kaneohe, most of them in November 1970; 46 traps were set between 110 and 220 m off Haleiwa in April and November 1970. In both areas, the trapping effort was about evenly distributed throughout the depth ranges. One gillnet set was made at 185 m over sediment-covered bottom off both areas. Gill nets were set at 110 and 275 m over rocky areas near Kaneohe.

One series of deeper trap sets was made off Kaneohe in November 1970. Sets of eight, four, four, and three traps per string were made at 550, 640, 730, and 920 m, respectively.

## RESULTS

### *Fishes*

Since the survey concentrated on depths below 150 m, the lower limits of most shallower water species were not determined. *Aulostomus chinensis, Caesioperca thompsoni, Holocanthus arcuatus, Heniochus acuminatus, Chromis verater,* and an unidentified balistiid were all seen frequently down to about 150 m, but never deeper. Four species, *Velifer multispinosus, Epinephelus quernus, Pristopomoides microlepis,* and *Histiopterus typus,* which apparently

TABLE 2

FISHES (BY FAMILY) AND DECAPOD CRUSTACEA (BY TRIBE) OBSERVED OR CAUGHT BELOW 150 METERS

| TAXON | METHODS | DEPTH RANGE (m) | STANDARD LENGTH (mm) |
|---|---|---|---|
| Fishes | | | |
| Odontaspidae | | | |
| *Odontaspis ferox* | G (2) | 185–310 | 1,600–2,230 |
| Carcharhinidae | | | |
| *Carcharhinus milberti* | G (1) | –185 | 1,200 |
| Sphyrnidae | | | |
| *Sphyrna lewini* | G (1) | –275 | 865 |
| Squalidae | | | |
| *Squalus blainvillei* | G, T | 165–320 | 300–500 |
| *Centrophorus tesselatus* | G (10) | 260–370 | 655–870 |
| *Centroscyllium granulosum* | T (1) | 920 | 310 |
| Dasyatidae | | | |
| *Urotrygon daviesi* | G (1) | 370 | 650 |
| Argentinidae | | | |
| *Glossanodon* sp. | S | 300 | — |
| Ateleopidae | | | |
| *Ateleopus plicatellus* | S | 370 | — |
| Muraenidae | | | |
| *Gymnothorax berndti* | S, G, T | 150–225 | 300–940 |
| *Gymnothorax nuttingi* | T | 165–275 | 650–1,030 |
| *Gymnothorax nudivomer* | T (1) | 165 | 670 |
| *Gymnothorax* sp. | G, T (4) | 150–185 | 800–890 |
| Congridae | | | |
| *Conger oligoporus* | S (?), T (6) | –365 | 54–127 |
| *Congrellus aequoreus* | T (2) | 275–640 | 210–265 |
| Ophichthidae | | | |
| *Muraenichthys macropterus* | T (1) | 275 | 370 |
| Synaphobranchidae | | | |
| *Synaphobranchus brachysomas* | T (1) | 730 | 518 |
| Moridae | | | |
| *Physiculus grinnelli* | S*, G, T | 165–320 | 110–280 |
| Polymixiidae | | | |
| *Polymixia japonica* | S, G | 165–310 | 105–146 |
| Trachichthyidae | | | |
| *Hoplostethus mediterraneus* | G (2) | 185 | 240 |
| *Paratrachichthys* sp. | T (1) | 185 | 28 |
| Holocentridae | | | |
| *Myripristis chryseres* | S*, G | 90–175 | 165–190 |
| *Ostichthys* sp. | G (5) | 120–220 | 174–207 |
| Antigoniidae | | | |
| *Antigonia steindachneri* | S, T (2) | 190–275 | 50–105 |
| Serranidae | | | |
| *Pseudanthias kellogi* | S | 245–310 | — |
| Priacanthidae | | | |
| *Priacanthus alalaua* | G (3) | 110–185 | 125–448 |
| *Cookeolus boops* | S* | –175 | 260 |
| Apogonidae | | | |
| *Apogon maculiferus* | T | –150 | 45–95 |
| Carangidae | | | |
| *Seriola rivoliana* | S | –245 | (1,000) |
| Emmelichthyidae | | | |
| *Erythrocles schlegelii* | S*, G (2) | 120–255 | 235 |
| Lutjanidae | | | |
| *Symphysanodon typus* | S, G (1) | 175–185 | 147 |
| *Pristopomoides sieboldii* | T, G (6) | –185 | 180–248 |

