Project Report: ISSP Celebes Sea

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Executive Summary:

The center of shallow water marine biodiversity for the tropical seas of the world lies in the Indonesia/New Guinea/Philippine triangle between the Pacific and Indian Oceans. The goal of the ISSP Celebes Sea expedition was to make a vertical survey of the water column in the Celebes Sea to determine whether the biodiversity in the mesopelagic and bathypelagic realms were as rich and diverse as has been reported for shallow water fishes and corals. Our research was a joint effort of foreign and Philippine scientists, photographers and cinematographers. We used a combination of sampling techniques to investigate the water column, including blue-water diving, a 3,000m ROV with HD TV, benthic baited video 'Ropecams', a video plankton recorder, bongo nets, and a Tucker trawl. The team from National Geographic and four US and 3 Philippine research and educational institutions spent 10 operational days in the deep basin of the Western Celebes Sea exploring and collecting biological data and images.

Our research focused on the distribution, biodiversity and natural history of epipelagic, midwater and bathypelagic fish and invertebrates. Use of a deep-water ROV in the Celebes Sea allowed us to conduct unprecedented midwater surveys in an area noted for the exceptionally high species diversity and endemism of shallow water fishes and invertebrates, but where the deep waters are almost totally unexplored. Specimens collected in trawls and Bongo nets will permit the detailed taxonomic and genetic analyses essential to document biodiversity.

During ISSP Celebes Sea we conducted 9 blue-water scuba dives, 7 ROV dives, 2 RopeCam deployments, 4 VPR profiles, 5 Bongo nets, and 3 Tucker trawls. We found that the water column in the Celebes Sea to a depth of 3,000 meters is structured vertically much like temperate and tropical water columns in the Atlantic, Pacific and Indian Oceans, but with some important differences. Overall biomass of the water column was high because of previously described upwelling near the Sulu Ridge. Our new findings include the exceptional abundance of the nitrogen fixing, blue-green alga *Trichodesmium*, down-slope benthic accumulations at 1,390 m of decomposing sea grasses, and the input of large quantities of anthropogenic products (trash) to the deep sea from the densely populated islands along the Sulu ridge. The presence of sperm whales and spinner dolphins seen at the surface, squid seen from the ROV, and high abundance of myctophid fishes collected in the Tucker trawl and seen on a night dive, also point to locally high biomass of the water column.

Species diversity of epipelagic gelatinous zooplankton was quite high with 10 of the 23 world-wide known species of salps collected by blue-water divers. The upper column was dominated by marine snow, *Trichodesmium*, copepods and appendicularians, whereas mid-water was dominated by marine snow. Two probably undescribed species were discovered: a black, benthopelagic lobate ctenophore and a large pelagic polychaete worm with ten long cephalic tentacles.

Background

The midwater environment is the largest ecosystem on our planet, and its inhabitants are major constituents of oceanic ecosystems. Midwater animals occupy trophic levels between the primary producers and the large pelagic fishes and cetaceans for which they are forage. They also provide a major nutrient source for the benthos, and a link in the transfer of energy and material from the top to the bottom of the ocean. Despite their significance in open-ocean ecosystems, most of what we know about their ecology is sketchy, and usually at the species or population levels. Knowledge at the community or ecosystem levels is generally lacking.

Research on midwater organisms has traditionally followed five lines of investigation: systematics, natural history, zoogeography, vertical distribution, and physiology. Taxonomically, the major groups are fairly well known and recent revisions have greatly facilitated the identification of specimens in trawling collections (e.g. Baird, 1971; Paxton, 1972; Johnson, 1974; Peitsch, 1974; Nafpaktitis, 1975; Wisner, 1976). However, the Southeast Asian portion of the Indo-West Pacific has been little studied and many of the specimens collected there represent undescribed species and genera.

The Celebes Sea lies among the narrow maze of twisted trenches and small basins that link the great basins of the Indian and Pacific Oceans. These interlocking depressions in the seafloor provide the only deep-water gap between the continental shelves of Australia and Southeast Asia. The many seas of this region are filled with water from the western Pacific, but hydrographically they form a discrete geographical unit -- distinct from either the Pacific or Indian Oceans (Wyrtki, 1961). The numerous island chains that divide the seas also restrict the flow of subsurface waters between them, and in many cases the sill depths of the troughs and basins are less than 1000 m deep. Enclosure, and the restricted exchange of deep water, has resulted in a characteristic homogeneity of its water masses within individual basins. The surface layers, however, are subject to the highly variable local effects of reversing monsoon winds and currents.

