MARSHALL ISLANDS
GH BALA25

UNIVERSITY OF WASHINGTON
SEATTLE, WASHINGTON 98195

School of Fisheries
Laboratory of Radiation Ecology, WH-10
(206) 543-4257

10 June 1985

Dr. George H. Balazs
NOAA, NMFS
Southwest Fisheries Center
Honolulu Laboratory
P.O. Box 3830
Honolulu, Hawaii 96812

Dear Dr. Balazs:

In response to your letter of 31 May, the following comments and suggestion are offered.

The Laboratory of Radiation Ecology (Applied Fisheries Laboratory, 1943-56; Laboratory of Radiation Biology, 1957-66) collected several thousand biological samples for radiological sampling at the Pacific Test Site and nearby locations in the period 1946-64. In later years most of our laboratory's involvement was on a lesser scale and sample collections and analyses were from Central Pacific areas other than Bikini and Eniwetok. Dr. L.R. Donaldson was Laboratory Director from 1943 to 1966. I joined the Laboratory in 1947 and succeeded Dr. Donaldson as Director until my retirement in 1978.

In regard to green turtle samples, I cannot say with absolute certainty that no turtle samples were collected and analyzed because our policy was to sample as many species as possible, at least once. We did capture turtles occasionally, but on those occasions when I was present they were released because we were of the opinion that the radiological information to be obtained did not warrant sacrific of the animal. I can say positively if any samples were taken, they were few in number and there was nothing unique in the results of the radiological analyses of the samples. If there had been something unique, turtles would have been classified as a "biological indicator" species and placed high on the collection list of biological samples, and they were not. The general scheme was to collect and analyze everything possible during early collections, but later reduce the number of species to biological indicators for specific radionuclides.

Two anecdotes about turtles. In 1948 while visiting Likiep Atoll we were served turtle eggs, soup, and meat but I do not recall taking any samples for analyses. A few years later, an expedition led by Robert Rhinehart of the Naval Radiological Defense Laboratory, Hunter's

cont'd / . . .

Point, California, visited Bikar Atoll for the purpose of collecting turtle eggs (and turtles?) for radiological analyses. As I recall, none were collected.

Now for the suggestion. Even if radiological analyses of turtle samples from the past were available, current samples and analyses would be much more meaningful if your concern is about the health hazard to man from the consumption of green turtles. Therefore, why don't you obtain the samples and then submit the samples for radiological analyses? If you choose to do this and are looking for someone to do the analyses, I suggest that you contact Dr. Ahmad Nevissi at the School of Fisheries, University of Washington, or Dr. William Robison at Lawrence Livermore National Laboratory, or a commercial laboratory in the radiological analysis business. An important part of the analyses is the interpretation of the results and either Dr. Nevissi or Dr. Robison could do this. Based upon my experience with samples from the Pacific Test Site and the mouth of the Columbia River, I would guess that in addition to the natural radionuclides present, a radionuclide of nuclear detonation origin might be identified because of the extreme sensitivity of radionuclide detection methods; however, if present, the quantity would be far below the health hazard level to man.

Sincerely,

A. H. Seymour
RAN

Allyn H. Seymour
Professor Emeritus

AHS:as
cc: Dr. Nevissi
Dr. Robison

Motupore Island Research Station
THE UNIVERSITY OF PAPUA NEW GUINEA

P. O. BOX 320
UNIVERSITY
PAPUA NEW GUINEA
TELEPHONE: 253900
TELEX: NE 22366

Reference Action Officer

26 June 1985

Dr. George Balazs
NOAA, NMFS
Southwest Fisheries Center
Honolulu Laboratory
P.O. Box 3830
HOnolulu, Hawaii
96812
U.S.A.

Dear George;

Thanks for your letter of 13 June regarding turtles samples from Enewetak Atoll. I don't personally know whether any sea turtle samples have ever been analyzed from Enewetak. I do know, however, that samples from two green turtles were provided by MPRL personnel to the Marine Biology group of the Lawrence Livermore Laboratory. These samples were actually taken from a turtle used for human comsumption by Bob Richmond and personally frozen and delivered to the LLL group by me. I remember it so well since I had to make a special trip out to the Liktanur II as it was steaming out the east pass of Enewetak to pass them the samples from our small boat! We had a considerable interest in results from those samples since I did not recall any mention of turtles being considered in the dietary dose estimates for Enewetak and this seemed a logical hole in those dose estimates to fill using those samples. Informal inquiry as to any results amongst the LLL personnel when they visited Enewetak usually brought a "don't know anything about it" response.

I feel your concern about the possible impact of turtles on the radionuclides being ingested by the Enewetakese is valid. In my experience there most of the turtles captured came from the northern portion of the atoll, often times from the area of the Mike-Koa craters, where there are the highest concentrations of radionuclides. I suggest that you contact Dr. Vic Noshkin at LLL for more direct information regarding any turtle samples or as an alternate Dr. Bill Robison at LLL.

I can't really comment about the portions of the letter from Dr. Seymour that you underlined for comment. There may well have been turtle samples taken from Bikini. Perhaps an inspection of the many reports prepared by the LRE at Washington could provide that answer. They were all in the MPRL files which are presently at HIMB. As I said before, if there has not been any reasonable sampling of turtles for radionuclides, then this should be regarded as a potentially signficant omission in radionuclide studies and filled as soon as possible.

Sincerely yours,

Patrick L. Colin

May 31, 1985 F/SWC2:GHB

Dr. A. Seymour
School of Fisheries
Laboratory of Radiation Ecology, WH-10
University of Washington
104 Fisheries Center
Seattle, WA 98195

Dear Dr. Seymour:

The attached copied correspondence will give you a brief history of my efforts over the past few years to learn if radionuclides have ever been analyzed from sea turtles at Enewetak or Bikini Atoll. Sea turtles, and especially the green turtle, Chelonia mydas, are often eaten by Pacific islanders. Informal reports I have received indicate that 40 or more green turtles are being consumed each year during the Christmas holidays by the natives that returned to Enewetak. Green turtles feed directly on certain kinds of benthic algae which, I understand, are known to take up and concentrate radionuclides.

In a telephone response to my last letter to Mr. Jackson (copy attached), he provided me with your name and address and suggested that I contact you as a possible source of information on this potentially important subject. Any help that you are able to offer will be greatly appreciated.

Sincerely,

George H. Balazs
Zoologist

Attachment

cc: Balazs
HL

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southwest Fisheries Center
Honolulu Laboratory
P. O. Box 3830
Honolulu, Hawaii 96812

January 14, 1985 F/SWC2:GHB

Mr. Bill Jackson
Department of Energy
P.O. Box 29939
Honolulu, Hawaii 96734

Dear Mr. Jackson:

I regret to inform you that I have still not been able to obtain information on analysis for radionuclides conducted on sea turtles at Enewetak Atoll. You will undoubtedly recall that back in November of 1983 you suggested I write to Edward Lessard, Program Manager for the Marshall Islands Radiological Safety Program. I had previous sent three inquiries to Dr. Noshkin at Livermore Laboratory without receiving a reply. Mr. Lessard wrote to me in March of 1984 indicating that an Ed Held and Vic Nelson are the persons with direct knowledge of the Marshall Island Marine Program over the past 30 years. I sent letters of inquiry to them in April and again in July of 1984, but have not received a response.

As I originally described to you, we now know that the Enewetak people have used turtles as a regular part of their diet since they were resettled at the atoll. Greater numbers are especially caught around Christmas for use in the holiday celebration. Both from the standpoint of people and turtles, it would behoove us to know what, if any, levels of radionuclides are present in these turtles. Like many other Pacific islanders, Marshallese eat the entire turtle except for bones and scales. Large adult turtles may be very old (in excess of 40 years), and migrate long distances to and from other areas where they may also be taken for food by native people. Do you have any new thoughts on this potentially important subject? I am anxious to follow through on any suggestions you may have to offer. Many thanks for your continued help.

Sincerely,

George H. Balazs
Wildlife Biologist

August 13, 1985 F/SWC2:GHB

Dr. Ahmad Nevissi
School of Fisheries
Laboratory of Radiation Ecology
University of Washington
Seattle, Washington 98195

Dear Dr. Nevissi:

At the suggestion of Dr. Allyn Seymour, I am writing to ask if you would be willing to do radiological analyses of bone and tissue biopsies from green sea turtles, Chelonia mydas. A copy of Dr. Seymour's letter discussing this subject has been attached for your information. My immediate concern is to obtain analyses on samples that will be collected during early September at Johnston Atoll. Our Laboratory has been commissioned by the Pacific Ocean Division, Army Corps of Engineers, to assess and monitor the population of green turtles that resides near the forthcoming JACADS project (nerve gas disposal plant). I anticipate being able to collect somewhere between 10 and 20 samples during our September field study.

I would greatly appreciate hearing from you at your earliest convenience. Our arrangements for analyses must be finalized in the near future.

Sincerely,

George H. Balazs
Zoologist

Enclosure

GHB/ll

bc: HL
Balazs

August 15, 1985 F/SWC2:GHB

Dr. William Robison
Lawrence Livermore National Laboratory
P. O. Box 808
Livermore, CA 94550

Dear Dr. Robison:

At the suggestion of Dr. Allyn Seymour, I am writing to ask if you would be willing to do radiological analyses of bone and tissue biopsies from green sea turtles, Chelonia mydas. A copy of Dr. Seymour's letter discussing this subject has been attached for your information. My immediate concern is to obtain analyses on samples that will be collected during early September at Johnston Atoll. Our Laboratory has been commissioned by the Pacific Ocean Division, Army Corps of Engineers, to assess and monitor the population of green turtles that resides near the forthcoming JACADS project (nerve gas disposal plant). I anticipate being able to collect somewhere between 10 and 20 samples during our September field study.

I would greatly appreciate hearing from you at your earliest convenience. Our arrangements for analyses must be finalized in the near future.

Sincerely,

George H. Balazs
Zoologist

Enclosure

cc: Balazs
HL

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southwest Fisheries Center
Honolulu Laboratory
P. O. Box 3830
Honolulu, Hawaii 96812

April 23, 1984 F/SWC2:GHB

Mr. Edward Held
Mr. Victor Nelson
Laboratory of Radiation Ecology
University of Washington
Seattle, Washington 98105

Gentlemen:

At the suggestion of Edward Lessard, Program Manager of the Marshall Islands Radiological Safety Program, I am writing to you in an effort to locate information regarding analysis for radionuclides in sea turtles. Are you aware of any such data resulting from studies in the Marshall Islands? The attached correspondence will provide you with a record of my previous efforts to obtain information. Unfortunately, not much has resulted. Although there is mention of a sea turtle (Chelonia mydas) specimen in the 1973 Enewetak Radiological Survey, the results of analysis are not given.

Any assistance that you are able to offer will be greatly appreciated.

Sincerely,

George H. Balazs
Wildlife Biologist

Attachment

BROOKHAVEN NATIONAL LABORATORY
ASSOCIATED UNIVERSITIES, INC.

Upton, Long Island, New York 11973

Safety & Environmental Protection Division

(516) 282-4250
FTS 666-

March 13, 1984

Dr. George Balazs
U.S. Department of Commerce
National Marine Fisheries Service
Southwest Fisheries Center
Honolulu Laboratory
P.O. Box 3830
Honolulu, Hawaii 96812

Dear Dr. Balazs:

I have scanned Marshall Island reports for information regarding analysis for radionuclides in sea turtles. One turtle, Chelonia, was written about in the 1973 Enewetak Radiological Survey (NV0140). The persons with direct knowledge of the Marine Program over the last 30 years are Ed Held and Vic Nelson, Laboratory of Radiation Ecology, University of Washington, Seattle, Washington. I am sure Dr. Noshkin or his predecessor will direct you to archival information regarding sea turtles.

The Marshall Islands Radiological Safety Program is for the benefit of the Marshallese people, consequently our studies are centered on people. Most of the radiological results we obtain relate to body burdens and excreta activity. Some work has been done on dietary items, however, we have not analyzed sea turtle meat.

I hope you obtain the results without further delay. Best regards.

Sincerely,

Edward T. Lessard

Edward T. Lessard
Program Manager
Marshall Islands Radiological
Safety Program

EL/lg

cc: Bill Jackson

NOTE: SENT TWICE - NO RESPONSE

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southwest Fisheries Center
Honolulu Laboratory
P. O. Box 3830
Honolulu, Hawaii 96812

December 1, 1981 F/SWC2:GHB

Dr. Victor Noshkin
Lawrence Livermore Laboratory
P. O. Box 808
Livermore, CA 94550

Dear Dr. Noshkin:

For the past 10 years, I have been involved in various aspects of research on sea turtles here in Hawaii and at several other areas of the Pacific. It has come to my attention that the native people that returned to Enewetak are highly motivated to catch and eat turtles. This is not surprising since islanders throughout the Pacific are fond of turtles and their eggs. Usually the entire animal is consumed with the exception of bones, gastrointestinal contents and the gall bladder. There is little waste.

If I understand the situation correctly, over the years there have been very few, if any, analyses of sea turtles at Enewetak or Bikini to determine radionuclide content. Is this in fact the case? If so, it would seem highly desirable to have some of this work conducted. The two species that regularly occur at Enewetak are the green turtle (Chelonia mydas) and the hawksbill turtle (Eretmochelys imbricata). The green turtle is predominantly herbivorous, feeding on benthic algae and sea grasses where they occur. Adult green turtles are also highly migratory. The green turtles at Enewetak could very well be regularly undertaking reproductive voyages of 1,000 miles or more to other areas of the Pacific where they may also be used for food. The hawksbill appears to be less of a high-seas migrator, but this could just be a reflection of less research focused on the species. Hawksbills are omnivorous and seem to feed heavily on sponges and ascidians.

I would appreciate hearing from you on this important matter. I am prepared to assist you in any way that may be helpful.

Sincerely,

George H. Balazs

George H. Balazs
Fishery Biologist

cc: Dr. Robison, Lawrence Livermore Laboratory

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southwest Fisheries Center
Honolulu Laboratory
P. O. Box 3830
Honolulu, Hawaii 96812

March 6, 1984 F/SWC2:GHB

Dr. Edward T. Lessard
Project Manager
Marshall Islands Radiology Study
Safety and Environmental Division
Brookhaven National Laboratory
Associated Universities of New York Inc.
Upton, NY 11937

Dear Dr. Lessard:

Mr. Bill Jackson of the Honolulu office of the Department of Energy gave me your name and address and suggested that I write to you concerning my interest in sea turtles of the Marshall Islands. I met Mr. Jackson on a return flight from Johnston Island where our agency recently conducted an assessment of sea turtles for the Army Corps of Engineers.

I am interested in learning if any analyses for radionuclides have ever been done on sea turtles at Enewetak and/or Bikini. The final report for the Enewetak Radiological Support Project mentions one turtle, but the size, site it was collected, and results of analyses are not presented. Our studies of the green turtle, Chelonia mydas, here in Hawaii indicate very slow growth rates, and probably a long reproductive life.

As you will note from the attached letter, I previously made an inquiry on the subject of radionuclides in sea turtles to the Lawrence Livermore Laboratory. Unfortunately, no response was received.

I look forward to hearing from you when your time permits.

Sincerely,

George H. Balazs
Wildlife Biologist

Enclosure

Kiesch

Feb 23, 1983

Dear George,

This is just a quick letter to pass on to you something interesting that Scott & I recently heard. I have a picture of a Hawaiian Monk seal by my desk. Recently, a Marshallese friend of ours was visiting and told us that a Monk Seal lived for a while on the atoll of Maloelap, Marshall Islands. He said it just showed up on a beach there in 1958, and that the natives were afraid of it, probably because they'd never seen one before. Apparently, it lived there for weeks and never bothered anyone, but because they were afraid of it they killed it with some big rocks. I don't think they ate it. The guy who told us this story we trust in, and he is unusually well educated and traveled, so we believe him. While he didn't see the seal with his own eyes, the story of a seal visiting the Marshalls seems well established. Interesting, huh? I thought perhaps you would know who is involved in seal work these days and would pass the story along. Of course we can't be sure it was a monk seal, but it seems the most likely candidate since we know they make it to Johnston Atoll, and that is 1/3 of the way between Hawaii and the Marshalls.

→

We see lots of turtles here but no evidence of nesting. The Marshallese say the turtles don't nest here. They kill and eat about 50 turtles a year, mostly around the Christmas season.

We've seen turtle nests on the atolls of Rongelap, Bikini, and Ujelang; at Ujelang we saw empty turtle egg cases floating in the surf. Also at Wotje Atoll, Marshall Islands, one of the natives had captured about a dozen newly hatched turtles.

That's all the news we have for you. I hope that these little anecdotes are somehow useful to you. Scott + I are still enjoying Enewetak. Hope all is well with you and your family.

Sincerely,
Lisa Boucher

Lisa Boucher
Mid Pac Res Lab
Enewetak, M.I.
P.O. Box 1768
APO San Francisco 96555

Mid-Pacific Research Lab
P. O. Box 1768
APO San Francisco 96555
March 23, 1983

Dear George,

It was nice to hear from you, and I'm glad that my information was useful and interesting to you. We really liked the poster too and have hung it up in the lab for decoration - many thanks.

In order to answer many of the questions that you asked about turtles here, I talked to an anthropologist, Dr. Laurence M. Carucci, who lives here among the Marshallese people. He has lived with them for several years, both here and at Ujelang (the atoll where the Marshallese lived during the period of bomb testing and clean-up), and he is very knowledgeable about their ways. Here's what we were able to find out:

My original estimate of how many turtles the Marshallese here catch per year was too high. They probably take only 25/year, though they take as many as they can catch. The islands in the northern part of the atoll (around Engebi) and the western part (Glenn to Leroy; the Marshallese names for these islands are Ikuren and Biken) are considered to be the best fishing grounds for turtles. The Marshallese say that turtles are more rare in the summertime and more common in the winter. This may explain why they are considered to be a Christmas feast food - most of them are sought after and taken at Christmastime.

There are two main methods of fishing for turtles. One way is they stake out the nesting grounds and camp out on the small islets where the turtles come ashore (care being taken not to light any fires or make any sounds) and nab the turtles when they come up on the beach). Larry says they are very good at figuring out when the turtles will come ashore. One way they do it is to check the stage of development of eggs that are already on the beach. They seem to think there is a nesting cycle, and supposedly can look at eggs that have already been laid and figure out when the turtle will come ashore to lay again. Perhaps this makes more sense to you than it does to me. With the Marshallese it is sometimes hard to separate fact from fiction or their "old wives tales." They are a very superstitious bunch to be sure.

The second method of fishing for turtles is to jump on top of them from moving boats. They try to find turtles in relatively shallow water (30 feet or less) jump on top of them, flip them over, and bring them to the surface. It is interesting that they traditionally did this from their sailing canoes. Obviously, its a lot easier to do from a motorboat than from a sailing canoe which requires tricky sailing, so the advent of outboard motors in these islands means that turtles are easier to catch.

The Marshallese also love to eat turtle eggs. By tradition, half of the eggs in each nest were always left behind as a conservation measure. These days the old traditions are dying out for a number of reasons, and Larry has seen them clean out the nests totally. Also, by tradition, every turtle taken and all turtle eggs (all food of any kind really) belonged to the chief who divided it among all the people. This distribution system was in effect as

(the Marshallese word is "iroij")

recently as 15-20 years ago, but the chief has now lost his power to a more democratic form of government, the old ways are dying, and its more or less every family for itself. Now when a turtle is taken, it is generally consumed by the family that got it instead of divided up for everybody.

As for species, both greens and hawks are taken. They say there is a third species here too. Neither Larry nor any of us has ever seen a third species, but the Marshallese say they sometimes get a large, ocean going turtle. Your guess I'm sure, would be a lot better than mine as to what species this might be. Hawks are not considered poisonous here.

Larry Carucci also told us that traditionally, small turtles were not taken, only medium to large ones. Certainly, the turtles we've seen them take have been very large, but I'd be hard pressed to guess what they weighed. One turtle I saw took two big Marshallese men to lift it so it must have been pretty heavy. Larry says that the turtles he's seen taken for food were usually on the large side, but couldn't give a good weight estimate.

The Marshallese say that nests around this atoll are few and far between. They say there are neither as many nests or turtles here as there are at Ujelang (a much smaller atoll 130 south of here) and that this has always been the case. They cannot get to all the other islets here at will, mostly because fuel for the outboards is scarce and very expensive (as much as $6 per gallon). A single round trip to the other end of the atoll can cost them as much as $50 for their tiny boats depending on how many people are on board. I don't know why there should be fewer turtles here, but I can attest to the fact that we have never seen a nest or tracks on any island here, though we get around a lot. But we saw plenty at Ujelang, Rongelap, and especially Bikini (so it can't just be a matter of radiation).

The catching of a turtle here is always a big event, and the story gets told over and over and over again. As for the turtle shells, Scott and I have seen them discarded at the local dump (a shame really). One Marshallese man gave a turtle shell to me, but for obvious reasons, Pat Colin didn't think I should keep it - so the man later traded it to a haole guy from Kwajalein for a carton of cigarettes.

Sorry, I forgot to mention above, that the reason only medium to large turtles were taken traditionally was as a conservation measure. Smaller turtles could be found but were released. Now though, they probably take whatever they can find.

About the seal that cäme to Maloelap - I am told that the remains were disposed of at sea. As I have said, the Marshallese are very superstitious, and killed the seal because they were afraid of it. To this day they still believe in spirits and demons. I'm sure they didn't want the evil spirit of that seal hanging around on their island.

Well, I hope that some of this information will help you in writing up your chapter on the Enewetak book. If you use this info, it would be really great if you could acknowledge Larry Carucci. If you want more detailed info about turtles here or at Ujelang, you may want to write him directly c/o us. He keeps excellent detailed notebooks of his observations, and may even be able to give you precise numbers of turtles taken on Ujelang while he lived there.

The 3 underwater slides were taken by Pat Colin - he says you can have them. The other two I'm sending so you can see what size some of the turtles taken are, I'd like them returned. That's all for now. Hope things are fine with you. We're really enjoying our stay here.

Yokwe,

Lisa

Helfrich

RESEARCH
MID-PACIFIC ~~MARINE~~ LABORATORY
ENEWETAK ATOLL, MARSHALL ISLANDS

Supported by
UNITED STATES DEPARTMENT OF ENERGY

17 December 1980

Dr. Bill Robison
Lawrence Livermore Laboratory
P.O. Box 808
Livermore, California
94550

Dear Bill;

This letter to Vic Noshkin should be self explanatory. I just wanted you to know that the sea turtles are making a significant contribution to the diet of the dri-Enewetak and that if you do not have any data already, the bones I am sending might give you some information on some of the radionuclides. As I told Vic we are attempting to get samples of the muscle, internal organs and more bones. The sea turtles are not identified as to species. We are getting the remains after they have been eaten, but are most likely green turtles.