TABLE 2 (*Continued*)

| TAXON | METHODS | DEPTH RANGE (m) | STANDARD LENGTH (mm) |
|---|---|---|---|
| *Etelis marshi* | G, T | 120–310 | 145–303 |
| *Etelis carbunculus* | G (5) | 120–185 | 187–345 |
| Chaetodontidae | | | |
| *Chaetodon modestus* | S, G (2) | 120–190 | 90 |
| Parapercidae | | | |
| *Neopercis roseoviridis* | S, T (4) | 150–230 | 75–105 |
| Gempylidae | | | |
| *Promethichthys prometheus* | S, G (5) | 90–360 | 210–222 |
| *Epinula magistralis* | G (1) | 185 | 310 |
| Callionymidae | | | |
| *Callionymus caeruleonotatus* | S | 250–325 | — |
| Brotulidae | | | |
| *Brotula multibarbata* | G (2) | –220 | 300–427 |
| Scorpaenidae | | | |
| *Setarches remiger* | S | 310 | — |
| *Plectrogenium nanum* | S | 380 | — |
| *Pontinus macrocephalus* | S, G | 120–300 | 174–307 |
| Peristediidae | | | |
| *Peristedion engyceros* | G (1) | 275 | 218 |
| Platycephalidae | | | |
| *Bembradium roseum* | S | 325–335 | — |
| Triacanthidae | | | |
| *Hollardia goslinei* | T (1) | 365 | 42 |
| Lophiidae | | | |
| *Lophiomus miacanthus* | G (1) | 365 | 140 |
| Chaunacidae | | | |
| *Chaunax umbrinus* | S | 330 | (25) |
| Decapod Crustacea | | | |
| Penaeidea | | | |
| *Penaeus marginatus* | G, T | 110–220 | 35–46 |
| Caridea, Pandalidae | | | |
| *Plesioneka martia* | G, T | 110–275 | 8–25 |
| *Plesioneka ocellus* | T (7) | 110–150 | 13–15 |
| *Plesioneka ensis* | T (1) | 365 | 25 |
| *Parapandalus* sp. | T | 110–220 | 10–16 |
| *Heterocarpus ensifer* | G, T | 150–730 | 11–34 |
| *Heterocarpus laevigatus* | T | 365–730 | 13–55 |
| Caridea, Oplophoridae | | | |
| *Acanthephyra eximea* | T (16) | 550–920 | 12–46 |
| Scyllaridea | | | |
| *Scyllarus timidus* | S, T, G | 110–185 | 25–39 |
| Brachyura | | | |
| *Lyreidus tridentatus* | G, T | 185–320 | 50–65 |
| *Notopoides latus* | G (2) | 185 | 30–32 |
| *Notosceles* sp. | G (3) | 130 | 20–30 |
| *Thelxiope orientalis* | G, T | 110–220 | 28–58 |
| *Homala japonica* | S, G, T | 165–375 | 22–50 |
| *Randallia distincta* | S, G | 275–310 | 37–42 |
| *Mursia hawaiiensis* | G | 165–365 | 34–38 |
| *Cyrtomaia smithi* | S, G, T (5) | 255–360 | 45–54 |
| *Dairoides kusei* | G, T | 120–200 | 49–64 |
| *Portunus sanguinolentus* | G, T | –185 | 50–80 |
| *Micropanope sexlobata* | T (1) | 165 | 14 |

NOTE: The second column gives methods—S, submarine observation; S*, submarine observation with at least one specimen being collected from *in situ* poisoning; G, gill net; T, trap. Where fewer than 10 specimens were collected, the total number is given in parentheses. The third column gives depth or depth range in meters; for species known to occur substantially shallower than 150 m, only the deepest record is shown. The fourth column gives standard length of fishes or carapace length of crustaceans in millimeters; numbers in parentheses were estimated from the submarine.

do not occur above about 75 to 100 m were collected at 110, 110–135, 110, and 110 m, respectively, but were neither observed nor collected deeper. These species are apparently restricted to a rather narrow depth range. Other species taken in gill nets at 90–110 m were *Ostichthys pilwaxii, Priacanthus meeki, Mulloidichthys pflugeri, Sarda orientalis*, and *Naso hexacanthus.*

Fishes collected or seen and identified below 150 m are given in Table 2. Other, distinctly different species were observed from the sub but not definitely identified. These included one or more lutjanids (probably *Aphareus rutilans*) observed down to 330 m, one or two species of scorpaenids down to 300 m, and holocentrids and priacanthids down to 225 m. A small chaetodontid and a serranidlike species observed between about 150 to 175 m were probably *Hemitaurichthys* sp. and *Odontanthias* sp., respectively. Several other species observed between 150 to 200 m are almost certainly undescribed and unfortunately uncollected. Two species of congrids collected from 330 m, an ophichthid from 330–365 m, and a macrourid from 730 m are at present unidentified and not included in Table 2.