The oceanography of some of the basins in the Indo-Pacific Archipelago has been described in general by Zijlstra and Baars (1990) from data collected during the Dutch Snellius II expeditions of 1984-85. The Sea is characterized by periods of upwelling (southeast monsoon in summer and fall) and downwelling (northwest monsoon in winter and spring). During the upwelling period productivity of the pelagic ecosystem is enhanced by 3 to 5 times above levels seen during downwelling periods. Indeed, the primary productivity of the eastern Banda Sea to the south of the Celebes Sea is exceptionally high, 400-500 g C m^{-2y}, a figure higher than temperate waters of the North Sea! This high primary productivity is probably responsible for the disproportionately large numbers and perhaps the large sizes of so many of the midwater fish, while the periodic isolation of the deep basins during periods of lowered sea level is probably responsible for the disproportionately high endemism of the fauna.

The complex of seas in Southeast Asian waters provides a natural laboratory for the study of midwater ecosystems. Within a small geographical area there exist a number of isolated and semi-isolated tropical midwater communities, organized along certain ecological "dimensions" (Schoener, 1974), primarily: depth, temperature, light, oxygen and productivity. The feasibility of such comparisons is indicated by successful studies of the midwater fauna in isolated or circumscribed regions (Paxton, 1967; Robison, 1972; Ebeling et al., 1971, Baird, et al., 1973:

1975). The potential of Southeast Asian waters as a natural laboratory for ecological and physiological studies is self-evident. The region is also important in studies of zoogeography, evolution, and systematics. This part of the Indo-Pacific has long been considered as the center of distribution (or origin) for many families of midwater organisms. It is the least known, but perhaps the most important, link in the circum-tropical belt of oceanic faunal regions. Based on the limited sampling conducted so far, the midwater fauna, especially the fishes, appears to be highly diverse and to include a large number of undescribed species.

In 1874, H.M.S. CHALLENGER passed through the seas of Southeast Asia and made 12 stations, chiefly with bottom trawls and dredging gear. The Siboga Expedition of 1899-1900 collected 47 species of midwater fishes throughout the "Dutch East Indies." In 1907-1909 the U.S. Fisheries steamer ALBATROSS made several explorations of the Philippine Islands and adjacent seas. Again, most of the midwater animals were collected by benthic sampling gear. The 1929 DANA Expedition made 39 ring trawl hauls in 7 Southeast Asian seas; and in the same year, the SNELLIUS conducted an extensive hydrographic study of the region. The Swedish ALBATROSS Expedition of 1948 did more hydrographic and benthic work. In 1951 the GALATHEA Expedition made a total of 11 deep, benthic stations in 6 of the seas. The Dutch returned with the SNELLIUS II expedition in 1984-85, which included sampling of zooplankton (Baars et al., 1990, Schalk 1987, Shalk et al. 1990, van Couwelaar 1994). In most cases, the midwater and other pelagic fauna collected by these expeditions have been examined piecemeal, as distributional records of taxonomic subunits in larger-scale studies of families or genera of organisms (Bertelsen, 1951; Haffner, 1952; Brinton, 1962; Mukhacheva, 1964; Bekker, 1964; Kramp, 1965; Gibbs, 1969; Baird, 1971; Mead, 1972; Judkins, 1972; Kawaguchi et al., 1972; Kobayashi, 1973; Johnson, 1974; Pietsch, 1974; Fleminger and Hulsemann, 1974; Collette and Chao, 1975; Bertelsen et al., 1976). There have been few detailed or comprehensive studies of the faunal assemblage of the region itself or any of it subdivisions.

During the 1975 ALPHA HELIX Expedition, B. Robison made 99 midwater trawls in the Banda Sea. The samples from those trawls still represent the most extensive collection of midwater animals ever taken from Indonesian waters. These collections are composed primarily of hard-bodied midwater fish and crustaceans. There are almost no soft-bodied, gelatinous invertebrates in the preserved samples from Indonesia because trawls destroy delicate organisms. Nonetheless, gelatinous invertebrates, such as medusae, ctenophores, squid, appendicularians, pteropods, salps, and chaetognaths, are critical components of all tropical midwater communities, and accordingly we expect to find a high diversity of gelatinous forms in the Celebes Sea.

Methods.

Participants

The total science party on board the BRP Hydrographer Presbitero for this cruise was 27 persons, including 20 from the U.S. and 7 from the Philippines (see Table 1). The ship's crew, catering staff, doctor and security force brought the total number on board to 61.