Sincerely yours,

Pat

Patrick L. Colin
Resident Scientist

cc: P. Helfrich

Helfrich

MPML

RESEARCH
MID-PACIFIC ~~MARINE~~ LABORATORY
ENEWETAK ATOLL, MARSHALL ISLANDS

Supported by
UNITED STATES DEPARTMENT OF ENERGY

DEC 17 '80 AM

17 December 1980

Dr. Victor Noshkin
Lawrence Livermore Laboratory
P.O. Box 808
Livermore, California
94550

Dear Vic;

Since the return of the Enewetak people in force a couple of months ago it turns out that sea turtle is a prized item in their diet. During the two weeks before I came out of Enewetak, I know of at least 12 sea turtles being captured and eaten. During the Christmas season, the people travel long distances to gather these and other sea food, with the prime turtling spot being very close to the Mike and Koa craters at the north end of Enewetak.

Consequently I am sending you a number of turtle bones under separate cover that you may want to use for radionuclide analysis. Looking at the NVO-140 radiological survey I see there was no information obtained at that time on turtle radionuclides, so hope these samples will be of some use. In addition I have some frozen flesh from the turtles at MPRL which I will give to the researchers coming on the Liktanur II in January. I hope to obtain samples of the internal organs, more flesh and bones whenever another turtle is caught, but will have to rely on the local fishermen to catch it. With a little luck we can also have these ready to go on the Liktanur II, thus simplifying our shipping arrangements.

The bones I am sending were from a cooked turtle, if that makes any difference and were air dried. The turtles are making a significant contribution to the diet of the dri-Enewetak; I would say as much or more than the coconut crabs. Perhaps once they get fished down somewhat this will not be the case, but for the present they are something to be considered in any reevaluation of dose rates.

Since I am uncertain whether you or Bill Robison have the most interest in these samples, I am sending a copy of this letter to him also.

Sincerely yours,

Pat-

Patrick L. Colin
Resident Scientist

PS. Forgot to mention that these are most likely green turtles, but since we have only gotten the remains after eating and the shells are destroyed in the cooking process, we can not be absolutely certain.

cc: P. Helfrich, Director, MPRL
B. Robison, LLL
H. McCammon, USDOE

Marshall's name for green turtle?

567-6696

Green Turtles - WUN

August 4, 1983

George,

Glad to see you're back in one piece from Costa Rica. Must have been fun. I understand that Costa Rica is very conservation minded and have accomplished a lot in that respect.

I finally got a reply from my sources in the Marshalls re turtles, seals, etc. Earlier you had sent me an article/written comments concerning the alleged appearance of a seal at Maloelap Atoll and I wrote to someone in the Marshalls to confirm it. Well, from very reliable sources I learned that a seal did indeed come up on a beach at Maloelap. Furthermore, two addition sightings were reported. In 1963 another seal showed up at Wotje Atoll but was not harmed. It apparently stayed around for a while and then swam away. 15 years later in 1978 another seal appeared again at Wotje but this time the natives killed it but did not eat it. In my travels throughout the Marshalls I did not see any seals, nor do I remember hearing any stories about them being there. However, the guy I got the Wotje story from is very reliable and furthermore is from Wotje so I have no reason to doubt him. On the other hand, I've been to the far reaches of the Marshalls archipelago and did **not** see any seals first hand. At the remote atolls of Bikar and Bokar which humans very seldom visit, one would expect to them if they are around. Maybe they are there but don't bask on the beaches like they do here in Hawaii with the turtles. What do you think?

Some other info you might like to know...hawksbill (called jabake in Marshallese) have been known to nest in the Marshalls. Eight atolls have been identified as nesting grounds for jabake and they are: (1) Bikar; (2) Bokar; (3) Wotje; (4) Jemo; (5) Erikup; (6) Wotto; (7) Alinginae; and (8) Rongdrik. They apparently don't come up on beaches in hords during certain choice nesting periods as do the green sea turtles. Another kind of turtle described to me was wunatol which from the description appears to be the leatherback turtle. They apparently have been seen by Marshallese but it is not known if they nest anywhere in the archipelago.

Some time ago you asked if any turtles were sampled by the DOE in the Marshalls relative to radiation aftermath. I wrote but have yet to receive a reply. But I do have someone chasing it down. I'll let you know as soon as I get word.

In regards to "Vikai" islet in Enewetak, it cannot be confirmed. My informant met with several people from Enewetak but could not come up with anything. I wrote back and told him to go see Johannes himself. The people from Enewetak mentioned that no turtles were seen there since 1970. I'm not sure if this is because there is a scarcity of turtles or if it is because they haven't been on the island long enought to notice them.

I did get the additional tags you sent. Ed and Diane have been fishing at Palaau and had bagged many turtles but simply let them go. It is very tempting to go with them one day...but I don't know considering the apparent no-no of the bullpen technique.

All for now. I'll get back to you as things develop.

Bill

P.S. Did I tell you that Mickey (our son) is spending the summer in Majuro?

Volume 25, Number 13
Friday, April 1, 1994
The Marshall Islands Journal
PAGE 3

JUDGE: HERMIOS TRUST HAS NO LEGAL EFFECT

Mary Ann Cordova
MIJ Staff

Majuro, Mar. 28 — In a judgment filed in High Court today, Associate Justice Allen P. Fields ruled that the Iroijlaplap Murjel Hermios Eleemosynary Trust "is void and has no legal effect whatsoever."

The constitutionality of the trust, which was signed by Hermios on April 6, 1989, was the question before the court when it heard the parties' oral arguments.

In his judgment decree, Judge Fields quotes the Marshall Islands Constitution: "...it *shall not be lawful* or competent for any person having any right in any land in the Republic, under the customary law or any traditional practice *to make any alienation or disposition* of the land, whether by way of sale, mortgage, lease, *license*, or *otherwise*, without the approval of the Iroijlaplap, Iroijedrik where necessary, *Alap and Senior Dri Jerbal of such land*, who shall be deemed to represent all persons having an interest in the land."

The judge found that the trust document submitted to the court doesn't have approval of the Alap and the Senior Dri Jerbal, and it violates the RMI Constitution, & is therefore void on its face."

Fields also found that the December 2, 1992, lease between Islander Investments Ltd. and "the owners and holder of rights and titles at law under customary and traditional practices of the Marshall Islands to all of Erikub Atoll" have consented and approved the terms of the lease, and the lease is declared valid and in full force and effect.

In a footnote to the judgment, the court writes that it was advised by an attorney for Murjel Hermios that trustees Robert Moore II and Luman N. Nevels, Jr. have resigned from the trust and been replaced by Marshallese citizens, and that the current trustees "will move to formally dissolve the trust in the near future, following this decision."

Iroijlaplap = paramount chief; *Iroijedrik* = lesser chief; *Alap* = chiefs' overseer; *Senior Dri Jerbal* = spokesman for the clan's working people from the particular area in question.

May 21, 1994

George,

Here's a couple of articles I thought you'd be interested in. The main one concerns the situation in the Marshalls re the "Pacific Atoll Marine Preservation Society, Inc." and it's alleged permanent lease on the major turtle rookeries of Erikup and Bikar. As you can see from the article, the local courts have judged the lease to be void. I'm glad I took your advice and did not get too deeply involved with this scheme. Who knows though...they may be able to resurrect themselves from the grave and try again. It's unbelievable what these promoter types will do to make a few bucks. The other article is from the Maui News re your old friend, Rene Sylva. 180 degrees ain't it? I hope it isn't another resurrection job.

Thanks for sending Penny the article on her scholarship award. Yes, we're quite proud of her accomplishments. One would like to think we had something to do with it...and who knows, maybe we did do something right along the way. However, I still think there's an element of truth is my primary suspicion...that our kids do well in spite of us. Elsewise, why some in the same family do well and other don't? My guess is that it's up to the kids. All we can hope to do is to nudge them one way or another. They really have the final say. In a way it's good this way. Anyone from less favorable environment can also find success if he so desires and works hard at it. He's future is not pre-determined because he doesn't have certain advantages. It's really up to each individual. I suppose this is the great hallmark living in America and being an American!

Bee

from - Bikini - Eniwetok Studies 1964
Part I Radiobiological studies

MARINE ALGAL STUDIES AT BIKINI AND ENIWETOK ATOLLS

by Ralph F. Palumbo[1] and Arthur D. Welander

Evaluation of the effects of nuclear devices on the algae of the shallow reef areas of Bikini and Eniwetok Atolls would be a difficult task even with adequate facilities and time to concentrate studies at particular test sites. During the surveys at the islands, one, or at most two, of the botanists explored the shallow reefs bordering the islands to collect samples of algae for radionuclide analysis as well as for species enumeration, in the hope that gross changes in algal populations might be noted. In addition the condition of the underwater plants was recorded. Among the factors that had to be considered in these observations were the effects of fishes, many species of which feed on algae almost exclusively, and the effects of shifting sands near the islands.

Perhaps the most obvious difference between reef areas around islands that were close to the tests, such as Sanildefonso and Romurikku Islands, as compared with islands some distance away from test sites, was the presence of layers of silt. Algal

[1] The untimely death of Dr. Ralph F. Palumbo, algologist for the expedition, left the report on the algae unfinished. In this section we have attempted to give Dr. Palumbo's conception of the problem as determined from his notes and tables, although we are well aware we cannot hope to attain the completeness envisioned by the senior author.

growth appeared to be most abundant in rocky areas which offered a firm base for attachment as well as a protection against excessive currents and wave action, thus the areas which had been leveled and subsequently covered with silt would not be very suitable for algal growth. The most striking example of this condition was seen in the area around Sanildefonso Island, which is due west of the Mike test crater and which has been covered by silt drifting westward from the crater with the prevailing winds.

In previous visits to this area (1953, 1954, 1955, 1956 and 1958), species of algae belonging to eleven genera were collected (Appendix Table 5). In August 1964 only one genus was found. Although the senior author explored widely, he found only small scattered plants of Boodlea near the islands.

The changes that have taken place on and around the island of Sanildefonso show clearly why sedentary algae are not well established in the area. Fig. 176 is an aerial photograph taken in August 1954 and shows Sanildefonso Island on the right with the Mike test crater at the edge of the picture. At this time the island was fairly wide, with a small sand spit extending north along the edge of the crater. In Fig. 177, ten years later, the island is long and narrow, extending north along the crater; the contour of its former shape may be seen

Fig. 176. Aerial view of Eniwetok Atoll showing Ruchi, Cochiti, and Sanildefonso Islands, left to right, and the ocean reef at the top, 0.74 miles from the lower edge of Cochiti Island. The Mike crater is to the right. August 1954.

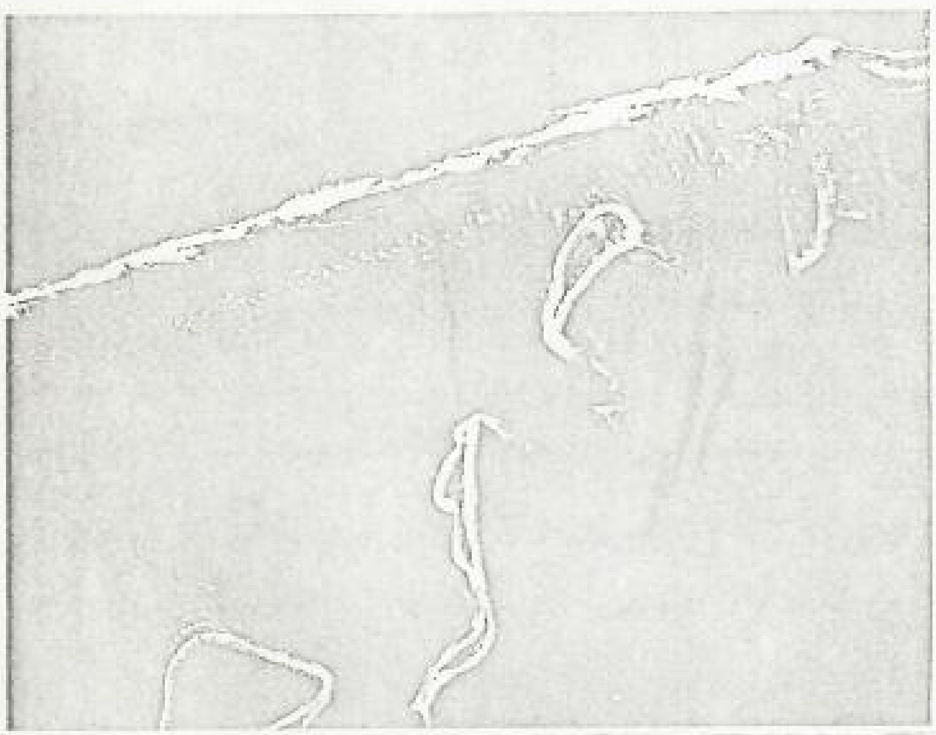

Fig. 177. Aerial view of Eniwetok Atoll, showing Cochiti, Sanildefonso, and a new island near the ocean reef, bordering the Mike crater, with the ocean reef at the top. April 1964. Submerged beach rock outlines the former shape of Sanildefonso Island.

outlined by beach rock in shallow water near the south end of the island.

Although no firm conclusions can be made from the brief observations at so many islands, it should be noted that fewer genera of algae were seen in 1964 (Appendix Tables 5 and 6) than in previous years (Taylor, 1950; Dawson, 1957; and Palumbo, 1950). Part, if not all, of the differences in numbers of genera collected could be due to the more intensive effort, covering a longer period---from 1946 through 1958---and a wider seasonal range, as compared with the collections made in 1964. It will take more intensive study of the environment of certain islands to determine conclusively if the algal populations of the atolls have been generally affected by the nuclear tests.

Appendix Table 5. List of genera of algae collected on the reefs of Eniwetok and Bikini Atolls in 1964 (x), compared with previous collections (0). Collections made both in 1964 and earlier indicated by Ω.

Genus	Igurin I.	Bogombogo I.	Engebi I.	Runit I.	Rigili I.	Sanildefonso I.	Yurochi-Aomoen I.	Bokororyuro I.	Namu I.	Bikini I.	Enyu I.	Airukiiji-Eninman I.	Japtan I.
Acetabularia								x		0			
Anacystis												x	
Asparagopsis	x			x			x			x		x	x
Avrainvillea						0	0		0	Ω			
Boodlea	0	x		x	x	Ω	Ω	x	x				
Botryocladia										0	0		
Bryopsis		0		x				x	Ω	Ω	Ω	x	
Caloglossa							0			Ω			
Calothrix							0						x
Caulerpa	Ω	Ω	x	Ω		0	Ω	Ω	Ω	Ω	Ω	Ω	x
Centroceras													x
Ceramium	x		x		x				x	0		0	x
Chlorodesmis										x			
Chnoospora					x								
Cladophora				x			0		0	0	0	0	x
Cladophoropsis							0			0		0	
Coccochloris								x	x				
Codium		Ω		x			x	x			0		
Dasya						0	0		0	0	0		
Dasyopsis									0				
Derbesia										Ω		x	
Dictyopteris										Ω			
Dictyosphaeria	0			Ω			0		0	x	x	0	x
Dictyota		Ω	x	Ω	x		x	x	Ω	x		x	x

Appendix Table 5 (continued)

Genus	Igurin I.	Bogombogo I.	Engebi I.	Runit I.	Rigili I.	Sanildefonso I.	Yurochi-Aomoen I.	Bokororyuro I.	Namu I.	Bikini I.	Enyu I.	Airukiiji-Eninman I.	Japtan I.
Dictyurus										0			
Ectocarpus		0	x	Ω				x	0				
Enteromorpha			x							0			
Entophysalis					x								
Falkenbergia													x
Gelidiella			x										
Gelidium					x		x	x	x		x		
Gloeocopsa	0						0			0		0	
Gomphosphaeria				0									
Gonidithon										x			
Goniolithon							0		0				
Halimeda	Ω	Ω	x	x	x	0	Ω	x	Ω	Ω	Ω	Ω	x
Haloplegma										0	0		
Hassallia		0											
Herposiphonia							0	x		0			
Heteroderma								x		x			x
Hormothamnion					x	0			x	x			
Hydrocoleum	x			Ω						0			
Hydroclathrus	0			0					x				
Hypnea				0	x								
Jania	0	x	x	Ω			x	x	x	0		x	x
Laurencia		x		x		0				Ω		Ω	
Liagora									0	0			
Lithothamnion		0											
Lomentaria							x						
Lophosiphonia		x											
Lyngbya	0	Ω	x	x	x		x		Ω	x	0		x
Microcoleus							0						
Microdictyon				0		0	0		0	Ω	Ω	0	
Neomeris									0	Ω	0	0	

Appendix Table 5, (continued)

Genus	Igurin I.	Bogombogo I.	Engebi I.	Runit I.	Rigili I.	Sanildefonso I.	Yurochi-Aomoen I.	Bokororyuro I.	Namu I.	Bikini I.	Enyu I.	Airukiiji-Eninman I.	Japtan I.
Oscillatoria								x					
Ostreobium									0	0			
Padina		0		x			x		x	x			
Peyssonnelia									0	0			
Phormidium		0						x					
Plectonema				0					0				
Pockockiella				Ω		0			0	0		0	
Polysiphonia			x		x		0		0			0	
Porolithon	0	0		0			0		0	Ω	0	0	
Porphyrosiphon												0	
Pseudochlorodesmis				x									x
Rhipidiphyllon	0								0	0			
Rhipilia		0		0					0	Ω	0		
Rhizoclonium													x
Rivularia									x				x
Roschera				0									
Rosenvingea		0		0					0				
Schizothrix			x				0		x	0		0	
Spermothamnion									0				
Sphacelaria										0			
Spirulina									x				x
Spyridia				0	x		x		0				
Syctonema									0			0	
Symploca			x	x	x		0		x		x		
Tolypiocladia	x			x									
Turbinaria		Ω		Ω		0			x	Ω			x
Tydemania		0											
Udotea	x	0		Ω			Ω	x	0	x	0	Ω	
Valonia				0		0	0		0	Ω			
Valoniopsis				0						0			
Wrangelia	x							x	0		x		
	*10	17	0	21	0	11	21	1	29	35	14	17	0
	** 8	10	12	21	13	1	12	17	17	24	8	10	18

*No. genera collected in previous years. **No. collected in 1964.

Appendix Table 6. List of genera and species of algae collected at Eniwetok and Bikini Atolls in 1964.

	Igurin	Bogombogo	Engebi	Runit	Rigili	Yurochi	Bokororyuro	Namu	Bikini	Enyu	Airukiiji-Eninman	Romurikku	Uorikku	Japtan	Sanildefonso
Anacystis dimidiata											+				
Acetabularia sp.							+								
Asparagopsis taxiformis	+			+		+			+		+			+	
Avrainvillea nigricans									+						
Boodlea composita		+		+	+	+	+	+							+
Bryopsis indica							+								
Bryopsis pennata v. secunda				+				+	+	+	+				
Caloglossa leprieurii									+						
Calothrix crustacea														+	
Caulerpa acuta	+														
Caulerpa antoensis		+					+								
Caulerpa arenicola								+							
Caulerpa lentillifera									+						

Appendix Table 6 (continued)

	Igurin	Bogombogo	Engebi	Runit	Rigili	Yurochi	Bokororyuro	Namu	Bikini	Enyu	Airukiiji-Eninman	Romurikku	Uorikku	Japtan	Sanildefonso
Caulerpa peltata	+	+		+							+				
Caulerpa racemosa v. clavifera							+			+					
Caulerpa racemosa v. peltata								+							
Caulerpa racemosa v. peltata f. nummularia								+							
Caulerpa racemosa v. turbinata								+							
Caulerpa serrulata									+		+				
Caulerpa serrulata v. typica						+	+	+							
Caulerpa taxifolia									+						
Caulerpa urvilliana	+					+			+		+	+		+	
Caulerpa urvilliana v. typica			+						+					+	
Caulerpa vickersiae						+									
Caulerpa webbiana	+						+								
Centroceras clavulatum														+	
Ceramium gracillimum var. byssoideum			+											+	

Appendix Table 6 (continued)

	Igurin	Bogombogo	Engebi	Runit	Rigili	Yurochi	Bokororyuro	Namu	Bikini	Enyu	Airukiiji-Eninman	Romurikku	Uorikku	Japtan	Sanildefonso
Ceramium mazatlanense														+	
Ceramium serpens								+							
Ceramium sympodiale	+				+										
Chlorodesmis hildebrandtii									+						
Chnoospora implexa					+										
Cladophora crystallina														+	
Cladophora inserva v. ungulata														+	
Cladophora socialis				+											
Coccochloris stagnina							+	+							
Codium arabicum		+		+			+								
Codium geppii		+		+			+					+	+		
Derbesia minima									+		+				
Dictyopteris repens									+						
Dictyosphaeria cavernosa									+						
Dictyosphaeria intermedia				+						+				+	

Appendix Table 6 (continued)

	Igurin	Bogombogo	Engebi	Runit	Rigili	Yurochi	Bokororyuro	Namu	Bikini	Enyu	Airukiiji-Eninman	Romurikku	Uorikku	Japtan	Sanildefonso
Dictyosphaeria versluysii														+	
Dictyota divaricata		+	+	+	+	+	+				+			+	
Dictyota pinnatifida								+	+						
Ectocarpus sp.			+	+											
Ectocarpus indicus							+								
Entophysalis conferta					+										
Enteromorpha ralfsii			+												
Falkenbergia hillebrandii														+	
Gelidiella bornetii			+												
Gelidium crinale v. perpusillum							+	+							
Gelidium pusillum					+					+					
Gonidithon sp.									+						
Halimeda fragilis										+					
Halimeda gigas									+						
Halimeda gracilis		+		+					+					+	

Appendix Table 6 (continued)

	Igurin	Bogombogo	Engebi	Runit	Rigili	Yurochi	Bokororyuro	Namu	Bikini	Enyu	Aitukiiji-Eninman	Romurikku	Uorikku	Japtan	Sanildefonso
Halimeda gracilis f. lata										+					
Halimeda monile	+								+						
Halimeda opuntia	+	+		+		+	+		+	+				+	
Halimeda opuntia f. elongata		+		+											
Halimeda opuntia f. triloba							+			+	+				
Halimeda stuposa		+	+		+	+	+	+							
Halimeda taenicola							+								
Herposiphonia secunda							+								
Heteroderma minutula							+		+					+	
Hormothamnion enteromorphoides					+			+	+						
Hydroclathrus clathratus								+							
Hydrocoleum sp.				+											
Hydrocoleum lyngbyaceum	+														
Hypnea nidulans					+										
Jania decussato-dichotoma		+	+	+		+	+	+			+			+	

Appendix Table 6 (continued)

	Igurin	Bogombogo	Engebi	Runit	Rigili	Yurochi	Bokororyuro	Namu	Bikini	Enyu	Airukiiji-Eninman	Romurikku	Uorikku	Japtan	Sanildefonso
Laurencia mariannensis		+							+		+				
Laurencia parvipapillata				+											
Lomentaria hakodatensis						+									
Lophosiphonia obscura		+													
Lyngbya aestuari				+										+	
Lyngbya confervoides		+	+											+	
Lyngbya majuscula		+	+	+	+			+						+	
Lyngbya semiplena						+			+						
Microdictyon pseudohapteron														+	
Microdictyon setchellianum									+	+					
Neomeris bilimbata									+						
Oscillatoria nigro-viridis							+								
Padina australia								+	+			+	+		
Padina sp.				+											
Phormidium crosbyanum							+								
Phormidium penicillatum							+								

Appendix Table 6 (continued)

	Igurin	Bogombogo	Engebi	Runit	Rigili	Yurochi	Bokororyuro	Namu	Bikini	Enyu	Airukiiji-Eninman	Romurikku	Uorikku	Japtan	Sanildefonso
Pocockiella papenfussii				+											
Porolithon sp.									+						
Polysiphonia sp. (fragilis?)			+		+										
Pseudochlorodesmis furcellata				+										+	
Rhipilia diaphana									+						
Rhizoclonium sp.														+	
Rivularia polyotis								+							+
Schizothrix lacustris			+					+							
Spirulina subsalsa								+							
Spirulina tenerrima														+	
Spyridia filamentosa					+	+									
Symploca hydnoides			+	+	+			+		+					
Symploca laete-viridis				+											
Tolypiocladia calodictyon	+			+											
Turbinaria ornata		+		+				+	+					+	

Appendix Table 6 (continued)

	Igurin	Bogombogo	Engebi	Runit	Rigili	Yurochi	Bokororyuro	Namu	Bikini	Enyu	Airukiiji-Enhnman	Romurikku	Uorikku	Japtan	Sanildefonso
Udotea palmetta	+			+		+	+		+		+				
Udotea palmetta v. marshallensis Udotea indica by Taylor							+		+						
Valonia aegagropila									+						
Wrangelia anastomosans	+														
Wrangelia argus							+			+					

from- Bikini-ENIWETOK Studies
Part II Radiobiological Studies

p64-76

RADIOACTIVITY IN THE ALGAE

by Ralph F. Palumbo and Arthur D. Welander

Need Enewetak Gray book showing Turtle sighting by Runit and other "hot" areas

Algae were collected, for the most part, in the same areas as those chosen for the collection of fish samples and usually at about the same time. The majority of the algae samples were collected in depths ranging from about six feet to the shoreline of the inner and outer reefs, and in small tide-pools along the shore among the rocks. Some specimens were picked up on the beach and on debris that floated ashore.