The most abundant fish in the depths surveyed was *Polymixia japonica.* Large schools of 100 or more were seen just above the bottom during the day, mostly between 240 and 300 m. At night up to 20 were caught per 30 m link of 1.5-inch-mesh gill netting. They were caught in large numbers as shallow as 185 m, which suggests that this species migrates up and inshore at night. *Polymixia* was the only species that did not regularly disgorge stomach contents on the way up. Of 31 specimens with food, 17 had eaten shrimp, mostly benthic carideans; 12, fishes; five, crabs; and four, small cephalopods, probably octopi. Isopods, a stomatopod, a mysid, and a trochophore larva were also recorded. *Polymixia*, judged by its abundance, is probably a major consumer of small benthic organisms in this depth range and is likely an important forage fish for larger predators there.

Lutjanids and muraenids were the most abundant predatory fishes. The most common lutjanid seen from the sub during the day was probably *Aphareus rutilans*; it was not collected in the gill nets at night. *Etelis marshi* was the most commonly caught predator in the gill nets. Muraenids appeared to be very abundant in the rocky areas between 150 to 200 m off Barbers Point, but were rarely caught over sediment-covered bottoms off Kaneohe or Haleiwa. Traps set off Barbers Point caught as many as nine individuals overnight. The eels almost certainly excluded other organisms from the traps and biased results. Many smaller Crustacea, e.g., *Scyllarus timidus* and the pandalid shrimps, were caught rarely or only in gill nets off Barbers Point but were quite common in traps set off Kaneohe and Haleiwa.

### *Decapod Crustacea*

Of the crabs, only *Homala, Randallia,* and *Cyrtomaia* could be identified from the sub. These species and *Mursia* were not well sampled by traps and may occur below the deepest gillnet set and below the sub's range. The ranges given for other species are probably valid and indicate that most occur within the depths surveyed. *Notopoides latus* and *Notosceles* sp., in contrast to most raninids, appear to prefer rocky bottom; they were caught only in gill nets on steep rocky bottoms off Barbers Point and never in the same depth range over sediment-covered bottoms elsewhere.

*Heterocarpus ensifer* was by far the most abundant and widespread shrimp. Between 275 and 365 m during the winter months, catches averaged 1 to 2 kg/trap and sometimes exceeded 10 kg. Data on depth and seasonal changes in abundance, sex ratio, etc., for this species and other pandalids will be presented in a separate, more detailed report.

*Plesioneka martia* and *Parapandalus* sp. were also taken frequently but were most abundant at 150 to 200 m and 110 to 180 m, respectively. Between 240 and 330 m a few groups of distinctly smaller shrimps were seen from the submarine. Apparently the larger species are either inactive during the day or move into shallower depths only at night.

## DISCUSSION

In the present survey, shallow-water reef fishes were noted less frequently and not as deeply as recorded by Brock and Chamberlain

(1968). Rather than being "essentially a selected portion of the near shore fauna," the fishes observed and collected between 150 and 200 m included deeper, as well as shallower, water forms and a few species apparently restricted to this depth range, e.g., *C. modestus, Ostichthys* sp., and probably the *Gymnothorax* spp. For the most part, the crustaceans caught in this zone either were also found substantially deeper or occurred only within the zone, i.e., they were not an extension of the shallow-water fauna.

Of the 47 species of fishes taken or seen above about 365 m, six are known species not previously recorded from Hawaii: *Odontaspis ferox, Centrophorus tesselatus, Urotrygon daviesi, Muraenichthys macropterus, Hoplostethus mediterraneus*, and *Epinula magistalis. Paratrachichthys* sp. may prove to be a new species and is definitely unrecorded in Hawaii. (The latter species and *Urotrygon* have also been taken in recent trawling surveys, P. J. Strauhsaker, personal communication.) *Gymnothorax* sp., *Ostichthys* sp., two congrids, and an ophichthid appear to be undescribed. The two specimens of *Chaetodon modestus* represent the first Hawaiian record of the species since Jordan (1922) described a 5-cm individual as *Loa excelsa* (*Heniochus exselsa* of some authors). W. E. Burgess (personal communication) has placed *excelsa* in the synonymy of *modestus*, a species described from Japan.

Of these 13 undescribed or unrecorded species, the gill nets collected nine species; seven were collected only in gill nets. Several other forms taken in gill nets have been recorded rarely in the past, e.g., *Symphysanodon typus, Velifer multispinosus*, and *Histiopterus typus.* Not only did the gill nets collect species missed by previous surveys, but also species not seen from the submarine. Of 28 species collected by gill nets, only 10 were definitely identified from the submarine.