Sampling and Observation

The diversity of sizes, morphologies, behaviors and distributions of the water column fauna requires that more than one approach be used to observe and sample them. We tried to use multiple, overlapping sampling methods that would give us a fairly comprehensive view of the

organisms present, within the limited time we had. These sampling methods are described briefly here.

Remotely operated vehicle (ROV):

Remotely operated vehicles (ROVs) are rapidly becoming the preferred tools for many kinds of in situ work in the deep sea. They provide the capability for direct observation and measurements at depth, as well as selective sampling of individual specimens. Because ROVs are tethered to, and powered from, the surface, they can work underwater for long periods of time. The *Global Explorer* ROV that we used on the Celebes Sea cruise can dive to 3,000 meters. It is equipped with a High Definition (HD) color video camera, a digital still camera, a 12-chambered suction sampler and static canister samplers. The ROV has thrusters in 3 spatial planes, allowing it to hold position in midwater for extensive observations and to follow and collect individual animals. The *Global Explorer* was designed and built by Deep Sea Systems International, an Oceaneering International Company (Fig. 1)

We made a total of 9 ROV dives during the ISSP program, two of which were for testing purposes and seven for observation and collecting. The maximum depth reached was 3,000 meters, and samples of deep-sea organisms were collected on all dives, along with HD video tape of their behavior.

Blue-water SCUBA diving

Marine biologists dive with SCUBA in the open ocean to observe and collect undisturbed and undamaged organisms - usually animals called zooplankton - that live in the water column from the surface down to about 100 feet. The ocean away from land is clear and blue, so the technique is called bluewater diving. It is a particularly important way to study soft-bodied, gelatinous animals such as jellyfish because these animals are terribly damaged or destroyed when they are caught in nets. Bluewater diving is also the best way to learn how any undisturbed pelagic animal behaves in its natural environment. Animals that live in the water column away from the sea floor never run into floors or ceilings or walls, so they have never adapted to encountering surfaces. When these animals are put into an aquarium, it is difficult to know how much their physical confinement within the container's walls alters the way they behave. Entering their natural underwater environment allows the scientist to learn about their normal behaviors.

We made 9 bluewater dives in the Celebes Sea and collected zooplankton such as jellyfish and ctenophores in wide-mouth jars. Specimens were also collected on one night dive. Undisturbed animals were photographed underwater with still and video cameras and also brought back alive to study in aquariums aboard ship.

Bongo Nets

Bongo nets are paired plankton nets mounted on a common frame, so that two replicate samples can be made in one tow. We used bongo nets for five short hauls in the mixed layer to collect zooplankton samples for photography and preservation for later taxonomic identification. The preserved samples will be identified and added to the database of the Census of Marine Zooplankton.

Tucker Trawl

We had originally planned to use a multiple net system, the MOCNESS (Multiple Opening Closing Net Environmental Sensing System) which would allow us to make 5 separate depth samples in each haul. This net has a 10 m2 mouth opening and is good for collecting small fish and zooplankton. However, we determined that the handling capabilities of the BRP Hydrographer Presbitero were not adequate for the safe deployment of the large rigid frame of this net system. Instead we used the individual nets in a simpler "Tucker Trawl" frame that allowed them to be deployed over the stern of the vessel and fished as open nets. Due to limitations of time and some problems with deck equipment, we made only three hauls with this single net.

RopeCams

National Geographic has been developing this low-cost, simple set of underwater-housed digital video cameras over the past 12 years (Fig. 2). Deployed on 5/16" lines and retrieved using a "pot hauler," the camera packages are baited with fish and can be placed on the sea floor or hung anywhere in the water column down to 4,500 meters. Timers turn the lights and cameras on and off during a set time period. The resulting digital video is as good as any recorded from much more expensive manned submersibles or ROVs. Animals that are not easily caught or trawled to the surface, such as giant deep sea sharks, can sometimes be observed feeding and swimming.

During the ISSP cruise we made four deployments of the Ropecams, but unfortunately only two recoveries. It sometimes happens that the anchor or some other part of the camera system becomes caught on the bottom and cannot be retrieved when the line is pulled up. This happened with two camera systems, which are still somewhere near the bottom of the Celebes Sea. The systems that were recovered provided good video footage of deep sea fishes and crabs attracted to and attacking the bait.