Analyses for radioactivity were made on one or more species of algae collected at 11 islands at Bikini Atoll and at 10 islands at Eniwetok Atoll. Details of these analyses are given in Appendix Table 5, Part II, and are summarized in other tables in this report.

In spite of intensive efforts, only one genus was found in sufficient quantities for analysis at more than half the collecting areas. Halimeda, for example, was found in sufficient quantities at 13 of 21 collecting areas; Caulerpa was found at 8 and Lyngbya at 7 sites (Table 30). Nineteen other genera and a total of 28 species are represented in 79 samples used in the analyses for radioactivity.

Table 30. Species of algae analyzed for radioactivity, with location of collections and the wet to dry weight ratios.

Major groups / Families / Genera and species	Islands	Wet/dry ratios
CHLOROPHYTA - Green algae		
Ulvaceae		
Enteromorpha sp.	Bikini, Enyu, Eniwetok	6.5
Cladophoraceae		
Chaetomorpha sp.	Engebi	6.0
Rhizoclonium sp.	Reere	6.0
Cladophora sp.	Mike crater, Runit	4.6
Valoniaceae		
Dictyosphaeria cavernosa	Enyu	6.3
Caulerpaceae		
Caulerpa serrulata	Bikini, Romurikku, Yurochi, Engebi, Igurin, Parry	6.5
" racemosa	Enyu	10
" urvilliana	Japtan	8.5
Codiaceae		
Codium geppii	Bokororyuro, Uorikku, Bogombogo	12
Halimeda opuntia	Airukiiji, Bikini, Bokororyuro, Enyu, Yurochi, Bogombogo, Igurin, Japtan, Rigili, Runit	2.8
" stuposa	Namu, Bogombogo, Engebi, Igurin, Parry, Runit	3.0
" gigas	Bikini	3.0
Udotea indica	Bikini, Igurin	3.1
Boodleaceae		
Boodlea composta	Namu, Rigili, Sanildefonso	10
PHAEOPHYTA - Brown algae		
Dicthotaceae		
Dictyota sp.	Namu, Yurochi	4.2
Padina commersonii	Namu, Romurikku, Uorikku	5.5
Punctariaceae		
Hydroclathrus clathratus	Namu	6.5
Fucaceae		
Turbinaria ornata	Bikini, Bogombogo, Runit	7.1

Major groups Families Genera and species	Islands	Wet/dry ratios
RHODOPHYTA - Red algae		
Bonnemaisoniaceae		
Asparagopsis taxiformis	Bikini, Reere, Igurin, Parry	9.3
Corallinaceae		
Porolithon sp.	Bikini	2.5
Rhodomelaceae		
Laurencia mariannensis	Airukiiji	5.0
Polysiphonia sp.	Runit	4.3
Ceramiaceae		
Spyridia filamentosa	Yurochi, Igurin	7.0
SCHIZOPHYTA - Blue-green algae		
Oscillatonaceae		
Lyngbya majuscula	Namu, Yurochi, Bogombogo, Engebi, Japtan, Rigili, Runit	5.8
Symploca hydnoides	Runit	7.0

Comparison of the Radioactivity at Different Localities

Algal samples were examined by gamma spectromety and the following radionuclides were detected in decreasing order of their contribution to the total activity: cerium-144, cobalt-60, ruthenium-106, bismuth-207, manganese-54, cesium-137 and antimony-125. Bismuth-207 is apparently more abundant at Eniwetok than at Bikini Atoll while cerium-144 and ruthenium-106 are more abundant at Bikini. In general, however, there is a marked similarity in both quantity and quality of radionuclides (Table 31), and for the most part, gamma spectrum analysis indicated that algal samples often contained the above radionuclides in approximately the same relative proportions (Tables 32 and 33). Cerium-144 was, by far, the dominant radionuclide, and it appears that most species have an affinity for this radionuclide (Palumbo, 1963; Held, 1963; Wallauschek and Lutzen, 1964; Hiyama and Shimizu, 1964).

The data in Table 32 indicate that the highest average total radioactivity of seven radionuclides occurs in algae found around islands on the north rim of Bikini Atoll, Uorikku, Yurochi and Romurikku (68 to 167 pCi/g), followed by activity in algae from Eninman Island (100 pCi/g), located on the southern edge of the atoll. Radioactivity was lowest in algae from Bikini and Enyu Islands at the eastern side of the atoll (13 and 9.5 pCi/g respectively).

Table 31. Average radionuclide content, by islands, of algae from Bikini and Eniwetok Atolls, August 1964. Values expressed in picocuries per gram of dry weight at time of collection.

	Mn^{54}	Co^{60}	Ru^{106}	Sb^{125}	Cs^{137}	Ce^{144}	Bi^{207}
Bikini Atoll							
Number	11	11	11	11	11	11	11
Average	2.5	8.8	6.1	0.34	0.56	47.	0.46
Range	1.0-7.0	1.8-15.	0-23	0-2.1	0-2.1	6.2-120	0-4.8
Eniwetok Atoll							
Number	10	10	10	10	10	10	10
Average	1.3	9.6	2.6	0.91	1.4	22.	4.9
Range	0-3.1	0.5-33.	0-14.	0-6.6	0-9.6	0-38.	0-15.

Table 32. Average values for seven radionuclides in algae from islands of Bikini Atoll, August 1964. Values expressed in picocuries per gram of dry tissue at time of collection.

	Mn^{54}	Co^{60}	Ru^{106}	Sb^{125}	Cs^{137}	Ce^{144}	Bi^{207}	Total
Aomoen								
No. samples	1	1	1	1	1	1	1	
Average	1.7	9.0	8.3	0	0	49.	0	68.0
Airukiiji								
No. samples	2	2	2	2	2	2	2	
Average	1.0	3.8	0	0	0	16.	0	20.8
Range	0.79-1.2	1.9-5.6	0	0	0	15.-17.	0	
Bikini								
No. samples	10	10	10	10	10	10	9	
Average	1.3	5.6	0.23	0	0.049	6.2	0.067	13.45
Range	0-2.7	0-14.	0-2.3	0	0-0.49	0-13.	0-0.67	
Bokororyuro								
No. samples	2	2	2	2	2	2	2	
Average	1.6	10.	0	0	0	30.	4.8	46.4
Range	0-3.1	6.5-14.	0	0	0	19.-40.	1.2-8.3	
Eninman								
No. samples	1	1	1	1	1	1	1	
Average	2.1	8.6	8.6	0	2.1	79.	0	100.4
Enyu								
No. samples	6	6	6	6	6	6	6	
Average	1.1	1.8	0	0	0	6.6	0	9.5
Range	0-3.2	0.46-3.3	0	0	0	0-22.	0	

	Mn^{54}	Co^{60}	Ru^{106}	Sb^{125}	Cs^{137}	Ce^{144}	Bi^{207}	Total
Namu								
No. samples	7	7	7	7	7	7	7	
Average	2.1	5.0	2.1	0	0.48	27.	0.20	36.88
Range	0-5.7	1.6-7.2	0-4.5	0	0-1.1	13.-34.	0-0.62	
Reere								
No. samples	2	2	2	2	2	2	2	
Average	1.7	14.	5.0	0	0	26.	0	46.7
Range	0-3.4	8.2-19.	4.9-5.1	0	0	21.-30.	0	
Romurikku								
No. samples	2	2	2	2	2	2	2	
Average	5.8	9.5	9.3	0.95	1.6	64.	0	91.15
Range	5.4-6.2	8.0-11.	8.6-10.	0-1.9	1.2-2.1	46.-83.	0	
Uorikku								
No. samples	2	2	2	2	2	2	2	
Average	7.0	14.	23.	2.0	1.4	120.	0	167.4
Range	5.6-8.5	12.-16.	22.-24.	0-4.0	0-2.8	110.-130.	0	
Yurochi								
No. samples	5	5	5	5	5	5	5	
Average	2.1	15.	11.	0.77	0.56	92.	0	121.43
Range	0-4.1	6.9-20.	0-21.	0-2.9	0-2.4	30.-130.	0	
Average by island	2.5	8.8	6.1	0.34	0.56	47.	0.46	66.

Table 33. Average values for seven radionuclides in algae from islands of Eniwetok Atoll, August 1964. Values expressed in picocuries per gram of dry tissue at time of collection.

	Mn^{54}	Co^{60}	Ru^{106}	Sb^{125}	Cs^{137}	Ce^{144}	Bi^{207}	Total
Bogombogo								
No. samples	7	7	7	7	7	7	7	
Average	3.1	14.	7.0	1.4	0.68	35.	6.0	67.18
Range	0-9.2	3.5-35.	0-16.	0-3.4	0-1.8	7.9-80.	2.3-14.	
Engebi								
No. samples	4	4	4	4	4	4	4	
Average	2.9	2.8	0	0	0.50	20.	0.98	27.18
Range	0-7.0	0.52-5.1	0	0	0-1.1	7.4-38.	0-2.0	
Eniwetok								
No. samples	1	1	1	1	1	1	1	
Average	2.3	2.9	0	0	0	38.	7.2	50.4
Igurin								
No. samples	6	6	6	6	6	6	6	
Average	0.92	3.8	0	0	0	7.8	10.	22.52
Range	0-2.2	1.5-7.7	0	0	0	0-20.	2.4-38.	
Japtan								
No. samples	3	3	3	3	3	3	3	
Average	1.3	1.0	1.3	0	0.16	35.	1.2	39.96
Range	0-2.2	0-2.2	0-4.0	0	0-.49	11.-42.	0-3.6	
Mike crater								
No. samples	1	1	1	1	1	1	1	
Average	0	33.	---	---	0	0	0	33.00

Table 33 (continued)

	Mn^{54}	Co^{60}	Ru^{106}	Sb^{125}	Cs^{137}	Ce^{144}	Bi^{207}	Total
Parry								
No. samples	3	3	3	3	3	3	3	
Average	1.1	0.50	0	0	0	11.	7.2	19.8
Range	0-3.4	0-1.0	0	0	0	0-17.	0-20.	
Rigili								
No. samples	3	3	3	3	3	3	3	
Average	0.32	12.	0	0	0	24.	15.	51.32
Range	0-0.97	2.2-32.	0	0	0	0-62.	2.2-38.	
Runit								
No. samples	8	8	8	8	8	8	8	
Average	0.74	22.	14.	6.6	9.6	24.	.89	77.83
Range	0-3.0	0-58.	0-55.	0-29.	0-50.	0-62.	0-7.0	
Sanildefonso								
No. samples	1	1	1	1	1	1	1	
Average	0	4.1	3.8	1.1	2.4	26.	0.87	38.27
Average by island	1.3	9.6	2.6	0.91	1.4	22.	4.9	43.

Table 33 indicates that the highest total radioactivity at Eniwetok Atoll occurs in algae collected near Runit Island (78 pCi/g) with successively less radioactivity in algae from Bogombogo, Rigili and Eniwetok Islands (67, 51 and 50 pCi/g, respectively). The lowest values were found at Parry and Igurin Islands (about 20 pCi/g). With the possible exception of Eniwetok Island, the highest values tended to occur in algae from islands subjected to many tests, followed by islands in the fallout pattern, usually west of the test sites. The lowest values occurred on the eastern side of the atolls. Most of the radionuclides followed this pattern except for bismuth-207 which was highest in algae from Bokororyuro Island, Bikini Atoll, and from Rigili Island, Eniwetok Atoll, both of which are on the extreme western edge of the atolls.

As previously pointed out, only three of the 22 genera collected for analysis of radioactivity were found in sufficient quantities at more than six of the 21 islands. The genus *Lyngbya* was collected near seven of the islands, two at Bikini Atoll and four at Eniwetok. *Halimeda* was taken near 13 islands and *Caulerpa* was taken near eight, both more or less equally distributed at the two atolls. Tables 34 and 35 contain values of the total activity in the different genera compared by island localities; the scattered and incomplete nature of the collections makes comparison of radionuclide content in the different genera of algae difficult.

Table 34. Total radioactivity of seven radionuclides in algae from Bikini Atoll, August 1964, compared by genera and by islands. Values expressed in picocuries per gram of dry weight at time of collection.

Genera/island	Aomoen	Airu-kiiji	Bikini	Boko-roryuro	Enin-man	Enyu	Namu	Reere	Romu-rikku	Uo-rikku	Yuro-chi
Asparagopsis	---	---	28.47	---	---	---	---	46.5	---	---	---
Boodlea	---	---	---	---	---	---	61.8	---	---	---	---
Caulerpa	---	---	23.7	---	---	4.9	---	---	110.4	---	128.
Codium	---	---	---	58.3	---	---	---	---	---	178.5	---
Dictyosphaeria	---	---	---	---	---	27.6	---	---	---	---	---
Dictyota	---	---	---	---	---	---	39.48	---	---	---	150.8
Enteromorpha	---	---	26.7	---	---	2.8	---	---	---	---	---
Halimeda	---	17.69	6.17	33.8	---	7.02	18.3	---	---	---	49.05
Hydroclathrus	---	---	---	---	---	---	25.52	---	---	---	---
Laurencia	---	23.8	---	---	---	---	---	---	---	---	---
Lyngbya	---	---	---	---	---	---	52.64	---	---	---	112.
Mixed algae	68.	---	16.79	---	100.4	---	---	---	---	---	---
Padina	---	---	---	---	---	---	53.07	---	73.	156.4	---
Porolithon	---	---	7.51	---	---	---	---	---	---	---	---
Rhizoclonium	---	---	---	---	---	---	---	45.1	---	---	---
Scum algae	---	---	---	---	---	---	---	---	674.[1]	---	---
Spyridia	---	---	---	---	---	---	---	---	---	---	167.4
Turbinaria	---	---	8.7	---	---	---	---	---	---	---	---
Udotea	---	---	4.4	---	---	---	---	---	---	---	---

[1] Scum algae from target area on Romurikku Island

Table 35. Total radioactivity of seven radionuclides in algae from Eniwetok Atoll, August 1964, compared by genera and by islands. Values expressed in picocuries per gram of dry weight at time of collection.

Genera/island	Bogom-bogo	Engebi	Eni-wetok	Igurin	Japtan	Mike crater	Parry	Rigili	Runit	Sanilde-fonso
Asparagopsis	---	---	---	36.6	---	---	21.26	---	---	---
Boodlea	---	---	---	---	---	---	---	4.4	---	38.27
Caulerpa	---	13.62	---	16.4	30.01	---	17.	---	---	---
Chaetomorpha	---	53.2	---	---	---	---	---	---	---	---
Cladophora	---	---	---	---	---	33.	---	---	97.	---
Codium	62.7	---	---	---	---	---	---	---	---	---
Enteromorpha	---	---	50.4	---	---	---	---	---	---	---
Halimeda	25.02	7.92	---	7.31	11.49	---	21.0	15.77	10.76	---
Lyngbya	125.	35.3	---	---	49.4	---	---	132.	80.5	---
Mixed algae	---	---	---	---	---	---	---	---	154.4	---
Polysiphonia	---	---	---	---	---	---	---	---	166.	---
Spyridia	---	---	---	60.6	---	---	---	---	---	---
Symploca	---	---	---	---	---	---	---	---	108.3	---
Turbinaria	81.0	---	---	---	---	---	---	---	0	---
Udotea	---	---	---	7.9	---	---	---	---	---	---

Perhaps the only conclusion that can be made at this time is that Halimeda, in comparison with other algae from the same area, had lower values of radioactivity (Palumbo, 1950). Other genera of algae, irrespective of class or order, had approximately the same amounts of radioactivity. The filamentous, vesicular or succulent types of algae appeared, in general, to have higher concentrations of radioactivity than the coralline types (Palumbo, 1962).

The data in Appendix Table 5, Part II, indicate that the genus Lyngbya has an affinity for bismuth-207. In almost all instances values for bismuth-207 were higher in this genus than in other genera collected at the same locality at the same time.

Appendix Table 5. Gamma-emitting radionuclides in entire algae collected at Bikini and Eniwetok Atolls, August 1964. Values expressed as picocuries per gram of dry weight at time of collection.

Location	Species	Mn^{54}	Co^{60}	Ru^{106}	Sb^{125}	Cs^{137}	Ce^{144}	Bi^{207}
Bikini Atoll								
Aomoen I.	Mixed algae	1.7	9.0	8.3	0	0	49.	0
Airukiiji I.	*Laurencia mariannensis*	1.2	5.6	0	0	0	17.	0
	Halimeda opuntia	0.79	1.9	0	0	0	15.	0
Bikini I.	Mixed algae	1.7	1.3	2.3	0	0.49	11.	0
	Porolithon sp.	1.4	0.41	0	0	0	5.7	0
	Halimeda opuntia	0.66	0	0	0	0	0	0
	Turbinaria ornata	0	0	0	0	0	8.7	0
	Halimeda sp.	0.94	5.1	0	0	0	0	0
	Udotea indica	0	4.4	0	0	0	0	---
	Enteromorpha sp.	2.7	12.	0	0	0	12.	0
	Asparagopsis taxiformis	1.8	14.	0	0	0	12.	0.67
	Caulerpa serrulata	1.9	8.8	0	0	0	13.	0
	Halimeda gigas & *Halimeda opuntia*	1.8	10.	0	0	0	0	0
Bokororyuro I.	*Halimeda opuntia*	0	6.5	0	0	0	19.	8.3
	Codium geppii	3.1	14.	0	0	0	40.	1.2
Eninman I.	Mixed algae*	2.1	8.6	8.6	0	2.1	79.	0
Enyu I.	*Halimeda opuntia*	0	1.6	0	0	0	4.5	0
	Halimeda opuntia	0.42	0.46	0	0	0	8.0	0
	Dictyosphaeria cavernosa	2.3	3.3	0	0	---	22.	0
	Caulerpa racemosa	3.2	1.7	0	0	0	0	0
	Halimeda opuntia	0.57	0.70	0	0	0	4.8	0
	Enteromorpha sp.	0	2.8	0	0	---	0	0

* *Dictyota*, *Asparagopsis*, etc.

Appendix Table 5, (continued)

Location	Species	Mn^{54}	Co^{60}	Ru^{106}	Sb^{125}	Cs^{137}	Ce^{144}	Bi^{207}
Bikini Atoll, continued								
Namu	*Halimeda stuposa*	0.75	1.6	0.	0	0.45	15.	0
	Lyngbya majuscula	3.1	4.4	4.2	0	0.94	40.	0
	Dictyota sp.	2.4	5.0	4.5	0	1.1	26.	0.48
	Padina commersonii	5.7	8.1	3.8	0	.85	34.	.62
	Halimeda stuposa	0.96	4.9	0	0	0	13.	0
	Boodlea composta	0	6.8	0	0	0	55.	0
	Hydroclathrus clathratus	2.0	6.0	2.2	0	0	15.	.32
Reere	*Rhizoclonium* sp.	0	19.	5.1	0	0	21.	0
	Asparagopsis taxiformis	3.4	8.2	4.9	0	0	30.	0
Romurikku	*Caulerpa serrulata*	5.4	8.0	10.	1.9	2.1	83.	0
	Padina commersonii	6.2	11.	8.6	0	1.2	46.	0
	Scum algae	0	89.	74.	21.	10.	480.	0
Uorikku	*Padina commersonii*	5.6	12.	22.	4.0	2.8	110.	0
	Codium geppii	8.5	16.	24.	0	0	130.	0
Yurochi	*Halimeda opuntia*	2.5	6.9	8.7	0.95	0	30.	0
	Caulerpa serrulata	0	20.	21.	0	0	87.	0
	Spyridia filamentosa	4.1	12.	16.	2.9	2.4	130.	0
	Lyngbya majuscula	0	19.	0	0	0	93.	0
	Dictyota sp.	3.8	18.	7.9	0	1.1	120.	0
Eniwetok Atoll								
Bogombogo	*Turbinaria ornata*	0	15.	16.	3.4	1.5	41.	4.1
	Halimeda opuntia	1.2	5.0	0	0	0	20.	2.3
	Halimeda stuposa	1.4	8.7	3.1	0	0.47	12.	3.0
	Lyngbya majuscula	9.2	35.	11.	3.2	0	52.	14.