The gill nets were effective in collecting new or rare species, in part because they sampled steep, rocky bottoms where other methods, particularly trawls, are notably unsuccessful. They also collected species which, because of their size or behavior, are not successfully sampled by other means. Some of the larger fishes like *Odontaspis, Centrophorus*, and *Epinula* can probably avoid a trawl and likely retreated from the presence of the submarine. *Hoplostethus* and *Ostichthys* are probably cryptic forms and either withdrew into the rocks on the sub's approach or were not active during the day.

Of the 22 fishes identified from the sub, 10 were gillnetted. The species that were missed were mostly either eels or species seen only a few times over open sand. Eels and some of the latter were captured in traps, but nine species were not collected by any means. Most of the sand-bottom species are frequently taken by trawls. There was a minimum of 11 species seen but not identified from the sub. Of these, only *C. modestus* was collected. The other species all occurred in steep, rocky areas between about 175 and 200 m. *In situ* poisoning collections or possibly traps submerged for longer periods would seem to be the only methods to collect such species.

All of the shrimps found above 365 m were taken by traps, and the two most abundant species, *Heterocarpus ensifer* and *Plesioneka martia*, also were taken frequently by gill nets. The other *Plesioneka* species were caught rarely and only in traps. *Parapandalus* sp., the first record of this genus in Hawaii, was taken quite frequently. Its absence from previous surveys is thus somewhat puzzling. Its frequent capture here may be simply due to extensive use of smaller-mesh traps.

The slipper lobster, *Scyllarus timidus*, has been previously recorded in Hawaii from only one specimen, but it appears to be common. Only one individual was seen from the sub, but several were caught over rocky areas by gill nets. Off Haleiwa, where the bottom in their depth range is smooth and sediment-covered, up to 10 were taken in a single trap. Two other scyllarideans, *Scyllaroides squamosus* and *Panulirus marginatus*, were collected as deep as 110 m, but no deeper.

The gill nets proved quite effective for crabs as well as fishes. Of the 10 species collected, only *Micropanope sexlobata* (one specimen) was caught by trap only. Three of the remaining species were taken only by gill nets and, except for *Portunus sanguinolentus*, the others were taken nearly as frequently as in traps. Three species, *Notopoides latus, Thelxiope orientalis,*

and *Dairoides kusei*, have not been recorded from Hawaii, and *Notosceles* sp. is apparently undescribed (J. S. Garth, personal communication). All four were caught over steep rocky bottoms that had not been well sampled previously.

## CONCLUSION

The rather large number of undescribed and previously unrecorded species collected during this survey suggests that further use of different collection methods, particularly gill nets, in other areas would be of great interest to taxonomists and zoogeographers. Trawling surveys and local fisheries have been the usual sources of data for many parts of the world, but it appears that these sources consistently miss or only occasionally collect certain types of organisms. In future studies, investigators should attempt to use as many methods as possible to collect specimens, and zoogeographers should at least consider what sorts of species were likely missed by the methods used.

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The original impetus for this program came from V. E. Brock.

## APPENDIX

### NOTES ON UNCERTAIN OR TENTATIVE SPECIES NAMES

1. *Glossanodon* sp. was probably identical with a presently undescribed species frequently taken in bottom trawls (P. J. Struhsaker, personal communication).
2. *Gymnothorax nuttingi* Snyder has been placed in the synonymy of *G. pictus* by Fowler (1928) and in the synonymy of *G. meleagris* by Gosline and Brock (1965). Fresh material taken during this survey has revealed that *nuttingi* is a valid species (J. E. Randall, personal communication).
3. Gosline and Brock (1965) synonymized the muraenids *Gymnothorax goldsboroughi* Jordan & Evermann and *G. xanthostomus* Snyder with *G. meleagris*. These names, however, are synonyms of *G. nudivomer* (Gunther), as indicated by Fowler (1928) (J. E. Randall, personal communication).
4. *Gymnothorax* sp. in Table 2 is undescribed (J. E. Randall, personal communication).
5. *Ostichthys* sp. is undescribed. It represents one of two species of the genus in the Hawaiian Islands. The other is *O. pilwaxii* (Steindachner), erroneously placed in the synonymy of *japonicus* by Fowler (1928) and Gosline and Brock (1965) (J. E. Randall, personal communication).
6. *Seriola rivoliana* is used here instead of *S. dumerilii* (Gosline and Brock, 1965) based on personal communication to J. E. Randall by F. J. Mather III.
7. *Plesioneka martia* and *P. ocellus*, as used here, are probably identical with the usage by Rathbun (1906), but differ from descriptions by de Man (1920). *P. martia* from Hawaii bears about eight spines on the anterior part of the rostrum. For *P. ocellus* from Hawaii, the second pair of walking legs is of equal length.

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