Video Plankton Recorder

The Video Plankton Recorder (VPR) is a towed underwater video microscope that makes images of small organisms in the water column (Fig. 3). Digital images are recorded on a hard disk in the instrument and then downloaded to a computer on the ship after recovery of the VPR. Computer software recognizes and classifies the images, allowing a count of the different types of zooplankton organisms present. We made four deployments of the VPR to a maximum depth of 500 m. Collected data is being analyzed by Dr. Cabell Davis.

Preliminary Results

ROV Data

A summary of the organisms observed or collected is given in Table 2, organized into the three major depth zones, epipelagic, mesopelagic and bathypelagic, plus the benthos. The majority of these occurrences were sightings only, usually with images recorded on the High Definition videotape. A smaller number of specimens was collected with the suction or static ("D-samplers") collecting devices.

Organisms of particular interest in the ROV collections included two apparently undescribed species – a black lobate ctenophore probably belonging to the genus *Bathocyroe* (Fig. 1), and a large pelagic polychaetes worm with prehensile cephalic tentacles (Fig. 2). Two species of pelagic holothuroid were collected, one of which is possibly undescribed. Other specimens included the medusa *Atolla*, other scyphomedusae and hydromedusae, and siphonophores. A list of collected specimens is given in Table 3.

A formal description of the pelagic polychaete is currently being prepared for publication. When this is complete, the holotype specimen will be returned to the Philippines National Museum, along with representative identified specimens of the other organisms collected with the ROV. The black ctenophore could not be preserved, but a description of the species, based on photographs, is planned in collaboration with other researchers.

SCUBA diving collections

A variety of gelatinous zooplankton species was collected on the 9 blue-water SCUBA dives; a summary is given in Table 4. Salps, medusae, siphonophores and ctenophores were all fairly abundant. All collected specimens could be identified as described species.

Trawl net collections.

The three trawl collections made included a variety of midwater fishes (mainly Myctophidae), crustaceans (mainly decapod shrimp and hyperiid amphipods), coronate medusae, and smaller numbers of pteropods, pyrosomes, other crustacea. A representative image of these animals is in Fig. 4. All collected specimens will be identified and the data added to the Census of Marine Zooplankton. Representative specimens will be returned to the Philippines National Museum.

Table 1. Scientific Participants in ISSP cruise

US Participants

Last Name	First Name	Title	Position	Institution	Role in Project
Aw	Michael	Mr.	Publisher, photographer		photographer/scientist
Caughron	Lee	Mr.	video assistant	National Geographic Society	producer
Caba	Joe	Mr.	ROV pilot	Deep-Sea Systems International	ROV pilot
Caloyanis	Nick	Mr.	videographer	National Geographic Society	videographer, producer
Cole	Mike	Mr.	technician	National Geographic Society	technician
Davis	Cabell	Dr.	Senior Scientist	Woods Hole Oceanographic Institution	scientist
DeMars	Caron	Ms.	Embassy Officer	U.S. Embassy, Manila	Gov't liaison
Hamner	Peggy	Ms.	educator	University of California, Los Angeles	outreach/education
Hamner	William	Dr.	Professor	University of California, Los Angeles	scientist
Hopcroft	Russell	Dr.	Associate Professor	University of Alaska	scientist
Horgan	Erich	Mr.	Research Associate II	Woods Hole Oceanographic Institution	technician
Konotchik	Talina	Ms.	graduate student	Scripps Institution of Oceanography	graduate student
Kristof	Emory	Mr.	Photographer	National Geographic Society	photographer/scientist
Loomis	Nick	Mr.	graduate student	Massachusetts Institute of Technology	graduate student
Madin	Laurence	Dr.	Senior Scientist	Woods Hole Oceanographic Institution	Chief Scientist
Mikagawa	Toshinabu	Mr.	Chief ROV Pilot	Oceaneering Intnl.	ROV pilot
Nicholson	Mike	Mr.	ROV technician	Deep-Sea Systems International	ROV pilot
Noda	Gwen	Ms.	Research Assistant	University of California, Los Angeles	technician
Stone	Gregory	Dr.	V.P. of Global Programs	New England Aquarium	scientist
White	Ralph	Mr.	technician	National Geographic Society	technician

Filipino Participants

Borja	Val	Mr.	researcher	National Fisheries Research and Development Institute	scientist
Floren	Adonis	Mr.	researcher	Silliman University	scientist
Rayos	Joseph	Mr.	researcher	National Fisheries Research and Development Institute	scientist
Romero	Jumelita	Dr.	researcher	Mindanao State Univ., Tawi Tawi	scientist
Romero	Mon	Dr.	Researcher	World Wildlife Federation, Philippines	scientist
Nacorda	Hildie Maria	Ms.	researcher	Marine Science Institute, Univ. of Philippines	scientist
Rivera	Rogelio	Mr	researcher	National Museum Philippines	scientist