Appendix Table 5 (continued)

Location	Species	Mn^{54}	Co^{60}	Ru^{106}	Sb^{125}	Cs^{137}	Ce^{144}	Bi^{207}
Eniwetok Atoll, continued								
Bogombogo	*Lyngbya* sp.	4.4	17.	9.3	3.2	1.8	80.	10.
	Codium geppii	4.5	14.	6.6	0	1.0	31.	5.6
	Halimeda opuntia	1.2	3.5	2.6	0	0	7.9	2.7
Engebi	*Lyngbya majuscula*	3.1	4.3	0	0	0	26.	1.9
	Halimeda stuposa	0	0.52	0	0	0	7.4	0
	Chaetomorpha sp.	7.0	5.1	0	0	1.1	38.	2.0
	Caulerpa serrulata	1.6	1.1	0	0	0.92	10.	0
Eniwetok	*Enteromorpha* sp.	2.3	2.9	0	0	0	38.	7.2
Igurin	*Halimeda stuposa*	0.66	1.7	0	0	0	1.8	2.4
	Halimeda opuntia	0.77	1.5	0	0	0	2.6	3.2
	Udotea sp.	0	2.9	0	0	0	0	5.0
	Asparagopsis taxiformis	2.2	6.8	---	0	0	20.	7.6
	Caulerpa serrulata	0	2.5	0	0	0	9.6	4.3
	Spyridia filamentosa	1.9	7.7	0	0	0	13.	38.
Japtan	*Caulerpa urvilliana*	2.2	0.81	4.0	0	0	23.	0
	Halimeda opuntia	0	0	0	0	0.49	11.	0
	Lyngbya majuscula	1.6	2.2	0	0	0	42.	3.6
Mike Crater	*Cladophora* sp.	0	33.	---	---	0	0	0
Parry	*Caulerpa serrulata*	0	0	0	0	0	17.	0
	Asparagopsis taxiformis	3.4	0.50	0	0	0	17.	0.36
	Halimeda stuposa	0	1.0	0	0	0	0	20.
Rigili	*Halimeda opuntia*	0.97	2.3	0	0	0	9.0	3.5
	Lyngbya majuscula	0	32.	0	0	---	62.	38.
	Boodlea composta	0	2.2	0	0	0	0	2.2

Appendix Table 5 (continued)

Location	Species	Mn^{54}	Co^{60}	Ru^{106}	Sb^{125}	Cs^{137}	Ce^{144}	Bi^{207}
Eniwetok Atoll, continued								
Sanildefonso	*Boodlea composta*	0	4.1	3.8	1.1	2.4	26.	0.87
Runit	*Turbinaria* sp.	0	0	0	0	0	0	0
	Polysiphonia sp.	0	32.	55.	29.	50.	0	0
	Lyngbya majuscula	3.0	21.	5.2	2.3	0	42.	7.0
	Halimeda opuntia	0.50	0.22	0	0	0	5.1	0.11
	Cladophora sp.	0	20.	27.	15.	22.	13.	0
	Mixed algae	2.4	58.	28.	0	5.0	61.	0
	Symploca hydnoides	0	40.	0	6.3	0	62.	0
	Halimeda stuposa	0	8.3	0	0	0	7.3	0

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ALGAE

by

Ralph F. Palumbo

OCCURRENCE, HABITAT AND IDENTIFICATION

Algae were collected for the most part in the same area as that chosen for the collection of the fish samples, and usually at about the same time. Thus the bulk of the samples of algae were derived from localities similar to those for the fish, and should provide a good comparison between the two, as in many cases, the fish collected might have been feeding on the algae in that area. The majority of the algae were collected in water the depth of which ranged from six feet to the shore line of the inner reef, in pounding surf or in fairly rough water. The remainder of the collecting was done while wading along the shore line of the inner and outer reefs, in the tide flat between the reefs, and in small pools left along the shore among the rocks. Some specimens were picked up on the beach and on debris floated ashore. Samples were also obtained from the bottom of the lagoons by means of dredging from a small boat; other samples were obtained from buoys anchored in the Bikini Target Area.

Various habitats were included in the collecting. In deep water, samples were obtained mainly from coral heads and from the sandy bottom where the light was not strong. In other cases, the samples were located in very shallow water in strong light, either in tide pools or on the reef in the strong surf. In certain cases, the algae were found in crevices or on the under side of the rocks hidden from view, but in the path of constantly surging water.

Several different methods were attempted to facilitate the collecting and storage of the specimens for further study. Due to the depth of water involved, it was difficult to swim with much equipment attached to the person; so it was necessary to put all specimens into a capped jar and to transfer the separate species of algae to smaller bottles upon reaching shore. Because of the difficulty of submerging repeatedly with such a container, a small bag made of plastic screen was substituted and the collecting was made simpler and more effective. Collections along the shore were made without much trouble, requiring only a bucket and small sample bottles with the proper labels. A knife or scraper was often used to pry and cut samples away from the rocks. These in turn were placed in sea water for transfer to the appropriate containers. Once the samples were returned to the ship used as headquarters, they were sorted, preserved in an alcohol-formalin solution, or pressed for drying and later mounting. A complete sample of the collection was quick-frozen for radiological assay at the University of Washington laboratory.

The collecting of algae was separated into two phases. The first phase considered the collection of ten specific algae from each of the collection stations, and the second phase consisted of a general collection of any algae available. As a whole, most of the algae were not present at all the stations, or could not be found in the time allotted; in fact, the majority of the algae were to be found in but a few of the stations chosen. This statement holds true for all of the algae with the exception of the genus Halimeda, which was found in abundance at all the spots in which collections were made. At three of four stations no more than three different species of algae were obtained for further study because of the paucity of the flora at these points.

The ten algal groups selected were chosen because they were most abundant in the collections of former years and because they are probably used for food by the fish of the area. The genera in certain cases included more than one particular species; this was allowed because of the confusion and similarity between the species of the same genus and the difficulty involved in separating one from the other. The genera collected included species from different phylogenetic groups of the algae, but for the most part the algae were fleshy and undoubtedly eaten by the fauna of the region.

The genera chosen, their occurrence at the collecting stations, and their habitat are given in Table 1. The habitats of the various algae differed from one another in addition to the fact that their distribution was dissimilar. In most cases the same algae were found in the same habitat. As an example Halimeda was usually found attached to the bottom and to coral heads under water, whereas Ectocarpus was usually found attached to the reef at the water line.

As a whole the number of algae at Eniwetok Atoll is meager as compared to that at Bikini. This is undoubtedly a result of destructive forces and not a natural condition. As an example to illustrate this point, the collection made off Engebi

TABLE 1

Occurrence and habitat of ten common algae at collection stations.

	Station																	Habitat
	Bikini-inside	Enyu-channel	Aimen-general	Rokar-dredge 60-100'	Rokar-dredge 150'	Erik-inside	Boro-inside	Namu-general	Japtan-inside	Igurin-inside	Rigili-inside	Engebi-inside	Eberiru-inside	Eberiru-Aomoa dredge 40-60'	Runit-N.W. tip	Likiep-inside	Likiep-outside	
Halimeda	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	Attached to the bottom or to coral heads in all depths of water.
Udotea	P	P	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	Growing singly in small clumps in conjunction with Halimeda.
Microdictyon	P	P	P	P	P	P	P	P	P	P	-	-	-	-	P	P	P	Attached usually to other algae or to rocks at varying depths.
Cladophora	P	-	P	-	-	P	S	S	-	-	-	P	P	-	P	-	-	Found free floating or attached to rocks in low water.
Dictyosphaeria	P	P	P	-	-	P	-	-	-	-	-	-	-	-	-	P	-	Attached to coral heads in large clumps in 3-6' water.
Turbinaria	P	-	-	-	-	P	-	S	-	-	-	-	-	-	-	-	-	Attached always to the bottom in sandy areas.
Caulerpa	P	P	P	-	P	P	P	P	P	P	P	P	-	-	P	-	P	Attached to coral heads in deep water in large masses, or in shallow water in fast running water.
Polysiphonia type	P	-	P	P	-	-	-	S	P	-	-	P	P	-	P	-	-	In fast flowing deep water with low light.
Liagora	-	P	P	P	-	-	-	-	-	-	-	-	-	-	-	P	P	Attached to the bottom at varying depths.
Ectocarpus	-	-	P	-	-	-	S	-	-	P	-	-	-	-	-	-	-	Usually found in low water with plenty of light at the shore line.

P = collected for study - = not present S = present, but not in sufficient quantities for sampling

Island in the vicinity of the debris resulting from the blast consisted of two algae, Cladophora and Lyngbia. These algae are primitive in type and could be expected to be the first to reappear after the flora had been exterminated. Other more advanced forms were not present in this area but were found in abundance at the other islands not exposed to the effects of the blast. The algae were found in great numbers at Bikini, Enyu, Amen, Erik, Namu, and Likiep Islands, even though the number of different species was not great.

The second phase was to collect all algae that were found. Following is a summary of these algae including name, location, and usual habitat:

1.	Lithothamnion sp.	Bikini I., Likiep (Lado) - on outer reef, forming part of the reef itself, giving the characteristic red color to the reef.
2.	Lithopyllum sp.	Bikini I., Amen I. - on outer reef, and also making up the reef.
3.	Avrainvillea sp.	Bikini I., Enyu I. - found only in isolated spots attached to coral heads similar to Udotea.
4.	Scytonema Myochrous	Enyu I., Amen I., Runit I. - attached to rocks, found on LCT 816 at the water line.
5.	Padina sp.	Amen I., Eberiru-Aomon (dredge 40-60') - attached to rocks and barge at varying depths.
6.	Hydroclathrus sp.	Amen I. only - attached to the bottom, sparse growth.
7.	Lyngbia semiplena	Amen I., Erik I., Eberiru-Aomon (dredge 40-60') - in fast-flowing water attached to rocks.
8.	Valonia sp.	Igurin I., Rigili I., Eberiru-Aomon dredge, Likiep I. (outside) - attached on the under side of rocks usually in low water.
9.	Dictyota sp.	Rokar-Enyu dredge (60-100'), Eberiru I., Eberiru-Aomon dredge - attached to rocks at varying depths.

10.	Laurencia sp.	Rokar-Enyu (dredge 60-100'), Erik I., Japtan I., Likiep (inside)-attached to the bottom in large tufts.
11.	Asperogopsis Sanfordiana	Japtan I., Igurin I. - in tufts attached to the sandy bottom.
12.	Hormothamnion enteromorphoides	Rigili I., Eberiru I. - in fast-flowing wat on bottom or attached to rocks.
13.	Lyngbia majuscula	Rigili I., Engebi I., Eberiru I. - attached to debris on bottom in fairly deep water.
14.	Bryopsis pennatifida	Attached to rocks in large clumps at the water line.
15.	Pockockiella sp.	Eberiru-Aomon dredge, Likiep I. (inside) attached to the under side of rocks in low light.
16.	Neomeris sp.	Likiep I. (outside) - attached to the bottom and to the reef in low, fast, running water.
17.	Hydrocoleum confluens	Boro I. only - on outer reef in fast water, forming a slimy cover.
18.	Chlorodesmis comosa	Amen I. only - on rocks and inner reef in large clumps at water line.
19.	Jania sp.	Amen I., Japtan I., Engebi I., Eberiru I., Runit I. - may be confused with Polysiphon attached to rocks and coral heads in shallo water in tufts covering large areas.

This list does not include certain algae sent out for identification, nor does it include the different species of some of the genera, such as Halimeda and Caulerpa, of which there are several. A completed list of all of the species collected will be compiled as soon as all the information is gathered.

Dried specimens of the algae have been mounted, and a set will be available at the herbarium of the University of Washington. Preserved specimens will be kept at the Applied Fisheries Laboratory for future reference.

Aid in verification and identification of the samples has been given by the following people:

Dr. Francis Drouet of the Chicago Natural History Museum.

Dr. Lois Eubank of Mills College, Oakland, California.

Dr. Isabelle Abbott of the University of California at Berkeley.

Dr. G. J. Hollenberg of Redlands University, Redlands, California.

Dr. G. F. Papenfuss of the University of California at Berkeley.

RADIOACTIVITY

Radioautographs of Halimeda, Lyngbia, Udotea, Dictyota, Microdictyon and Bryopsis have been made but are not shown in this report.

The frozen algae samples were ashed and counted by the standard procedure outlined in an earlier section. After counting, the algae samples were grouped by area, by species, and by phylogenetic relationship, and the activity of the samples - expressed as d/m/g - was tabulated.

In Table 2 the average count of all algae samples from the same locality is listed according to descending order of activity. The four areas at the top of the list are in the vicinity of the Eniwetok Shot Islands and are followed by two samples from the Bikini Target Area.

The average d/m/g for each species from all areas combined are listed in descending order of magnitude in Table 3. This listing indicates that the more succulent forms contain the highest activity. These algae as a rule were found in low water close to the shore line. As an example, Bryopsis was found along the shore on Engebi Island; it is succulent and had a high activity. The same can be said of Lyngbia, Scytomema, and Hormothamnion. In contrast, the corallines such as Halimeda, Lithothamnion, and Lithophyllum showed hardly any activity even though also found along the shore.

Table 2 does not necessarily give a true picture of the algae activity by locality nor does Table 3 necessarily give a true picture of the algae activity by species because all species were not collected in all areas. The range in values from a common area and the variation in values between species are shown in the tabulation below of the activity of the algae samples collected from Engebi, Eberiru, and Runit Islands, Eniwetok Atoll:

TABLE 2

Activity of algae samples by locality, 1949.

Locality code	Atoll	Island	n	1949 average d/m/g
M	Eniwetok	Eberiru	7	2412
O	"	Runit	6	2289
L	"	Engebi	6	1224
N	"	Eberiru-dredged	4	270
E	Bikini	Target buoys	5	79
DD	"	Target-dredged	6	51
D	"	Rokar, dr. 2795	5	13
C	"	Amen	13	9
A	"	Bikini, 2407	10	9
F	"	Erik, 0390	7	7
B	"	Enyu, 2895	13	4
Q	Likiep	Lado (outside)	10	3
P	"	Lado (inside)	12	2
H	Bikini	Namu (W. tip)	4	1.5
J	Eniwetok	Igurin (inside)	7	1
I	"	Japtan (inside N. end)	6	1
K	"	Rigili (inside)	4	0
G	Bikini	Boro	4	0
		Total	129	

TABLE 3

Activity of algae samples by species, 1949.

Code No.	Name	n	Average d/m/g
42	Lyngbia majuscula	2	3366
28	Scytonema Myochrous	3	2238
41	Hormothamnion enteromorphoides	2	1668
23	Polysiphonaceous type	6	1525
43	Bryopsis pennatifida	1	1386
36	Dictyota major	3	1330
8	Cladophora lutoela	4	798
3	Microdictyon japonicum	10	249
30	Padina commersoni	2	114
1	Halimeda sp.	15	103
15	Caulerpa racemosa var. clavifera	9	100
35	Valonia fastigiata	3	30
12	Turbinaria ornata	2	24
29	Ectocarpus sp.	2	21
5	Microdictyon Okamurai	8	19
9	Dictyosphaeria cavernosa	4	18
39	Caulerpa Urvilliana	1	16
38	Laurencia	3	9
6	Lithothamnion sp.	2	7
14 and 21	Caulerpa racemosa var. uvifera	7	6
19	Udotea orientalis	2	4
7	Lithophyllum sp.	2	3
2	Halimeda tuna	2	1
26	Liagora farinosa and spp.	4	1
10	Halimeda sp.	2	0
20	Avrainvillea sp.	1	0
24	Halimeda sp.	1	0
25	Halimeda sp.	1	0
31	Polysiphonaceous red alga	1	0
32	Hydroclathrus clathratus	1	0
33	Cladophora sp.	1	0
40	Asperegopsis sp.	1	0
44	Udotea sp.	1	0
45	Laurencia sp.	1	0
46	Pocockiella Papenfussii	1	0

Alga	d/m/g
1. Ectocarpus sp.	6255
2. Lyngbia majuscula	3366
3. Hormothamnion enteromorphoides	3334
4. Dictyota major	3 309
5. Microdictyon japonicum	2392
6. Polysiphonaceous type	2287
7. Bryopsis pennatifida	1386
8. Cladophora luteola	1060
9. Caulerpa racemosa var. uvifera	901
10. Halimeda sp.	426
11. Caulerpa racemosa	42

Although most of the succulent forms appear at the top of the list, an exception is Caulerpa. It might be expected that Halimeda, a coralline alga, would be of relatively low activity because of its high percentage of calcareous material.

There is little correlation of activity with phylogenetic sequence as shown in the present data (see Table 4). However, the relationship may be obscured by the fact that all species were not available in all areas, and the data are from collections in all areas, both active and inactive. A more extensive collection would be necessary before any valid conclusions could be made.

A comparison between algae activity in 1948 and that in 1949 is given below:

ALGAE ACTIVITY, 1948 AND 1949

		1948		1949	
Atoll	Area	n	average d/m/g	n	average d/m/g
Eniwetok	Shot Islands	23	2710	23	1700
	Other	32	174	17	1
Bikini	Target Area	15	425	11	64
	N to E reef: Uku to Amen to Bikini to Rokar	97	45	28	10
	Other	54	20	28	4
Likiep	Lado	-	-	22	3

The 1948 values were converted from millimicrocuries per kilogram to d/m/g by multiplying by 2.2.

SUMMARY

To date, thirty-five algae types have been identified from samples collected at eighteen stations at Bikini, Eniwetok, and Likiep Atolls during July and August, 1949. One hundred and twenty-nine frozen samples were ashed and counted. The average d/m/g for Likiep, the control area, was three. For Bikini Atoll, the average count for the area from the north to east reef - Amen I., Bikini I., Rokar I. - was two to three times the Likiep average; for the Target Area, about ten times the Likiep average; and for the remainder of the atoll, approximately the same as Likiep. For Eniwetok, the average algae count of samples collected in the vicinity of the blast areas was five hundred to six hundred times the average Likiep value, but for the rest of the atoll, the average values were equal to or less than the Likiep average. Of the various types of algae, the succulent forms were usually the most active. The 1949 value for the active areas was roughly one-half the 1948 average value for the same area.

TABLE 4

Activity of algae arranged as to phylogenetic sequence, 1949.

			d/m/g
I.	Schizophyta - Blue Green Algae		
	A.	Rivulariaceae	
		Calothrix	3366
	B.	Oscillatonaceae	
		Lyngbia	1668
II.	Chlorophyta - Green Algae		
	A.	Valoniaceae	
		1. Valonia	30
		2. Dictyosphaeria	18
		3. Microdictyon	19
	B.	Cladophoraceae	
		1. Cladophora	402
	C.	Bryopsidaceae	
		1. Bryopsis	1386
	D.	Caulerpaceae	
		1. Caulerpa	61
	E.	Codiaceae	
		1. Avrainvillea	0
		2. Udotea	192
		3. Halimeda	75
III.	Phaeophyta - Brown Algae		
	A.	Ectocarpaceae	
		1. Ectocarpus	1260
	B.	Asperococcaceae	
		1. Hydroclathrus	0
	C.	Dictyotaceae	
		1. Dictyota	1330
		2. Padina	114
		3. Pocockiella	0
	D.	Fucaceae	
		1. Turbinaria	24
IV.	Rhodophyta - Red Algae		
	A.	Helminthocladiaceae	
		1. Liagora	1
		2. Asperegopsis	0
	B.	Corallinaceae	
		1. Lithophyllum	7
		2. Lithothamnion	3
	C.	Rhodomelaceae	
		1. Polysiphonaceous Red Alga	1306
		2. Laurencia	0

University of Washington
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Seattle 5, Wash.

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Part 3. Evaluation of the Counts of Beta-Gamma Activity of Algae Samples.

In the preceding discussion of the beta-gamma activity of fish, the sections pertaining to collecting areas, date of collection, sample preparation, counting procedure, correction in counts and calculations are also applicable to the algae data.

Collecting Methods

Samples were gathered by hand in the vicinity of the fish collecting stations in waters five feet or less in depth.

Groups and Number Sampled

An effort was made to collect the same genus in all areas for comparative purposes. However, only two genera were collected at all of the six major reef collecting stations. Sixteen genera plus one general group were gathered from all stations and from these, 64 samples were prepared and counted for beta-gamma activity. The samples were weighed wet, that is, the sample was removed from a bucket of salt water, drained but not dried, then weighed. The samples were counted between September 24 and 26, 1948, but were corrected to the same counting date as the fish samples, August 9, 1948.

As with the fish samples, recounts were made of those samples with net counts of 0 to 4 and the data of the two counts averaged.

Analysis of Data

Activity was calculated as millimicrocuries per kilogram of wet tissue. The average activity for all groups of algae from one area was determined as well as the average activity from all areas for one group.

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Results

Expressed as millimicrocuries per kilogram of wet sample the average value of samples from the collections in areas adjacent to the bomb sites was 1004 and ranged from 0 to 5335 for individual samples. For samples from the other areas the average was 79. Individual samples ranged from 0 to 544. See Table IV and Figure 6. The highest counts were of samples of the genus *Bryocladia*. Values for other groups of algae are listed in Table IV. Since there are only a few samples for each alga, and there is wide variation within groups the relationship between amount of activity and kind of alga as shown in Table IV is of doubtful meaning.

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TABLE IV

Beta-Gamma Activity of Algae Samples by Area Expressed
as Millimicrocuries per Kilogram of Wet Sample

	near bomb site areas					7 to 14 miles from bomb site areas			
	Runit	Engebi	Biijiri	Bogon	Average	Rigili	Igurin	Japtan	Average
Bryocladia	5242				5242	316			316
Sphacelaria	4705				4705				
Blue green	2390	780, 3191			2120	182	8		95
Pocockiella	5335		401	523	2086			23	23
Rhipilia	1974		220		1097			70	70
Polysiphonia			845		845				
Dictyota		832			832				
Ulotea	1640		384	296	773	544, 480	202, 28	19	255
Caulerpa urvilliana (Mont.) Weber van Bosse	1253		168	107	509	62, 71	8		47
Microdictyon			508		508				
Ectocarpus				215	215		125		125
Dictyosphaeria	96		53, 274		141		22, 38	22, 23	26
Halimeda	194	0, 49	130, 152	32, 78	91	44, 115	6, 14	8, 0	31
Turbinaria				47	47				
Lithophyllum							40		40
Spyridia filamentosa (Wulfen) Harvey								38	38
Hydroclathrus								28	28
Caulerpa racemosa (Forssk.) J. Ag.	13				13	0, 1	0, 0	0	0
TOTAL	22842	4852	3135	1298	32127	1815	491	231	2537
n	10	5	10	7	32	10	12	10	32
Average	2284	970	314	185	1004	182	41	23	79

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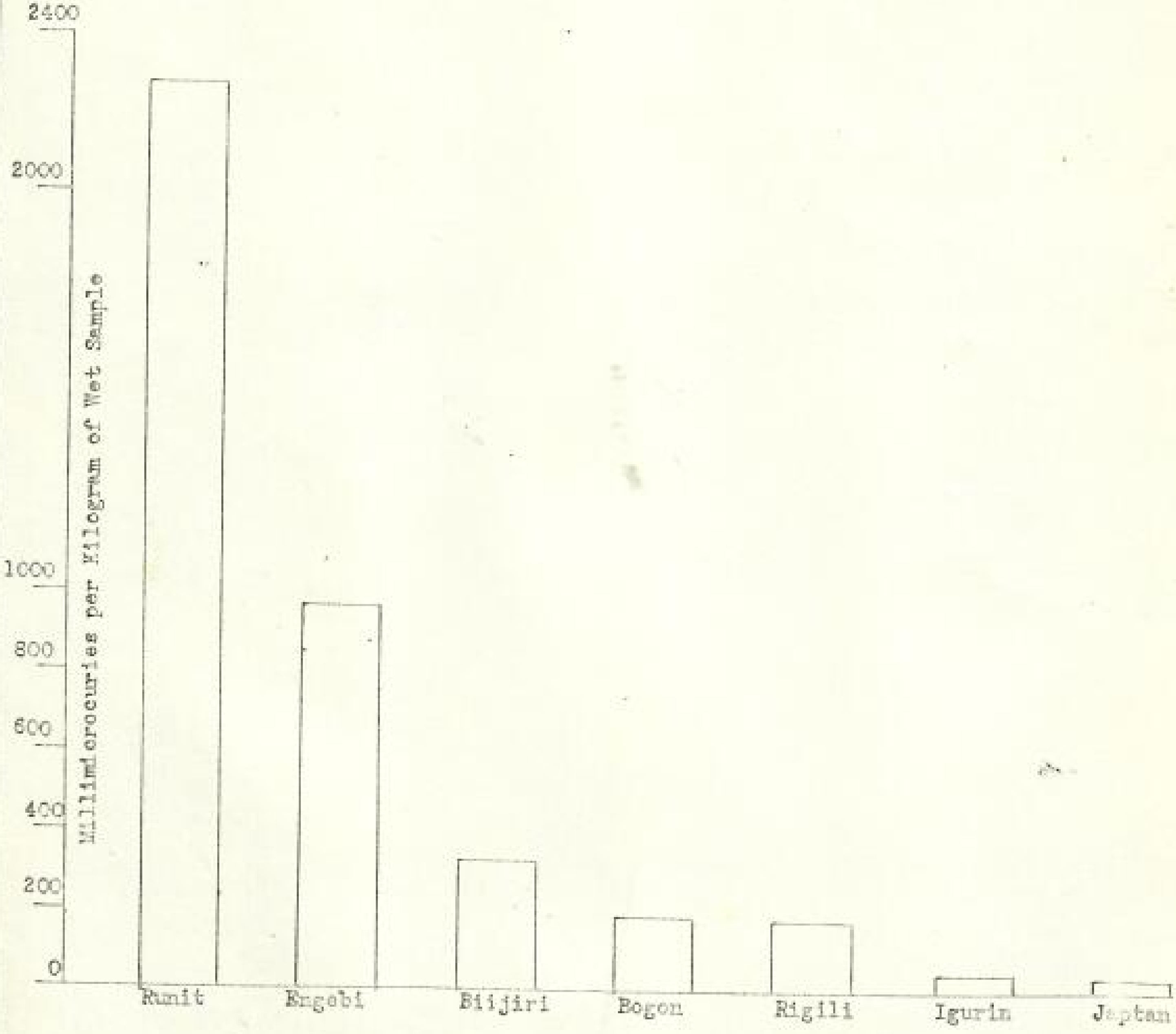
Figure 6.

Average Beta-Gamma Activity of Algae by Areas Expressed as Millimicrocuries per Kilogram of Wet Tissue.



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UNIVERSITY OF UTAH

INSTITUTE OF ENVIRONMENTAL BIOLOGICAL RESEARCH

ECOLOGY AND EPIZOOLOGY RESEARCH

A REVIEW OF THE

ECOLOGY OF ENIWETOK ATOLL, PACIFIC OCEAN

by

ANGUS M. WOODBURY, Ph. D.

This work was accomplished under U. S. Army Chemical Corps Dugway Proving Ground Contract No. DA-42-007-403-CML-427 with the University of Utah.

PHIL HELFRICH VIA
GEORGE BALAZS

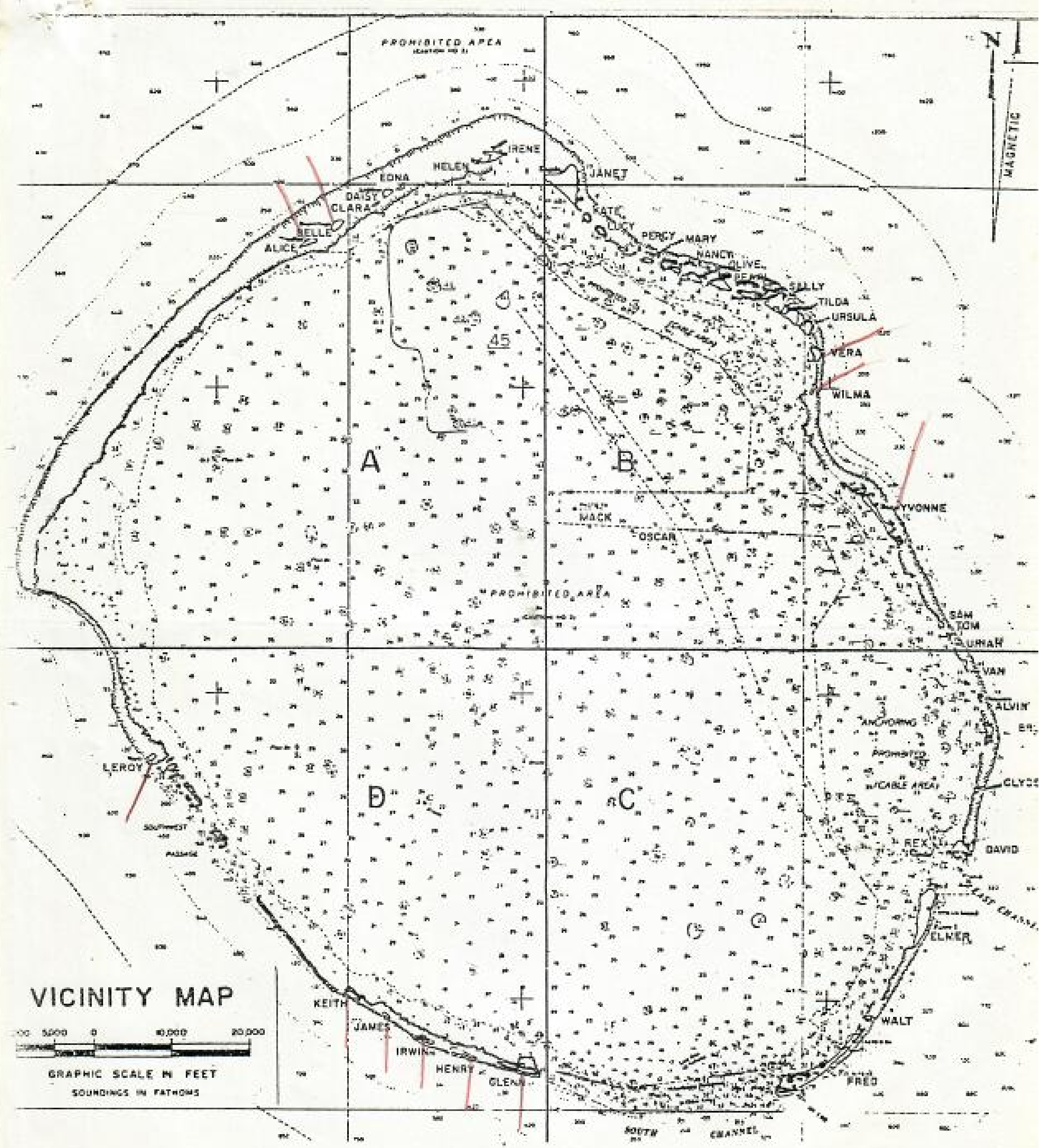
Report on the abundance of turtles and turtle nesting areas in the northern Marshall Islands

The following report resulted from an interview with Chief Johannes, the last remaining traditional chief of the Enewetak people, and the leader of the "Drei Enewetak", the people who normally inhabited the southern half of Enewetak Atoll. The interview took place on the 15th of March 1974 at Majuro, with other members of the Enewetak Council also present, and they occasionally submitted information or confirmed the information given by Chief Johannes. Under their system of protocol, however, an agreement with what Chief Johannes said might be more a matter of proper etiquette rather than an expression of what the other councilmen actually knew about the situation.

First, Chief Johannes indicated that turtles nested all around the island Ujilang. Ujilang is the island which has been occupied by the Enewetakese since 1947, and it is difficult to visualize that they did not decimate the nesting turtle populations, because Ujilang is such a small island. For further details on this, a reference is made to the Enewetak Radiological Survey in which Ken Marsh speaks of the eating habits of the Enewetakese. This document also gives population data of the Ujilang people.

Chief Johannes is a man of approximately sixty years of age, and lived on Enewetak Atoll until he departed in 1946. He claims that up to that time turtles nested from May through August on the following islands: Alice, Bell, Runit (Yvonne), Glen through Keith, Leroy, Wilma, and Vera (see attached map). He claimed that the best nesting areas were on Wilma and Vera. He also indicated that turtle nests were abundant on the island of "Vikai". I am not aware of where this island is located, but it seemed to be familiar to Chief Johannes.

I also quizzed him about the abundance of ciguatera on Enewetak. He indicated that fish were poisonous in the areas of Alice through David. These are essentially all of the islands in the northern and eastern side of the atoll down through the main pass. He claimed that the leeward islands were always O.K. Also, that the mullet used to be poisonous, but now they are O.K. I am not aware of how he has obtained this information, as he has only visited Enewetak briefly once or twice in the past two years. It may have been that he sampled the mullet during those two periods and they were not poisonous.


PROHIBITED AREA
N
MAGNETIC
IRENE
HELEN
EDNA
JANET
DAISY
CLARA
BELLE
ALICE
KATE
LUCY
PERCY
MARY
NANCY
OLIVE
PEARL
SALLY
TILDA
URSULA
VERA
WILMA
45
A
B
MACK
OSCAR
YVONNE
PROHIBITED AREA
SAM
TOM
URIAH
VAN
ALVIN
ANCHORING
PROHIBITED
CABLE AREA
LEROY
SOUTHWEST
PASSAGE
D
C
REX
DAVID
EAST CHANNEL
ELMER
WALT
KEITH
JAMES
IRWIN
HENRY
GLENN
FRED
SOUTH
CHANNEL
VICINITY MAP
5000
0
10,000
20,000
GRAPHIC SCALE IN FEET
SOUNDINGS IN FATHOMS

MARSHALL ISLANDS

MARINE TURTLES OF MICRONESIA

by Peter C. H. Pritchard, Ph.D.

Chelonia Press
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San Francisco, CA 94118

not only a better living for the fishermen of Ponape, but also provide for the general public a high protein food source, which is in great demand for consumption purposes;

NOW THEREFORE, BE IT RESOLVED by the Fourth Ponape District Legislature, Second Regular Session, 1976, that the Congress of Micronesia is hereby respectfully requested to amend Section 2 of Title 45 of the Trust Territory Code, relating to the limitations on taking turtles; and

BE IT FURTHER RESOLVED that certified copies of this resolution be transmitted to the Presiding Officers of the Congress of Micronesia, and to each Congressman and Senator of the Congress of Micronesia representing Ponape District.

I submitted a memorandum in response to this bill pointing our the great vulnerability of the turtle resource and the impossibility of it ever providing a significant economic benefit to the people of the islands if present regulations were liberalized. I also drew attention to its inaccurate statement of existing turtle regulations.

A second priority is to re-present Sablan's proposal that Oroluk be declared a turtle sanctuary. This would almost certainly require the removal of the people presently living on Oroluk. While this may appear to be a drastic proposal, the eighteen or so people there have only resided on the island since mid-1973, and they will probably move on when they have destroyed the turtle resource. Their presence is clearly inimical to the survival of the turtles, and they are presently sustained only by means of the highly subsidized Field Trip vessel supplying them with those necessities of life which the island cannot produce.

Having been declared a sanctuary, arrangements should be made for a tagging and research crew to encamp on Oroluk during the turtle nesting season. In this way the migrations could be elucidated, and the total nesting population evaluated.

MARSHALL ISLANDS DISTRICT

The Marshall Islands comprise a widespread District at the eastern end of Micronesia. With the exception of a few small small isolated reef islands, such as Jemo, the Marshalls are comprised exclusively of atolls, most of which are made up of a few to many dozens of islets. The atolls are roughly aligned along two parallel axes, the northeastern being the Ratak Chain and the southwestern the Ralik Chain. None of the islands reaches a height of more than a few feet above sea level, and the total land area of the District is only 69.84 square miles. The human population, numbering 20,206 in 1970, is widely distributed, but only the atolls of Majuro, Kwajalein and Ailinglapalap have more than a thousand people. Bryan (1971) lists Taongi, Bikar, Taka, Jemo and Erikub as the only atolls or islands that have never had human populations, while the people of Bikini and Enewetak were displaced after World War II when these islands were used for atomic weapons testing. Rongerik is listed by Bryan as having 6 people in 1935 and 1948, but as being uninhabited in 1970; this island was used temporarily by the displaced people of Bikini, but proved unsatisfactory. The Marshall Islands are well described by Anon (1965), while excellent maps and directories to names of islands are provided by Bryan (1971). Anon (1957) provided the following historical information on the use of turtles in the Marshall Islands:

A. Methods of Capture or Killing

The northern Radak atolls of Bikar, Bokak (Taongi), Toke, the island of Jemo and the islands of Lrik and Luij in Erikub Atoll have been used from time immemorial as game reserves by the Marshall Islanders. Periodically, turtles and their eggs were harvested there. The traditional practices of harvesting these animals and their eggs usually took place on special islands with the chief opening the season. Stylized and elaborate rituals were connected with these first food gathering expeditions of the year which occurred in the summer. This gathering was apparently done at the time when the turtles were ashore laying eggs. Both the eggs and the turtles would be taken at this time. Though turtles and their eggs are still taken the ceremonialism formerly connected with this activity is no longer practiced.

The ability of the Marshallese to capture turtles at sea depends to a great extent on the fact that the habits of turtles, an important source of protein to the atoll dwellers and highly prized by them, are well known, having been observed by them for centuries. Certain of the Marshallese know more than the others about these reptiles and their opinion and guidance as sought and respected.

B. Local Custom Regarding Capture of Turtles and Use of the Meat

As has been previously noted, expeditions were assembled to go to some of the islands known to be heavily populated by turtles. Upon arriving at the island the chief and all of the members of the expedition went ashore. The chief had to lead the first trip of the year and he was the first person to step ashore.

Before the party commenced their search for eggs, supernatural sanctions were requested. Everyone assembled on the beach, before proceeding in and cut a leaf of coconut frond. With the chief leading the way they walked in single file, each carefully stepping in the footprints of the person in front of his so that only one set of footprints would appear, as if only one person had been there.

The women were required to hold mats over their heads while on the island so that they could only see the ground well enough to gather the eggs and other items. Strict silence

was observed. Often medicine was made by the chief from the leaves of a small rare plant *(marutto)*. The leaves were pounded and the juice extracted and drunk by all to prevent anal bleeding and diarrhea which might result from the unaccustomed meal of turtle and birds' eggs. After the eggs were gathered the group assembled at a specified place before consuming any eggs. Four eggs were thrown in each of the four cardinal directions by the chief as an offering. These "sacrificial" eggs were then re-gathered and eaten by the leader of the party and the remaining eggs were then divided up and eaten by the others.

Turtle flesh was distributed according to a specified, traditional pattern but this custom is not followed today.

Only Kwajalein and Majuro were visited during the present survey. However, much useful information on turtles elsewhere in the Marshalls was provided by Ben Sablan on Ponape, who was formerly resident in the Marshalls; by Major Ron Barnett and Rev. Elden Buck on Kwajalein; Jim Hiyane, the Agricultural Officer on Ponape; George Balazs in Hawaii; and Jobel Emos, a janitor at the Kwajalein Missle Range. Valable information was also obtained from the writings of Anon (1957), Hendrickson (ms.),Fosberg (1969), Helfich (ms.), and Hiatt (1951).

BIKAR ATOLL

The atoll of Bikar, one of the northernmost of the Marshalls, is generally thought to have the highest concentration of beeeding green turtles in the District. The atoll is composed of several islets, the named ones being Jabwelo and Almani on the east, Bikar on the south, and the sandbank of Jáboero between Bikar and Almani. Bikar is the largest with an area of 0.063 square miles.

Anon (1956) said of Bikar: "Sea birds of many kinds are abundant, but the outstanding feature is the great number of turtles that come ashore to lay eggs on Bikar Islet." Fosberg (1969) recounted his experiences with the turtles of Bikar as follows:

> Bikar Islet, the largest of the three, is of sand, except for areas in the interior where this has been cemented into phosphate rock. On the western and southern coasts are sand flats with rather open vegetation much frequented by turtles as nesting sites. An outstanding feature of these parts, especially on the south coast, is the way the sand has been churned up by turtles digging holes in it. On the afternoon of August 6th I counted 596 tracks. That night 6 more turtles came ashore, of which 3 were seen by the party. One was measured, being 70 cm. across and 135 cm. long. She was strong enough to move on land with a small man sitting on its back. When caught she shed tears. When released she headed back to sea, climbing over very rough pitted rock remnants with some difficulty, but successfully. A few turtles came ashore on each of the following five nights, on August 10 about 15. On August 11 three were seen, but probably more came ashore. One night one blundered through our camp, creating much havoc. One that was spotted coming out of the water was frightened by the light and turned back. Two more turtles were measured, one being 80 cm. wide and 122.5 long, the other 70 cm. wide and 115 cm. long. Colors and patterns on shells were most varied.
>
> I watched one come ashore at 8:10 PM, August 11, before the moon rose. She walked about 50 m. inland, poked her front end into a large *Scaveola* bush, stopped and began to scratch with her hind feet, gradually excavating a hole less than 30 cm. across and as deep as the short hind flippers could reach, using a peculiar back-hand scooping motion with alternate feet, each time, while digging with the one foot, flipping away the sand that was brought up by the other foot previously. This appeared to be a very inefficient method of digging. When the hole was finished the rear

end of the turtle projected over the hole and the tail pointed downward. Eggs were expelled 1-2 or even 3-4 at a time, dropping into the hole. This turtle laid 92 eggs, taking 11 minutes for the actual laying process. Then she filled the hole very carefully with sand, which she patted and pressed down in a mound over the eggs. Gradually she spread this mound out and covered it with dead leaves, then dug a pit to one side and threw dirt over the hole where the eggs were laid, making a low broad mound over it, so that one would scarcely guess where the eggs were laid.The whole process took over three hours.

Newly laid eggs were seen from 3 different individuals, varying somewhat in size from turtle to turtle. In the clutch of 92 mentioned above was one tiny egg, the size of a marble.

The sand flats outside of and especially in the open *Tournefortia* belt around the *Pisonia* forest that covers most of the islet, were thickly spotted with the shallow pits, 60 cm. to 1 m. across, each with a low mound at one side. Two of these mounds were observed to have small holes in them, with numbers of small flies buzzing about them, and, in one case, hermit crabs in the holes. These holes may have been made by the hermit crabs, but were more probably made by young turtles emerging. One hole had a broken shell in it.

On the night of August 6 a few baby black turtles were seen hurrying toward the sea. They were being attacked by large red hermit crabs *(Coenobita perlata)* and by rats *(Rattus exulans)*. The hermit crabs bit through the carapace, the rats through the plastron. On August 10 and 11, at about 8 PM, batches of young turtles hatched out and came running through camp, on their way to the sea. They followed lights.

Almost all of the female turtles that visited Bikar Atoll, well over 300 in the 7 nights, August 5-12, came ashore on Bikar Islet. One set of tracks and a pit were noted on Jaboero Islet, a few on the south part of Almeni Islet, but none on Jaliklik Islet, which is rocky and has no loose sand.

The location of the hole containing the eggs beside the pit excavated by the turtle is in marked contrast with the situation in Malaya and Sarawak, reported by Hendrickson (Personal communication), where the hole with the eggs is some distance from the pit.

In 1958 Bikar Atoll and Pokak (Taongi) Atoll, which lies to the north of it, were set aside as preserved natural areas by administrative decree by the then DistrictAdministrator, Mr. Maynard Neas. It is hoped that this protection may be strengthened, as clearly Bikar is the principle turtle nesting area in the Marshalls and should be kept as a stocking area for the rest of the archipelago..

Judging by the numbers given in the earlier part of this quote, it is possible that the "over 300" turtles is a misprint for "over 30."

From the large numbers of tracks seen, the relatively light nesting observed and the observations on hatchlings, it appears that the season on Bikar reaches its peak probably around June and July.

Hendrickson (ms.) was able to visit Bikar on July 2-3 1971 and made the following observations:

> The consultant visited Bikar Atoll and all three of its islets judged suitable for green turtle nesting (Bikar, Arumeni and Jaboerukku). These are the only vegetated islets in the atoll, the remainder being barren bars and banks which are presumably swept by high wave action. The timing of the visit was particularly favorable, being at the end of a seven-day period of diminishing tides during calm weather. This left a series of high tide marks on the clear areas of beach where rocks had not confused the wave wash pattern and, for the most part, it was possible to identify the night on which recent beach ascents had been made by nesting turtles, by noting the particular high tide mark where the track ceased to be evident. It was possible to say with some confidence that 39 turtles had ascended the beaches during the preceding six days (78 tracks, half ascending, half descending). Thirty-five of the 39 turtles had used the beach on Bikar Islet, one had ascended Arumeni and two had ascended Jaboerukku. One of the 35 tracks on Bikar was a hawksbill track (not ridley); all others were presumed made by green turtles (loggerheads have not been reported from the area).

Hendrickson made some calculations of the possible size of the nesting population on Bikar, concluding that the order of magnitude of the population was 711 sexually active adult female turtles in the Bikar breeding population. From these figures, he reasoned that *"even the most favorable interpretation of the data available (granting the assumptions made) allows consideration of a population of only small size, not constituting an exploitable wild resource of any significant magnitude."*

JEMO ISLAND

Jemo is an isolated, tiny island situated at 10° 8' N, 169° 32'E, located between the atolls of Ailuk and Likiep. The land area of Jemo is only 0.06 square miles. The turtles on Jemo were described as follows by Anon (1956):

> Many turtles visit Jemo to lay their eggs. Jemo was formerly tabu for most of the year, being regarded as a bird and turtle reservation. Only during one month in the year were these animals hunted and their eggs taken.

Fosberg (1969) visited Jemo from December 18 to 22, 1951 and observed tracks corresponding to the nesting of 22 turtles during the past several days. A nesting turtle observed by Fosberg measured 75 cm across and 120 cm long (presumably total length).

The Rev. Elden Buck of Kwajalein informed me that a boat from Likiep sometimes brings ten to fifteen turtles for sale on Ebeye. These turtles were presumably caught on Jemo, which is the closest turtle island to Likiep. Likiep itself has few turtles, according to Ben Sablan on Ponape. Further confirmation of the presence of nesting turtles on Jemo was provided by several informants during my survey.

ARNO ATOLL

Green turtles nest occasionally on the sandy beaches of Arno Atoll but they are scarce and of no commercial importance (Hiatt 1951). Ben Sablan reported that nesting on Arno takes place on the islet of Ine, in the south and southwest.

ERIKUB ATOLL

Erikub is an uninhabited atoll composed of 16 islets lying just south of the inhabited atoll of Wotje. Jim Hiyane, the Agricultural Officer on Ponape, informed me that he had seen turtles nesting on Erikub, and estimated that 6 or 8 turtles nested nightly. He mentioned that people from Wotje go to Erikub for copra, coconut, crabs, etc., and often picked up turtles when there, but did not go specifically for turtles.

Jobel Emos on Kwajalein confirmed that turtles nested on Erikub, and pinpointed the northwestern islets of Enego and Loj as being the most favored for nesting. Emos claimed that nesting on Erikub was year-round, but that the turtles were usually exploited during the summer months because of the prevailing calm water at that season. He said that the Wotje people, when they caught a female turtle on Erikub, would tether it in shallow water so that it would attract males, which were captured as they mounted her. Emos' estimate was that 3 or 4 turtles nest nightly on Erikub.

On Kwajalein, the Rev. Buck showed me a photograph

of a boatload of over twenty turtles that had been brought in from Erikub and Bikar for sale on Ebeye, the islet where the Marshallese workers on the Kwajalein Missle Range reside.