Table 2. Organisms seen from ROV

Taxon	Epipelagic	Mesopelagic	Bathypelagic	Bottom	Totals
siphonophore	36	55	31	1	**123**
total jellies	6	98	37	4	**145**
other cnidaria	0	0	7	7	**140**
total ctenophores	10	35	3	11	**590**
isopod	0	9	20	11	**40**
shrimp	21	46	38	36	**141**
other crustacea	0	8	5	2	**150**
squid	35	11	3	0	**49**
other mollusc	2	6	0	2	**100**
Radiolarian	4	56	79	8	**1470**
appendicularian houses	16	162	250	30	**458**
total fish	9	59	30	47	**145**
larvacean, salp, tunicate	4	10	8	1	**230**
benthic holothuroid	0	0	0	40	**40**
pelagic holothuroid	0	2	6	7	**15**
other echinodermata	0	0	4	13	**170**
chaetognath	1	13	13	2	**29**
sinker	5	34	70	7	**116**
sponge	0	0	2	7	**9**
polychaete	0	2	18	10	**30**
Totals	**149**	**606**	**624**	**246**	**1625**

Table 3. Specimens collected on ROV dives

TAXON	Number collected
Medusae	
Atolla wyvillei	2
Atolla gigantea	1
Atolla parva	1
Atolla vanhoeffeni	1
Solmissus incisa	3
Halicreas minimum	5
Nausithoe sp.	1
Ctenophora	
Undescribed black lobate	3
Siphonophora	
Prayid nectophores	1
Physonect nectosome	2
Physonect colony	1
Agalmid physonect	1
Polychaeta	
undescribed swimming polychaetes	7
Isopoda	
Unidentified munnopsid	3
Radiolaria	
Tuscaridium sp.	4
Holuthuria	
Enypniastes eximia	3
Peniagone sp.	1
Pelagothuria natans	1
Benthodytes sp. 1	1
Fish	
Stomatioid	1

Table 4. SCUBA Collections on ISSP cruise

Divers: Madin, Horgan, Hamner, Stone, Konotchick, Noda, DeMars

TAXON	Number
Medusae	
Aequorea australis	**10**
Aequorea macrodactyla	**5**
Aequorea sp.	**2**
Amphinema australis	**1**
anthomedusa	**1**
coronate	**1**
Eirene palkensis	**1**
leptomedusa	**1**
Liriope tetraphylla	**1**
Melicertessa clavigera	**2**
Nausithoe sp.	**2**
Octocannoides sp.	**2**
Octophialucium aphrodite	**1**
Pandeopsis ikarii	**1**
Pelagia noctiluca	**2**
Solmundella bitentaculata	**3**
Staurodiscus sp.	**1**
Siphonophores	
calycophoran	**3**
diphyid	**2**
Forskalia sp.	**4**
Sulculeolaria sp.	**13**
physonect	**3**
prayid	**1**
Rosacea sp.	**1**
Ctenophores	
Beroe	**9**
Bolinopsis	**19**
Cestum veneris	**8**
cydippid	**1**
Eurhamphaea vexilligera	**9**
Leucothea multicornis	**11**
Ocyropsis maculata immaculata	**7**
Molluscs	
Cardiopoda	**1**
Corolla	**2**
Hydromyles globosa	**1**
thecosome pteropod	**1**

TAXON	Number
Thaliaceans	
aggregated salps	**1**
Brooksia rostrata agg.	**1**
Cyclosalpa affinis agg.	**3**
Cyclosalpa floridana sol.	**1**
Cyclosalpa sewalli agg.	**2**
larvacean	**1**
Pegea confoederata agg.	**2**
Pyrosoma atlanticum	**1**
Ritteriella retracta agg.	**1**
Salpa cylindrica sol.	**3**
Salpa maxima agg.	**1**
Salpa sp.	**1**
Crustacea	
amphipods	**1**
crab megalopa	**1**
Sappphirina (copepod)	**1**
stomatopod larvae	**1**
Other	
cerianthid larva	**2**
fish larvae	**3**
foram	**2**
larval polychaete	**1**
pipefish	**1**
Tornaria larva	**1**
Total	**165**

Figure 1. Global Explorer ROV being launched.

Figure 2. RopeCam ready for deployment.

Figure 3. Video Plankton Recorder

Figure 4. Representative animals collected in Tucker Trawl.