TAKA ATOLL

Taka is an uninhabited atoll lying very close to, and southwest of, the inhabited atoll of Utirik. It has five islets, the largest of which is Taka itself (0.0996 square miles). According to the Rev. Buck, people from Utirik collect turtles and turtle eggs on Taka, but further details are not available.

EBON ATOLL

Ebon is the southernmost of the Marshall Islands. It is a roughly circular atoll composed of 22 islets, by far the largest of which is Ebon itself, an elongate island that makes up the southern side of the atoll; it is about six miles long and has an area of 1.083 square miles. Bryan (1971) lists the 1970 population of Ebon as 480--substantially reduced from the 1935 and 1948 censuses. Ebon has a reputation for abundance for foods of all kinds, and although no definite information on turtle nesting was available, it is considered to be the best area for catching turtles in the water. The turtles are nearly all of adult size and are caught with nets. Two to four can be caught per night. An interesting observation passed on to me by the Rev. Buck was that, if a turtle on Ebon is captured in a certain place, the next night it is often found that another turtle has moved to the same spot.

KWAJALEIN ATOLL

Kwajalein is the largest atoll in the Marshalls, and reputedly the largest in the world. 93 islets are listed by Bryan (1971). The atoll is of irregular, meandering shape, generally elongate in form with the eastern end bent sharply downwards and the northern part formed into a point. The islets of Kwajalein (at the soutern tip) and Roi and Namur (now connected by a runway and called Roi-Namur) are devoted exclusively to U.S. military uses. The Marshallese residents live on Ebeye, a small and highly overcrowded islet a short distance north of Kwajalein, on the eastern edge of the atoll. Most of the other islets are very small, and in some parts the bounding reef is without islets for distances of ten or fifteen miles.

Major Ron Barnett on Kwajalein gave me considerable information on turtle observations on Kwajalein. Turtles are often seen around Kwajalein Islet, and between Kwajalein and Ebeye. A few turtles appear to be extraordinarily static in range; a certain green turtle is reported to have resided at a certain coral head (known as K5) off the lagoon shore of Kwajalein for 2 to 3 years, and is very familiar to skin divers. Green turtles are also seen on the ocean side of Kwajalein at the end of the runway, where they scavenge for the kitchen scraps that are thrown in each day. Major Barnett described how turtles are caught by children on the island off the ocean side of Kwajalein: A fishing line is equipped with a hook baited with bread and a children's balloon; the trade wind carries the balloon to the edge of the reef, where turtles often take the bait. Most turtles break the line or otherwise escape, but an estimated 25 turtles per year are caught in this fashion. They are usually of less than mature size. One turtle that I saw feeding on the kitchen scraps of Kwajalein, however, appeared to be of adult size.

Turtles are maintained in captivity in two pools on Kwajalein; one pool contained two yearling green turtles, while the other contained about ten half-grown greens and one nearly mature hawksbill, reportedly from Ebon.

No records are available for turtle nesting on Kwajalein, and indeed there is a shortage of good beaches. However, much of the atoll is poorly studied, and a Marshallese informant on Kwajalein informed me that turtles do nest sometimes on the islands at the northwestern end of the atoll (the islets from Keko to Boggerik, known to the Americans as

Hemel, Hamilton, Hampton, Harden, Harland, Harley, Harvey, Henry, Herald, Herlet, Herman, Herschel, Hollis and Homer).

Major Barnett, in a letter dated July 16, 1976, reported than on July 10 a green turtle was found nesting on the oceanside of Bigej Island, about 12 miles north of Kwajalein Islet. About 150 eggs were collected and eaten by the boy scouts who found the turtle.

UJELANG ATOLL

Ujelang, or Ujilang, is an elongate atoll about thirteen miles long located at the western extreme of the Marshalls, being closer to Ponape than to the population centers of the Marshalls. It had a small native population of about 40 people (plus 12 non-natives) in 1935. It was uninhabited in 1948 according to Bryan, but this is presumably in error, since Helfich (ms.) reports that the Enewetakese people displaced by atomic tests were settled on Ujelang in 1947. The 1970 population, according to Bryan (1971) was 281.

Ujelang is listed by Carr (1965) as a 'minor nesting beach' for the green turtle. The source of this information was not quoted, but Carr informs me that he based this record on an observation made by the crew of a U.S. Naval vessel anchored off Ujelang one night in 1962. Baby green turtles were attracted to the lights of the ship in very large numbers--- though at this point it is not possible to ascertain whether the numbers represented only one or two successful nests, or whether there were numerous nests erupting simultaneously. Two of these hatchlings were transmitted alive to Dr. Carr. Phil Helfich, in a brief manuscript report communicated to me through the courtesy of George Balazs, reports on an interview with Chief Johannes, chief of the exiled Enewetakese people on Ujelang. In this report, Helfich stated: "Chief Johannes indicated that turtles nested all around the island Ujilang. Ujilang is the island which has been occupied by the Enewetakese since 1947, and it is difficult to visualize that they did not decimate the nesting turtle populations, because Ujelang is such a small island."

None of the informants on my survey had any information about turtles on Ujelang. The island is extremely remote and is not often visited. This would appear to be a priority for future studies.

ENEWETAK ATOLL

Enewetak is a rather large, almost circular atoll in the western Marshalls. Accordingto Bryan (1971), it is composed of 44 islets, has a land area of 2.26 square miles and had 128 people in 1948, but none in 1970. However, Anon (1972) wrote that there are now 100 people, mostly civilians, living on Enewetak. Anon (1975) gives 1947 as the year in which the 136 Enewetakese residents were transfered to Ujelang; the island was used for nuclear tests between 1948 and 1958. Since 1954, the University of Hawaii has operated the Mid-Pacific Marine Laboratory on Medren Island, Enewetak, which is financed almost completely by the U.S. Energy Research and Development Administration.

Helfich (ms.) quotes Chief Johannes of Enewetak, who lived on the atoll until 1946, as reporting turtle nesting (up to 1946) taking place from May through August on the islets of Alice, Bell, Runit (Yvonne), Glen through Keith, Leroy, Wilma, and Vera. The last two islands had the best nesting areas. Another islet by the name of "Vikai" was reported by Johannes to have abundant nesting turtles, but no island of this name is shown on available maps of Enewetak.

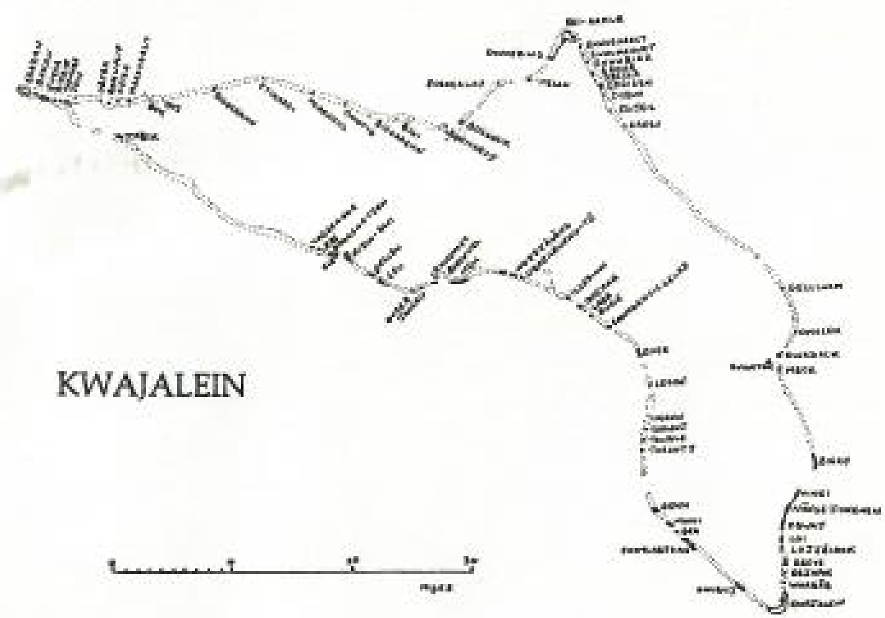
At the present time, there appears to be little turtle nesting on Enewetak. However, George Balazs has prepared reporting sheets for observations of turtles by scientists at the Mid-Pacific Marine Laboratory and others, and valuable information may eventually be forthcoming from this program.

MAJURO ATOLL

Majuro, the District Headquarters, is an elongate atoll approximately twenty miles long. The southern

rim of Majuro was originally composed of a single extremely attenuated island, Majuro, and a series of much smaller islands to the west. However, these islands have now been connected in order to provide vehicular access between the principal town (known as D-V-D, from its constituent and now coalesced islets of Carrit, Uliga and Dalap) and the airport; and the blockage of the former passages between islets, with no provision for bridges or culverts, has led to substantial pollution problems in the Majuro lagoon.

Turtle nesting has not been reported on Majuro, although turtles are spotted in the waters of Majuro relatively frequently. Ben Sablan informed me that large turtles are seen resting near the Windward Islands of Majuro, and on an afternoon dive one summer he had seen more than fifteen turtles, all females.



JALUIT

Jaluit is a large, irregularly shaped atoll, about thirty miles long from north to south. It is composed of 91 islets. Bryan (1971) gives the 1970 population as 881, substantially reduced from former years. Ben Sablan informed me that turtles nest in small numbers on Lijeron Islet, near the northern end on the west side of the atoll.

AUR, MALOELAP AND LIKIEP ATOLLS

Ben Sablan reports that turtles may be found on each of these atolls but that in no case were they plentiful.

BIKINI AND TAONGI ATOLLS

Although my informants did not mention these atolls, both were recorded by Hendrickson (ms) as being second in importance only to Bikar among the Marshall Island turtle nesting atolls. Hendrickson obtained his information about Bikini from Mr. Robert Ward, a heavy equipment maintenance supervisor for the Bikini Atoll Rehabilitation Project. Additionally, the popular movie *Mondo Cane* made several years ago showed rather large numbers of dead green turtles on Bikini, though the interpretation made that these had been disoriented by radiation damage and had wandered into the interior of the island to die is somewhat questionable. I have seen dozens of dead green turtles inland from the nesting beach on Baltra Island, Galapagos. This island appears to lack the normal sea-finding (or land-fleeing) cues that enable a turtle to identify the proper heading for the ocean.

RECOMMENDATIONS - MARSHALL ISLANDS

It is no coincidence that the turtles' nesting islands in the Marshall Islands at the present time are not only uninhabited by man, but they are also in nearly all cases parts of totally uninhabited atoll systems. In islands as small as the Marshalls, man has to look for food from the sea; and turtle provides a welcome change of diet from fish. It is likely that even on the uninhabited islands the turtles have only been saved from extermination by man by taboos and

primitive management and closed season customs, now fast dying. I concur with Hendrickson that the green turtles of the Marshall Islands do not at the present time constitute a renewable resource of any significant magnitude.

The present recommendation, therefore, is to urge the strictest possible enforcement of both U.S. Endangered Species Law and the Trust Territory Code as they relate to sea turtles. This would provide protection for the now very rare hawksbill turtle, and would also protect undersized and nesting green turtles. It has been suggested by some turtle biologists that if some human use of a turtle resource is unavoidable, then it should be aimed at the young turtles rather than the grown ones; however, to inject such thinking into the Trust Territory Code at the present time would create far more confusion that is justified.

The second necessity is to conduct tagging and beach patrols on the islands reputed to have good or even surviving nesting populations of green turtles. In this way, a turtle population estimate for the District could by made, turtle migrations could be monitored, and figures could be obtained on the number of turtles illegally removed from the nesting beaches each season. In contrast to the Yap District, there is no evidence that turtle capture in the Marshall Islands is a culturally important activity, and now that motorized vessels and modern navigation equipment is available, remoteness no longer serves as adequate protection for a turtle beach. There is no justification therefore for "cultural variances" from either Federal or TT law in the Marshall Islands District.

SUMMARY

Sea turtles have probably been declining slowly in numbers in Micronesia for several centuries, but this supposition is not based on historical fact. Rather it is based on the observation that turtles no longer nest on all but a very few of the inhabited islands, and the present scattered nesting colonies on isolated uninhabited islands are probably only a remnant of a once great sea turtle population. The fact that the decline has continued to the present day is evident to those, both native and expatriate, who have been close observers of the productivity of the territory for many years. This trend will result in extirpation unless steps are taken to reverse it soon, though it is not possible to predict whether it will be a decade or a century before the extirpation becomes complete.

Different conservation measures have been proposed for each of the Districts of Micronesia in this report; the intention has been to tailor recommendations to the biological, geographic, and sociological peculiarities of each District. However, certain recommendations have Territory-wide application. These are as follows:

1) Little alteration is required in existing law, but a great deal of alteration is needed in law enforcement. Upgrading law enforcement to a satisfactory level will inevitably be difficult, since the Territory is exceedingly far-flung, has always been and is being run on a shoe-string budget, and better protection of sea turtles is bound to be looked upon as an undesirable limitation on free enterprise among those who aspire to contribute to the food productivity of the Territory rather than follow the easy path and feed at the Government trough. Nevertheless, in my opinion, these restrictions are necessary if the turtle resource is ever to be of significant benefit to the people of the islands on a sustained, permanent basis.

The hawksbill shell souvenir trade is widespread and extremely harmful in Micronesia. U.S. Law forbids the capture or molestation of hawksbill turtles, and it is necessary that steps be taken in a direction leading to ultimate rigid enforcement of this law. The U.S. is currently properly sensitive about the propriety of enforcing endangered species laws in subsistence economies on the far side of the globe; but both the responsibility and the necessity

of enforcement must be faced.

2) Some of the conservation measures proposed in this report are mild and will meet little opposition; others, such as the recommended evacuation of the human inhabitants of the islands of Oroluk and Merir will seem heavy handed and dictatorial. Nevertheless, both of these islands have only been inhabited for a year or two and in both cases the total population is less than twenty individuals. Their presence on these islands poses a threat to the sea turtle breeding populations that may well be recruited from feeding grounds hundreds of miles away. Financial compensation should accompany compulsory return of these people to their islands of origin, and this evacuation should proceed before they either become too "settled" or wipe out the turtle populations that nest on the islands.

3) Most of the turtle beaches mentioned in this report have not been visited by a trained biologist, and present estimates of the numbers of turtles using these beaches may well prove inaccurate. It is therefore highly desirable that individuals be located who possess both the scientific knowledge to conduct a thorough survey and the self-sufficiency and toughness that will enable them to survive and operate on some of the most remote islands in the world for periods of weeks or months. Such persons should tag turtles and evaluate both natural and human predation upon the turtles and their eggs. I also thoroughly agree with the recommendation of Hendrickson (ms.) that, from the beginning of a territory-wide tagging project, promising young men (and women) should be selected as scientific trainees, chosen as far as possible in terms of residence near the turtle areas.

4) Turtle farming should *NOT* be recommended at this stage, either as a private or a government project. Capital in the Territory is too scarce to risk in unproven ventures of this sort and the only efforts at turtle farming to date (in Grand Cayman and Northern Australia) have both failed to demonstrate that the process could ever be economic. A captive

turtle simply has to be fed with too much high-protein food and grows too slowly to make captive culture for food purposes a paying proposition. Moreover, with any but the most expensive set-ups, turtles are liable to be washed away during typhoons. In short, the process is extraordinarily energy intensive, and is a poor and unproven way of investing scarce funds. Moreover, turtle farming in the Territory would perpetuate the taste for turtle meat, which is already too popular, and which may only fall from favor if it can be totally withdrawn from the native diet. Native families living on small islands with few advantages of civilization would be much better advised to raise chickens, that grow quickly to a size which confortably provides a meal without the problems of storing surplus meat for later times. Slaughter of a 100 pound turtle, on the other hand, requires either that the owner share with or sell to a rather large number of others when the animal is slaughtered or else that he own a refrigerator or laboriously dry the meat for later consumption.

5) Hatchery programs are justified in those situations where a relatively large proportion of the nests are subject to human or non-human destruction, and in certain areas, such as the Palau Lagoon, this approach is recommended. However, care should be taken to avoid using a hatchery to salve one's conscience while exploiting the adult turtles; experience in many areas has shown that augmenting the survivorship of nests does not offset heavy predation on the turtles themselves.

Many elaborate schemes for turtle conservation have been proposed at one time or another, but in the majority of cases the central issue has not been faced: to save a declining turtle population from extinction, it will be necessary to kill fewer turtles, and in many cases to kill no turtles at all. There is also a dangerous belief that turtle populations cannot be destroyed if the nesting grounds are protected. An adult female turtle on the feeding ground or in migration is just as important a member of the population as a turtle on the nesting beach; it is simply more difficult to catch.

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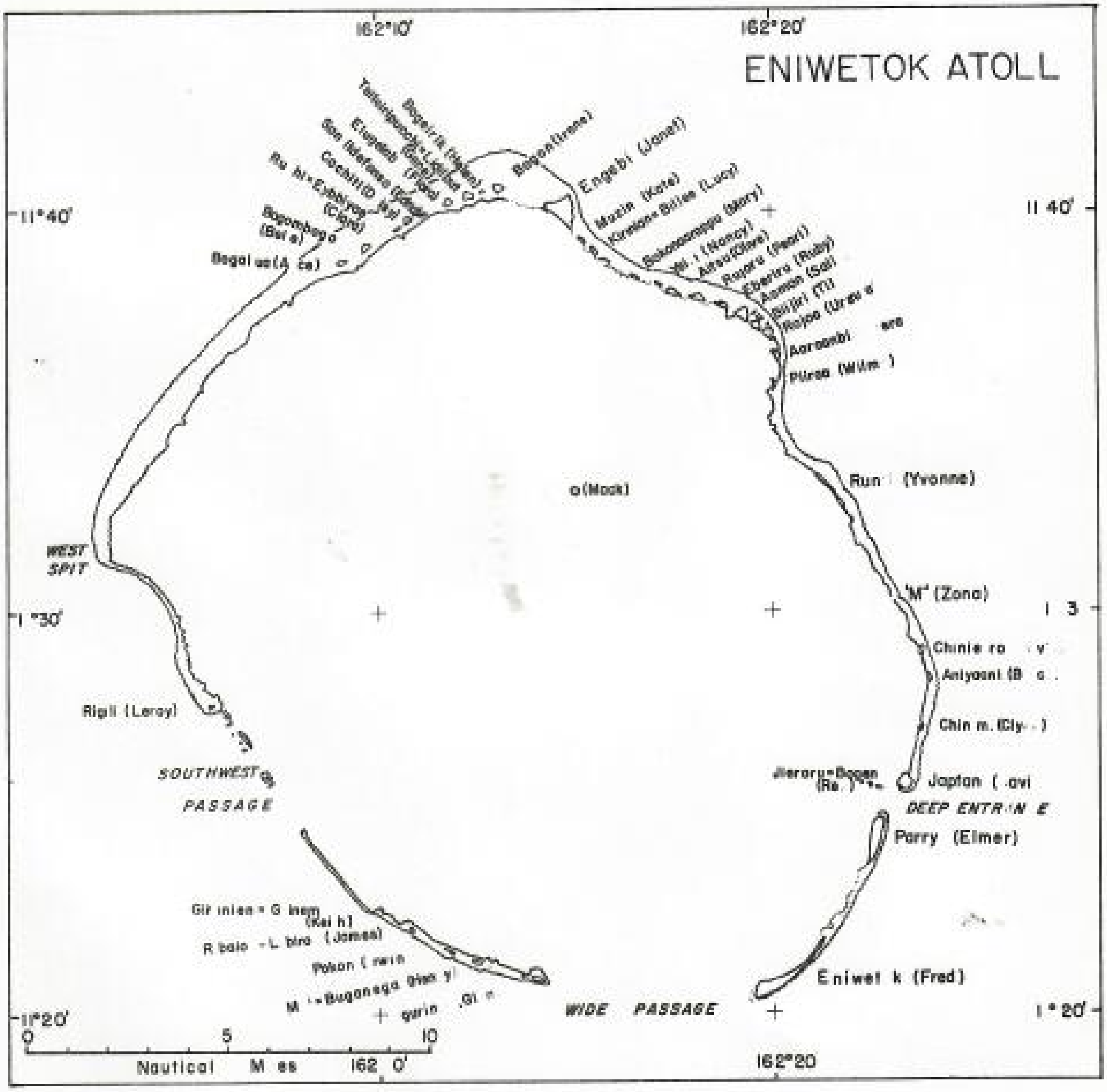

Fig. 6. Map of Eniwetok Atoll.

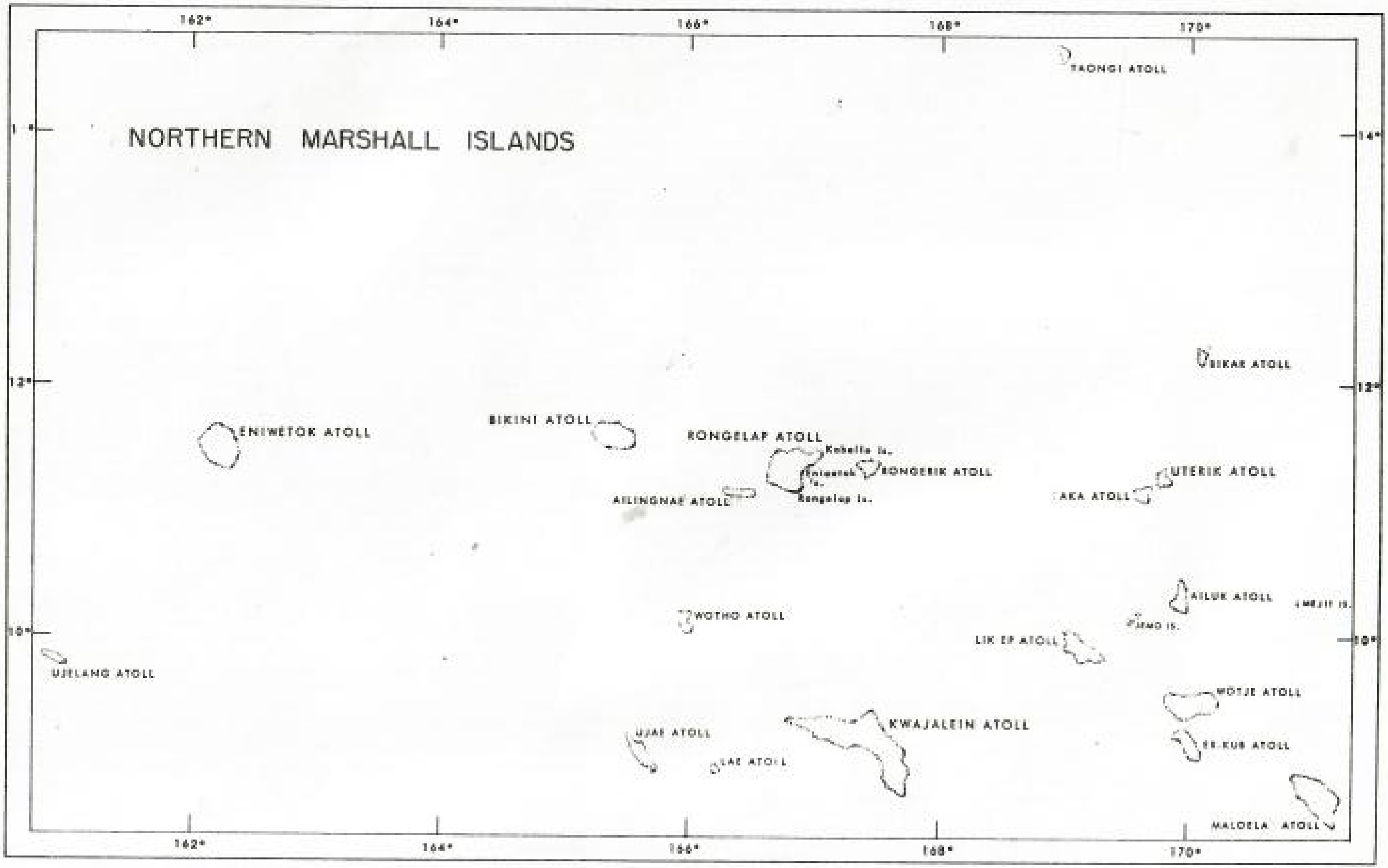

Fig. 5. Map of Northern Marshall Islands.

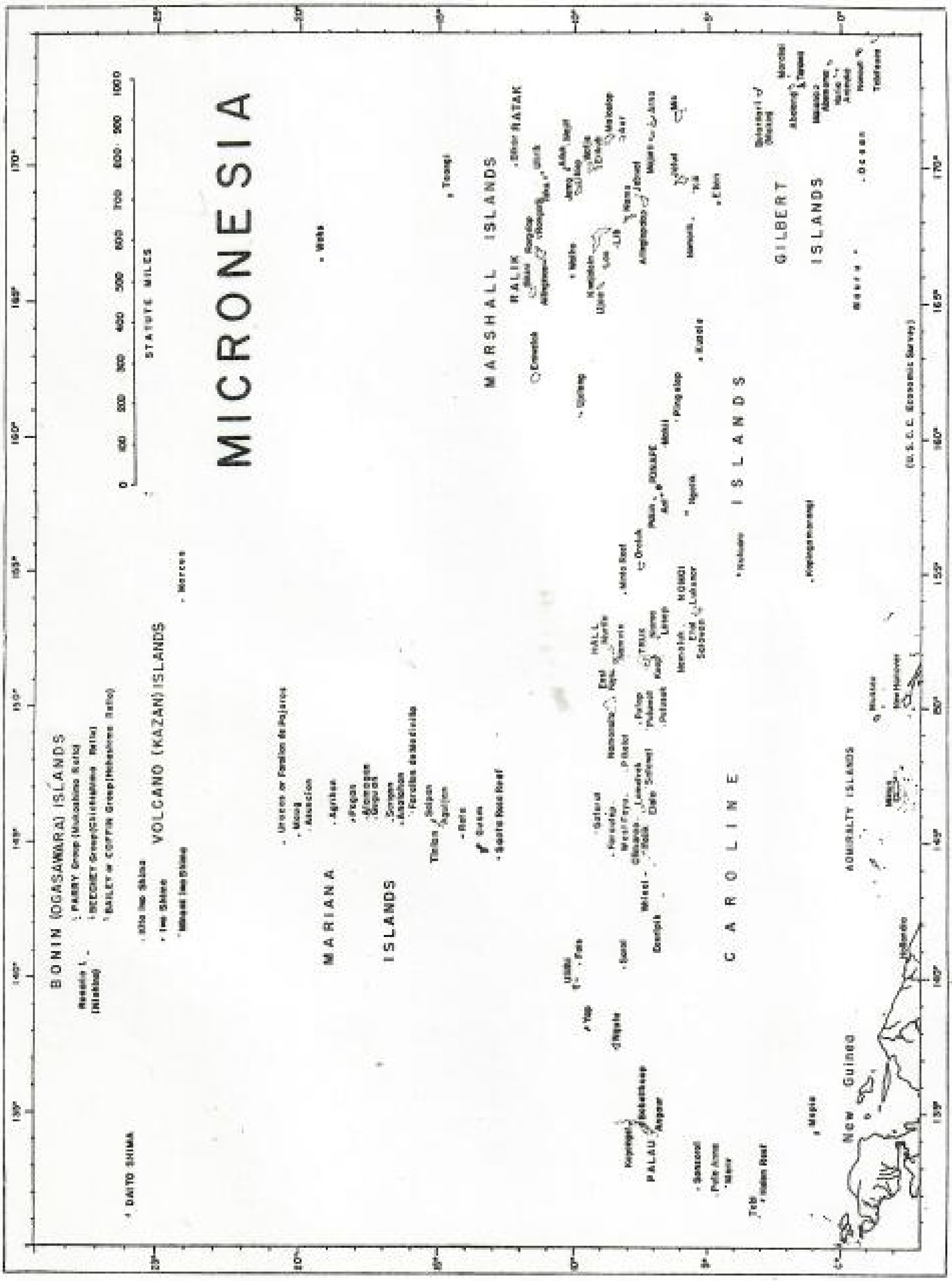

Fig. 3. Map of Micronesia.

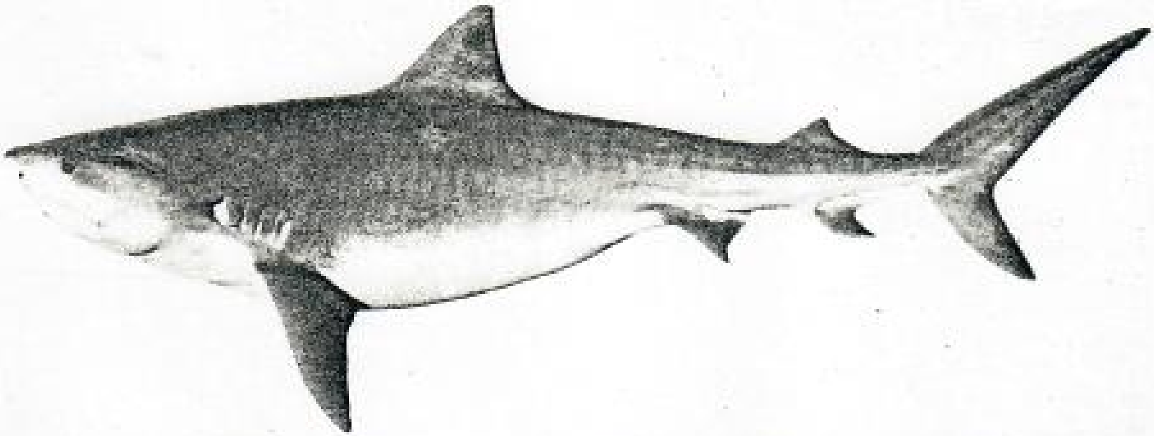

FIGURE 6.—*Galeocerdo cuvier*, 2,410 mm PCL, 3,055 mm TL, 175 kg, Enewetak, Marshall Islands.

The stomachs of the other two sharks were empty. Three other tiger sharks from Enewetak had food in their stomachs. One of 3,150 mm TL contained shark vertebrae. The second of 3,581 mm TL had the scutes of a green turtle and bird feathers. The third, 3,048 mm TL, was filled with pieces of a porpoise and the digested remains of shark fins.

A tiger shark of 3,327 mm TL from Ua Huka, Marquesas Islands, was empty, as was one of 2,895 mm TL from Oahu. Another from Oahu of 3,048 mm had an extremly distended stomach filled with heads of skipjack tuna (neatly cut by a knife, hence probably discarded from a fishing boat), plastic bags of garbage and aluminum foil, a cat, and two small reef fishes (one a balistid). It also contained the bait (the head of a calf). A 3,100 mm specimem weighing 174.6 kg taken by a set line at night at Rapa had eaten parts of a tiger shark larger than itself (probably from an individual caught on another hook), as well as a seabird.

Triaenodon obesus (Rüppell) (Figure 7): The whitetip reef shark, once classified by most ichthyologists in the family Triakidae, is now recorded as a carcharhinid (Compagno 1973). In spite of its scientific name, it is rather slender compared with most species of the family. Apart from its slim form and white-tipped first dorsal fin and upper caudal lobe, *T. obesus* is distinctive in its very blunt snout and teeth which bear a small cusp on each side of the main central one. It is widespread throughout the tropical and subtropical Indo-West Pacific region and ranges to the eastern Pacific as well. Banner and Helfrich (1964) and Brock et al. (1965) have reported this species as poisonous from Johnston Island.

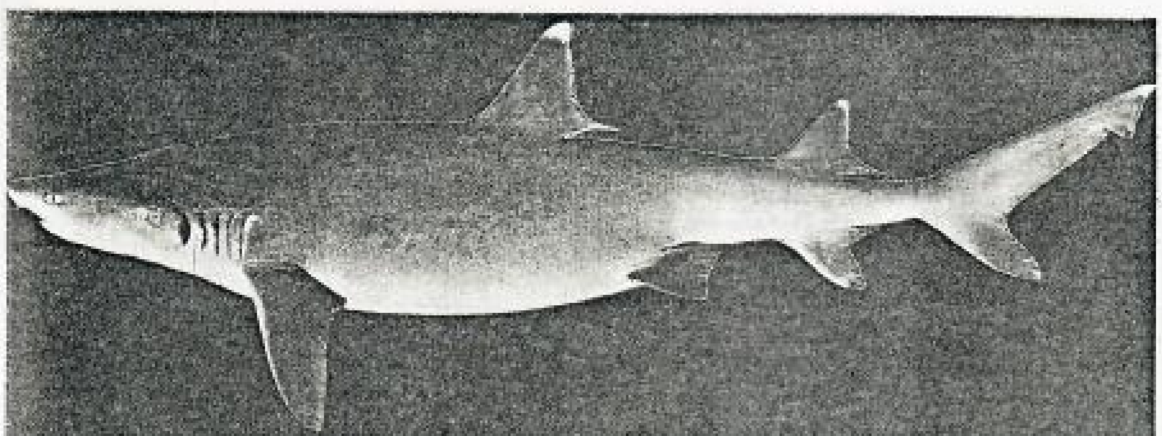

FIGURE 7.—*Triaenodon obesus*, 1,218 mm PCL, 1,520 mm TL, 23.5 kg, Tahiti, Society Islands.

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from II. Enewetak
by J. Koranda &
K. Marsh

Ujilang is also smaller than Enewetak, both in size of the lagoon and in the total dry land area (see Fig. 6). A comparison of the areas of both atolls shows:

	Area, mi^2 Lagoon	Dry land
Ujilang Atoll	25.47	0.67
Enewetak Atoll	387.99	2.26

From this comparison, it is apparent that the potential for production of food from the reefs and lagoon is considerably less on Ujilang than it is on Enewetak. The limited food potential on Ujilang has made it necessary to import more commodities than would normally be required on Enewetak. This has been reported to have presented some difficulty because Ujilang is located further from the sources of the needed commodities than Enewetak.

Living Conditions on Ujilang

The U.S. Navy constructed a village on the main island of Ujilang for the displaced Enewetakese, and a brush-clearing program was in progress when they arrived on the atoll. Coconut trees planted during German and Japanese administrations were still standing and bearing. Seedlings of breadfruit and pandanus were brought ashore and planted. After the Enewetak people had settled in, the Navy departed. There was no U.S. official remaining on the atoll, nor was there any radio communication with the outside world.

The former Enewetak inhabitants attempted to adjust to their new location. They had, and still have, several formidable problems with which to cope. The most obvious, and one which they have uppermost in their minds, is the great disparity in the sizes of Ujilang and Enewetak, as previously mentioned. The traditional Marshallese pattern of habitation is for family units to live on their land parcels, not in a village cluster. While it is common for community buildings, church, school, dispensary, and warehouse to be centralized for convenience and access to all, dwellings are usually dispersed over the length of the lagoon beach of an island. This pattern is obviously desirable from the point of view of environmental sanitation and public health. As described, the traditional settlement pattern of the Enewetakese was disrupted because of their relocations.

Natural Resources

The people practice a nonintensive type of agriculture but utilize the environment to the maximum, using the plants that can survive and produce in the atoll environment. Coconut is converted to copra for cash sale to the visiting Trust Territory supply ship. Consumer goods are purchased from the ship with the proceeds of the copra sales. The interest payments from the trust funds provided by the TTPI administration also help buy needed commodities. Rice, flour, sugar, canned meats, and other canned goods are staple items of the diet and have been for many years. Fish, clams, lobster, turtles (flesh and eggs), sea birds (flesh and eggs), chickens, and pigs provide protein in the diet. The marine resources are extremely important in the diet of these people.

Coconuts, pandanus, breadfruit, and arrowroot are the main vegetable

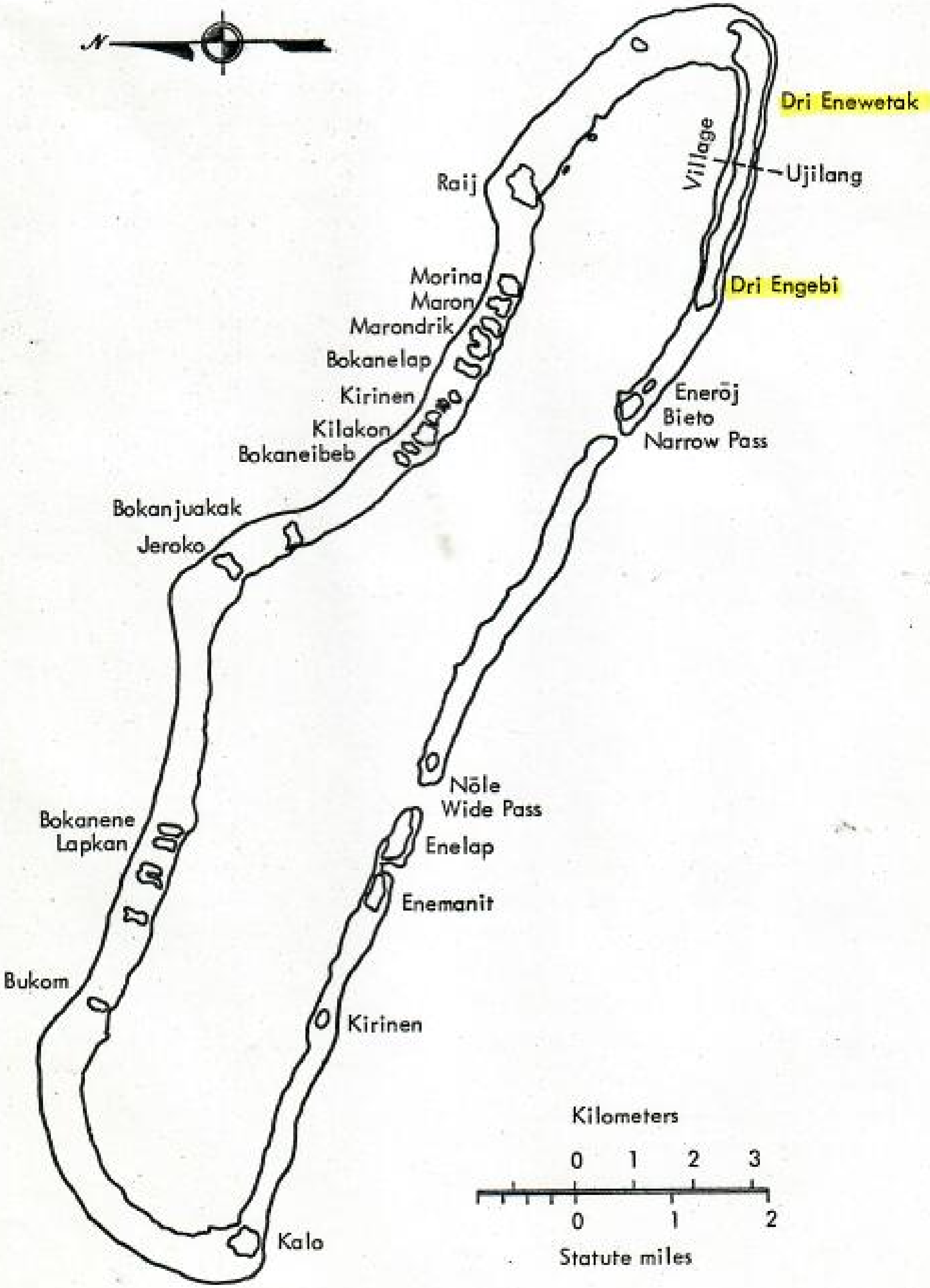

Fig. 6. Ujilang Atoll.

products used. Bananas, papayas, and squash are used to a lesser extent, probably due to the relative scarcity of the banana and papaya which do not seem to grow well on Ujilang.

The Enewetak population shares the upward trend of the rest of the Marshall Islands and Micronesia. Records show an increase from 104 in 1925 to 432 in 1972. This tendency toward increased population among the Enewetak people is resulting in a further drain on the inadequate resources of Ujilang. A census made in early November 1972 produced the following data on the location of Enewetak people:

Ujilang Atoll	340
Majuro Atoll (DUD)	31
Majuro Atoll, Rongron Is.	18
Maloelap Atoll, Marshall Is.	3
Kili Island, Marshall Is.	7
Ponape, Eastern Caroline Is.	5
Crew members on Trust Territory ships	4
Residing in the United States	3
Total Enewetak people	411
Married to Enewetak people and living on Ujilang (integral part of the community)	21
Grand total	432
Males	226
Females	204
Sex not reported	2
Grand total	432

(Tobin, 1973)

Economic Status

The TTPI administration has attempted to upgrade copra production and subsistence agriculture for the past several years with some noticeable improvement. However, the Enewetak people are not as economically well off as they would have been if they had not been uprooted from the larger Atoll.

The unfavorable economic situation and the persistent desire to return to Enewetak finally stimulated aggressive action by the people. They threatened to evacuate the atoll in 1967, and in 1968 the leaders petitioned the United Nations for assistance in returning to Enewetak. In 1968, they again threatened to evacuate the atoll and come to Majuro. Economic help was given them by the administration, and relief shipments of food were sent to the community. An *ex gratia* payment of $1,020,000 was made to them in 1969 and placed in a trust fund; the interest from the fund has helped. Funds were also allocated for a construction program to improve the housing on Ujilang and for the construction of badly needed public facilities on the atoll. The Ujilang community assumed the responsibility for doing the actual labor involved.

Preferences of the Enewetak People for their Future

Efforts to ameliorate living conditions on Ujilang, while welcome, did not lessen the desire of the people to return to their ancestral homeland. They continued to press for this goal. Discussions and meetings were held with government officials. Finally, on April 18, 1972, the High Commissioner informed the District Administrator that Enewetak Atoll would be returned to the jurisdiction of the TTPI by the end of 1973.

It is expected that all of the 432 Enewetakese will return to their Atoll. However, it is not known whether those who have interests elsewhere will remain permanently, or leave after visiting their relatives and old land claims. It is assumed that these people will eventually retire on Enewetak.

A planning council has been formed, consisting of Enewetakese, who are empowered by the people to make decisions within specified limits on matters pertaining to short-term, intermediate, and long-range planning. The council will be augmented by technical advisors to assist them in translating the desires of the Enewetak people into workable plans. The advisors will work closely with the planning group and other Enewetakese in their particular fields, e.g., architecture, short- and long-range economic development, and agriculture.

EXPECTED LIVING PATTERNS AFTER RESETTLEMENT

Introduction

The successful resettlement of the people of Enewetak will depend strongly on the interaction of their current life style with the provisions made for them by the U. S. Government. While the present life style is a result of over a hundred years of first German, then Japanese, and finally American influence, the greatest impact has occurred since the end of World War II. The creation, under U. N. charter, of the Trust Territory of the Pacific Islands, and the subsequent military development of strategic defense areas in the Marshall Islands, has brought the simple food-gathering culture of the Marshallese into close contact with twentieth-century technology.

In order to gather some first-hand information on the living habits, attitudes, and desires of the modern Enewetakese, a field team spent the period of July 21-31, 1973, on Ujilang. The team was composed of Carlton Hawpe (Holmes and Narver architect), Howard Schoss (Peace Corps architect), John Stewart (AEC/NVOO), Kenneth Marsh (LLL), and Thomas Makiphie (interpreter from Micronesian Legal Services). Hawpe and Schoss were to meet with the Enewetak planning council to determine where and how the people intended to live on Enewetak, what types of houses they preferred, and what they wanted in the way of cooking and sanitary facilities. Stewart and Marsh were to collect specific information on the people's daily activities and their diet, with particular regard for the implications to radiological dose-assessment calculations.

Victor Nelson, University of Washington marine biologist, was to be a member of the team, but transportation difficulties resulted in a two-week delay on Enewetak and, because of other commitments, Nelson had to return to Seattle. During the two weeks on Enewetak, however, he spent considerable time with Smith Gideon, a native of Enewetak who was then Magistrate of Ujilang, collecting data on the fish preferences of the Marshallese. In his report (see p.46) Nelson recommends that a composite of the Ujilang, Bikini, and Rongelap diets be used to estimate the average diet of the Enewetakese.*

Originally, the present residents of Ujilang lived as two tribes (dri) on separate islands around the Enewetak lagoon, the driEngebi on Engebi in the northern

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*See Chakravarti and Held, J. Food Sci. 28 (2) (1963).

half of the atoll, the driEnewetak on Enewetak in the southern half. The Ujilang Atoll, by contrast, has only one island large enough for permanent habitation; hence, today everyone lives on the main island of Ujilang. This island, roughly the same size as Enewetak, is about 2.5 mi long by 0.1-0.2 mi wide. The "town square" divides the island in half and consists of the meeting hall, dispensary, church, and school. The half of the island east of the town square belongs to the Enewetak people, while the western half belongs to the Engebi people. Even though the two tribes have intermarried to such an extent that, as Magistrate Smith Gideon says, "we are one big family," the old division is maintained.

Almost everyone lives in the village, which extends a few hundred feet to either side of the town square. There are a few houses scattered over the rest of the island, but these are used only a few days at a time, mostly by older people on food-gathering trips. Houses are constructed of plywood and corrugated sheet metal, with the floors usually about 0.7-1 m above ground. The space under the houses is used for relaxing in the shade, and the pigs generally rest there as well.

An increase in the birthrate has resulted in a very young population. Ninety percent of the people are under 40 years of age, and almost 50% are under ten. During the field team visit, a population anomaly existed in that there were no children of high school age on the island, even though they comprise about 10% of the population. This is explained by the fact that the high school is located 800 mi away at Majuro and, while school had been out over a month for summer vacation, no ship had been available to return the students to Ujilang.

There were many opportunities for misunderstandings to occur. Makiphie spoke Marshallese and English fluently, but had no knowledge of radioecology. Hawpe and Schoss spoke good Marshallese, but also had no knowledge of the radiological aspects of Enewetak. On the other hand, neither Stewart nor Marsh, the radiological experts, spoke any Marshallese. The tendency of the people to want to be polite and to please their visitors by giving what they believed to be the desired answer, a problem mentioned by other investigators, was evident and probably had some effect, but much of the data in this report is based on personal observations. These problems do, however, lend weight to Nelson's suggestion that a composite of data would best forecast living habits after resettlement.

This section was reviewed in draft form by Jack Tobin, Trust Territory Community Development Advisor, and many of his comments have been incorporated into the final version.

Development of Island Communities

The islands of Medren (ELMER) and Engebi (JANET) are preferred for permanent dwellings, with possibly some people living on Enewetak (FRED), depending on facilities remaining after the rehabilitation. Japtan (DAVID) has been suggested as a temporary location for a work force during the cleanup, but might develop into a semipermanent settlement. If too many restrictions remain on and around Engebi for comfortable permanent habitation, the people may divide Medren in half and live there, probably as they do now on Ujilang. Second-home houses on Engebi would still be desired by some people, and could be built either as part of the rehabilitation or by the people themselves at a later time. If the plan suggested by Carlton Hawpe is adopted by the Enewetakese, there will be three to six houses per cluster on each wato. The houses will be located about 100 ft or so inland from the lagoon beach, behind a "green belt" of coconut trees. A wato is a strip of land extending from the lagoon side to the ocean side, occupied by a single family group (10-40 people). On wide islands, such as Engebi, the wato may not include both beaches, but access to both sides of the island will be provided.

Houses will be constructed with the floors about 0.7 m above grade, the intervening space filled with concrete and coral aggregate. The floors themselves will be either concrete or plywood, and the walls will be either poured concrete or concrete block. Roofs will be corrugated sheet metal, provided with troughs for collecting and transporting rainwater to cisterns. A high degree of resistance to typhoons is desired.

There is no furniture in a typical Ujilang house, and no decorations on the walls. Some food may be stored inside and a few possessions like mirrors, hand-cranked sewing machines, kerosene lanterns, or anything subject to rain or pig damage are kept there, too. These items are usually on the floor and very rarely are there any shelves or definite storage facilities.

Areas around the houses will be covered with coral gravel. The Ujilang people renew and add to this covering from time to time by scattering gravel collected from the ocean beach. This area is kept free of grass and trash.

Rainwater, collected from the roofs of buildings, will be the principal source of fresh water. Ujilang has several concrete cisterns, but most people have two or three 55-gal drums, fed from the roofs of their homes. One of the concrete cisterns has a 10,000-gal capacity and uses the roof of the church as a catchment. It is used by the general community, and probably a similar cistern would be built on Enewetak. The proposed plan for the Enewetak houses calls for a built-in cistern in each house, with a storage capacity sufficient for several weeks. Well water is brackish and not used at all when rainwater is plentiful; however, as rainwater stocks decline, well water will be used first to wash clothes, then for the daily bath, and only as a last resort for drinking or cooking. It should be noted that Enewetak receives somewhat less rainfall than Ujilang, and therefore well water might have to be used to a larger extent. However, this same lack of rainfall also is responsible for a more brackish well water on Enewetak, making it even less palatable. Well depths on Ujilang varied from 2.5 to 6 or 7 m, but several people who lived on Enewetak remembered the wells there as deeper than any on Ujilang (therefore estimate about 10 m). Medren Island presently has considerable area in the form of concrete slabs and metal roofing which could be used for catchment purposes. The airfield alone on Enewetak could probably supply the entire population with water, given a collection and distribution system. It should be possible to make up in area what is lacking in rainfall, at least for the southern islands of the Atoll.

Routine for Daily Activities*

A few activities are common to all members of the household. Families retire for the night between 10 and 11 p.m. Everyone sleeps inside the house on a woven pandanus-leaf sleeping mat spread on the floor. A typical mat is made up of a double thickness of leaves, about 75-100 cm wide by 150-180 cm long, and weighs about 1 kg. Double mats are also used, with the width and weight increased about a factor of two. Almost everyone arises between 6:30 and 7:30 a.m.

Two or three days a year the entire family will go on a one- or two-day picnic to one of the other islands. However, transportation is a real problem, and there was one girl, 14, who had never been off the main island of Ujilang.

Married women (essentially all women over 16-17 years of age) spend the whole day in or around the house attending small children, cleaning, washing clothes, and cooking. The Marshallese are very concerned with personal cleanliness. Everyone bathes every day and washing clothes is a daily activity. Houses are swept several times a day, and the custom is to remove shoes or zories (if any) before entering the house. Clothes are washed outside, usually by teenage girls or older women. Many people have set aside a particular area for laundry by making a raised bed consisting of a framework of coconut logs filled with coral gravel. These beds are typically 2-3 m on a side and 1/2-1 m high. Clothes are washed in a pan (~50 cm diam) with soap powder, if available, by a combination of wringing, rubbing on flat rocks or plywood, and pounding with a stick. They are then rinsed and hung on a line to dry. This treatment is a little rough on the fabrics, but they are clean. Cooking and food preparation will be discussed in another section.

Men spend the morning hours in and around the houses, cleaning up outside the house, smoking, visiting with each other, and generally taking it easy. Afternoons are spent much the same way, although these days considerable time is spent in meetings regarding the return to Enewetak. If a breadfruit- or coconut-gathering trip is made away from the village, it will usually be early in the morning before the heat of the day. Similarly, a fishing trip near the village might be planned to take advantage of known fish movements. The only significant deviation from this routine occurs on Saturday, when the cooperative fishing

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*Tobin feels that the presence of the survey party had a strong influence on the daily habits of the people, especially the men. He says the Marshallese are naturally curious and tend to stay close to visitors. Also, the action and excitement were a welcome change from their usual routine. For these reasons, copra production and outer-island trips were probably curtailed. This points up the difficulty of gathering reliable information. The presence of the observers tends to affect that which is observed, but on the other hand, too much reliance on interviews runs the risk of bias from "cooperative answers." Again, the best picture is a composite from several sources. With regard to the survey party's effect on the people's routine, however, it should be mentioned that for at least several years after the resettlement of Enewetak, frequent and numerous visitors may be expected.

trip to other parts of the lagoon takes place. Fishing in general will be discussed in a separate section.

Children up to the age of about 3-6 years spend most of their time around the village close to or inside their houses, under the supervision of their mother and older children. Children from about 6 years up to about 10-15 years spend their time in school and playing around the village between the ocean and lagoon.

At least half of the children's free time is spent playing on the lagoon beach and in shallow water; the remainder is about evenly divided among the village, surrounding forest, and ocean beach. Girls from about 12 to 15 perform many of the arduous household tasks, such as grating coconut or preparing breadfruit. Boys of this same age climb the coconut and breadfruit trees to harvest green "drinking coconuts" or ripe breadfruit.

School was not in session in July; they observe a June-to-September recess. Children start first grade at about 6 years and are required to attend through the eighth grade. School hours are 8-12 a.m. and 1-3 p.m. The school is a one-room structure, and students sit on the floor. Subjects taught are English, mathematics, social studies, science, and physical education. Most eighth grade graduates can read and write Marshallese. If students wish to attend high school, they go to the district center at Majuro, and the official language is English. At about age 15, if they do not attend high school, children begin to assume more of the duties of adults.

Table 4 provides a rough estimate of the amount of time spent by men, women, and children in various locations. For dose-assessment calculations, hours per week is probably the best unit. Hours per day would carry a large standard deviation (~20-50%), while hours per month would be unnecessarily coarse, except for time spent off the main island. How these estimates would change for Enewetak is very difficult to predict. With the much larger and less protected lagoon there, transportation will have a strong influence. If reliable boats are available, the total time spent by men on the lagoon water and other islands would probably about double or triple, at the

Table 4. Time spent in various areas of the Ujilang Atoll.

Location	Time, hr/wk		
	Men	Women (children to age ~5)	Children (~5 to ~15)
Inside houses	60	60	60
Interior of island—outside	80	95	43
Lagoon beach	10	10	50
Lagoon water (boat)	5	0	7
Other islands	5	1	1
Ocean beach	3	2	7
Open sea	5	0	0

expense of time on the home island. Women's and children's time distribution would probably not change more than 10-20%, because their lives are more centered around the home and community. The table gives the time distribution of the residents of Ujilang who have lived there 26 years. It is probably typical of a completely rehabilitated Enewetak. After the cleanup, if the houses are completed, even the first year would be about as described.

Diet

At the time of the trip to Ujilang, no Trust Territory ship had called there for over two months. The people were subsisting on the local products, consisting of breadfruit, coconut, and fish. The survey party took 350 lb of flour, 150 lb of rice, 50 lb of sugar, and assorted canned goods to Ujilang; thus it was possible to observe the impact of imported food on the native diet. It could only be described as profound. There is little doubt that, given the opportunity, Marshallese consumption of imported foods would constitute at least 80% of their diet. The favorite imports, unanimously reported, are rice, flour, sugar, canned corned beef, and assorted canned fish, usually tuna, salmon, and mackerel. Marshallese who live on Majuro and Ebye (Kwajalein Atoll) and who, therefore, have money and access to "American" food, live almost entirely on imports, including such accessories as soft (and hard) drinks, beer, candy, cigarettes, and convenience foods, limited only by their ability to afford them. However, these people become hungry for the native diet (breadfruit, coconut, and fish), and a once-a-week Marshallese meal is traditional. However, the Marshallese foods are of limited availability due to population pressures. Thus an interesting picture emerges of the outer-island people desiring unavailable imported foods, while those in the population centers desire equally unavailable traditional foods. The lack of reliable inter-island transportation contributes greatly to this problem. Dose calculations based on the diet observed at Ujilang should provide good upper limits on ingestion of radionuclides at Enewetak, modified, of course, by a few factors such as the greater availability at Enewetak of some food sources (e.g., sea birds).

Cooking and eating are not big social events in Marshallese life. Food is usually cooked in the evening, some eaten then, and the rest during the next day. Families will sometimes eat together, but usually everyone eats whatever is available whenever he is hungry. When more cooked food is required, it is prepared then; thus cooking and general food preparation may take place at almost any time of the day, and usually is going on somewhere in the village all the time. On special occasions large meals will be prepared, and everyone, often the whole village, will eat together. This is about as close as the Marshallese come to the "American family dinner." A typical day's food consumption would be a light meal in the morning, usually a handful or two of food left over from the previous evening meal, perhaps a drinking coconut and some copra around the middle of the day, and then a larger meal of freshly cooked food in the evening. There were no plates or flatware in use on Ujilang:

everyone ate with his fingers from leaves of the breadfruit or coconut. In the case of large fish or meat, people would eat directly from the carcass, often passing it from person to person. Eating takes place outside the houses, and everyone sits on the ground.

A typical Marshallese "kitchen" has an area set aside for raw food preparation, a single-burner kerosene stove, an underground oven or um (rhymes with zoom), a fire pit with a grate for broiling or general cooking if there is no kerosene stove, and sometimes a pit for food storage. Again, everything is on the ground, and the cook sits or squats on the ground while cooking. Large pieces of coral serve to support pans and food baskets. Food is commonly gathered, as well as stored, in these baskets woven of coconut fronds. The kitchen is usually attached to the house by extending two walls and sometimes the roof; in other cases, the kitchen has its own roof. The fourth side is usually at least partially closed in, but rarely has a hinged door. The proposed houses to be built on Enewetak will have similar areas.

The um exists in two styles, shallow and deep. A shallow um is excavated in the coral to a depth of 10-20 cm, but is often not excavated at all. A fire is built on the rocks, and when only glowing coals remain, the food is wrapped in breadfruit leaves and laid on the coals. Everything is covered with more breadfruit leaves, then with sand and gravel, and finally with coconut fronds or burlap. Cooking time is about an hour. The deep um is excavated to 50-60 cm and is used in the same way, mostly for baking bread, which requires a higher temperature and longer baking time. Most people prefer a Coleman oven set on a kerosene stove, but these are rare. The food storage pit is excavated to a depth of about 50-75 cm (but not over an arm's length). These pits are used mostly to store preserved breadfruit, but may be used to store cooked leftovers. All food to be stored is wrapped in breadfruit leaves, and the pit is lined with either breadfruit or pandanus leaves.

Obviously the Marshallese kitchen is considerably more portable than the American version. Many fire pits and ums are located outside; in fact, they may be constructed and used at the food-gathering site. Kerosene stoves are valuable possessions which are kept under cover, although seldom in the house itself. There was one four-burner model occupying a place of honor in one Marshallese house. For broiling in an um, a fire is started with dry coconut frond; then either *Messerschmidia* wood, coconut shells or husk, or pandanus wood is added. Most other woods may be used, but coconut shell is preferred for the um because it produces good coals.

The important native foods on Ujilang, and presumably on Enewetak, are fish, coconut, breadfruit, and arrowroot. Pork and chicken are consumed in varying amounts, and water comsumption is highly dependent on the availability of tea and coffee. Fish, coconut, and breadfruit are eaten both raw and cooked in a variety of ways. Only cooked arrowroot is eaten. Table 5 represents an attempt to quantify the Marshallese diet on a daily basis and is based on information supplied by Dr. Mary Murai of the University

Table 5. Summary of Marshallese daily diet.[a]

Food item	At time of return, g/day Men	Women	Children (older than 3-4 yr)	10 yr post return, g/day
Fish	600	600	400	600
Domestic meat[b] (pork, chicken)	60	60	35	60
Pandanus fruit	0	0	0	100 (200-400 for children)
Wild birds	100	100	60	10
Bird eggs	20	20	15	5
Arrowroot	0	0	0	40
Coconut	20	20	20	100
Green coconut milk	20	20	20(?)	300 (0-1500)
Ripe coconut milk	20	20	15	100
Coconut crabs	25	25	15	0-5
Clams (and other shellfish)	10	0	0	25
Garden vegetables	100	100	80	200
Breadfruit	0	0	0	200
Imports[c]	400-1000	200-1000	150-800	0-1600
Total	~1600	~1600	~1300	~1800

[a]Every entry in this table is subject to qualifications and should not be used without reading the accompanying text.

[b]Ranges from 0 to 250 g/day due to individual possession of swine and fowl.

[c]Flour, rice, sugar, tea, canned meats, and canned fish are by far the favorites. These will comprise from 0 to 80% of the diet, depending on availability.

of California (Berkeley), and on observations gathered during the 10 days on Ujilang. It should be emphasized that imported foods are highly favored by the Marshallese and will constitute anywhere from 0 to 80% (perhaps even 100% for short periods) of the daily diet. The critical factor influencing the quantity of imported food consumed is availability, which for the Ujilangese means transportation. The breakdown into men, women, and children is perhaps more misleading than informative, particularly for the women and children, because they are constantly exposed to food during the daily preparation and their intake is highly variable.

Pregnant women eat the regular diet, sometimes reducing their intake for weight-control purposes. Infants are nursed up to about 1-1½ years of age, when they are weaned onto the current diet with only a modification in food preparation. Certain foods may be mashed or cooked somewhat longer to make them more suitable for infants. The meat of the green coconut, which is naturally soft, and arrowroot paste are popular infant foods.

Pandanus is the lollipop of the Marshall Islands, much favored by children and to a certain extent by adults.* Fried breadfruit is a favorite snack food, especially of older women who may spend many afternoons eating fried breadfruit, smoking, visiting, and playing bingo. Averaged over a monthly basis, the numbers in Table 5 are probably good to ±50%, the "10-year postreturn" column is strictly a guess; much depends on what becomes of Enewetak. The diet will depend greatly on the extent of American (or Japanese) influence.

Because it is very difficult to express the Marshallese diet in grams per day, the following discussion of the various food items and their uses is given.

Seafood

Fish is certainly a favorite item in the Marshallese diet. Even if imported food is available, local fish remains high on the list of variety foods. If imported food is not available, fish probably supply the entire protein intake. The favorite fish at Ujilang, and those observed caught and eaten, approximately in order of abundance are: rabbitfish (Siganus), grouper (Epinephelus), convict surgeon (Hepatus), goatfish (Mulloidicthys), pompano (Hynnis), surgeonfish (Naso), bonito (Sarda?), squirrelfish (several varieties), ulua (Caranx), and yellowfin tuna (Neothunnus). Bonito, ulua, and tuna must be caught by trolling; therefore their importance in the diet depends strongly upon motorboat availability. All three are a favorite fish, particularly for sashimi (raw).

Almost any fish which is caught and cooked will also be eaten raw. The head of the smaller fish is considered a delicacy, and the heart and liver are also occasionally consumed. Fish which are to be cooked within a few minutes of being caught are seldom eviscerated. Fish eaten raw, and those which will be kept even an hour or so are eviscerated. Large fish, such as the tuna and jacks, are usually cleaned back at the village because the heart and liver are practically always cooked and eaten. The smaller reef fish are cleaned on the spot, often just with fingers and teeth. Fish are usually cooked with the skin and scales left on; the scales peel off easily after cooking, and most of the skin is usually discarded. However, whether or not the skin is eaten depends on both the fish and the diner. Sashimi is always skinned first.

The Marshallese are opportunists and will tend to eat what they catch; however, they know where and when their favorite fish are likely to be found and plan their trips accordingly. Their techniques are

*According to Tobin, pandanus is probably more important in the diet than this report indicates. The fact that it was out of season during the visit may have contributed to the impression that it is not widely consumed. Tobin states that it is a very nutritious food, and that its consumption should be encouraged by planting it in abundance on Enewetak. Perhaps the amounts given in Table 2 should be doubled or tripled for the 10-year postreturn consumption. Murai originally estimated 200 g/day without regard to age or sex.

Not at certain times of the year!

also directed toward certain types of fish. The two principal factors which discriminate against certain fish in the diet are flavor and the occurrence of ciguatera or other forms of poison. Sharks are good examples of the flavor factor. The meat contains large quantities of urea, requiring laborious preparation which, when combined with the generally unpleasant disposition of these fish, serve to eliminate them from the diet. Moray eels, barracuda with three gill rakers, and one species of mullet are examples of fish which frequently contain ciguatera. The puffer fish and such obvious species as the stonefish and scorpion fish are also excluded from the diet.

Frying in oil or lard and broiling over coals are the principal methods of cooking fish, although boiling and baking in the um (particularly for large fish) are sometimes used. Cooked fish may be kept for several days by wrapping it in breadfruit leaves and covering it with coconut or pandanus fronds. It is reported that fish can be stored over longer periods by salting it raw and drying it in the sun. The Ujilangese make their own salt by evaporating ocean-side water in kettles over a fire. The preserved fish are rinsed in fresh water before they are eaten. Since fish are abundant, the daily intake depends mostly on personal preference. Many interviews indicated that the 600 g/day, wet weight, estimated by Murai and included in Table 5, is probably accurate to within 10-20%.

Tridacna and hippopus clams are about the only other seafood eaten in any significant quantity. Clams of edible size are not common at Ujilang (or Enewetak, for that matter), and most are consumed on the spot by the fisherman. The large adductor muscle is eaten raw, as well as the mantle, but dark parts are discarded. It is possible that some clam meat, particularly the mantle, finds its way into the diet of the women and children, but certainly not much. Sea turtles, spider snails, and helmet shell snails are also sometimes consumed, but again are only a small portion of the diet. Sea cucumber (Holothuria) and small crabs are not eaten. A variety of small snail (Littorina) is a delicacy, but the quantities consumed are insignificant.

Coconut

Until one has lived awhile with the Marshallese, it is impossible to realize what a useful tree the coconut palm is to these people. Essentially every part of it is used in at least one way. The leaves are used to make baskets, to thatch roofs, and for various handicrafts. The trunks are used for firewood and as logs for general building purposes. Coconut husks make good fire-building material, while the shells make good charcoal and are also used as cups and bowls. The sap from the blossom of a tree 4-5 years old is gathered and used as a syrup; it gives a pleasant coconut sweetness to several foods. This same sap may be fermented to produce an alcoholic drink; however, drinking is against the law for the Ujilang people. Small roots of the tree (~1-2 mm diam) can be bleached in the sun, dyed with the water extract of colored crepe paper, and woven into a variety of baskets. Hearts of palm are rarely eaten. The tree must be 4-5 years old before the top is cut off and the growing core is harvested. This yields about 4-5 kg of material and kills the tree.

The coconut itself is a dietary mainstay. A drinking nut, ni (pronounced "knee"), is full grown but totally green, and contains about 250-350 ml (grams) of liquid. The meat at this stage is only about 4-5 mm thick and, while firm, is covered with a gelatinous coating on the inside. Consumption of drinking nuts is highly variable. They are traditional at festive occasions and make an excellent "coffee-break" drink. Usually they are not used to quench thirst because water is preferred, but they are used more as the Marshallese version of soda pop. However, if water is not available, a working man might consume up to a dozen nuts or so a day. On Ujilang they are plentiful and there for the taking, which makes an accurate estimate of the consumption impossible. The meat of the drinking nuts, a popular baby food, is consumed only in small quantities by older children and adults.

Ripe coconuts, similar to those for sale in American stores, are consumed in a variety of ways, but mostly raw. Some of the liquid is used in cooking, and the meat, called "copra" by the Marshallese, may be eaten in pieces with fish, or grated and added to other foods. Favorite recipes include a mixture of grated coconut, wheat flour, water, and a little sugar which is baked in the um; a similar mixture containing baking powder which is deep-fried ("doughnut" in Marshallese); a mixture of breadfruit and grated coconut baked in the um; and grated coconut and coconut sap, mixed with steamed rice. All of the people interviewed said they ate about half a coconut per day. Since an average coconut yields about 200 g of copra, the figure of 100 g/day listed in Table 5 is fairly accurate. This also agrees well with Murai's estimate.

Commercial copra is prepared by spreading pieces of coconut meat on a grate about 2 m above an open fire. Coconut husks and shells are the favorite fuel, and complete drying requires about 24 hr. After drying, the copra is stored in burlap sacks to await a Trust Territory field ship. Copra-making was not in evidence on Ujilang because, the people said, it often spoiled before a ship would arrive. However, while the survey party was there, Smith Gideon built a copra-drying shed which he said would dry several hundred pounds at a time.*

There is a stage of the coconut between ripe and sprouted when it is not consumed. Once sprouted, the layer of meat is gone and the inside is filled with a pithy, yellowish mass called iu (pronounced ("you"), which is highly prized by the Marshallese. Iu may be eaten raw

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*According to Tobin, most copra is dried in the sun rather than over a fire, and official Trust Territory figures list the copra production of Ujilang as 51.6 tons ($5000) in fiscal 1971 and 110 tons ($11,000) in fiscal 1972. If these figures are reliable, it would seem that much more copra-making goes on than was evident during the survey party's visit. It is possible that copra is made on other islands, but the people generally said they did not make much copra. Certainly on the main island there did not appear to be an area large enough to sun-dry more than 100 tons of copra, even in a year. Current copra production is of little importance to dose-assessment calculations, but if copra is to be an important cash crop in the future, careful attention should be given to potential radionuclide levels.

or used like copra. In what is probably the favorite recipe for iu, it is grated together with copra and perhaps a little sugar, then slurried with ni to make a thick drink, a sort of Marshallese milk-shake. On Majuro this mixture is frozen on sticks and sold like Popsicles.

Breadfruit is the third main component of the Marshallese native diet and was in season during the visit there. Three varieties exist, two of which must be cooked, and the third, somewhat less plentiful, can be eaten either cooked or raw. A typical breadfruit will be about 15 cm long, 10 cm in diameter, slightly ovoid, with a rough, light-green skin and orange flesh. The general appearance is that of a very large avocado. Average weight is 1100 g, with about 10% as peel and core. The variety eaten raw is smaller, weighs perhaps 700-800 g and contains about 100 g of seeds which look like small chestnuts. These seeds can be roasted and eaten. Breadfruit is cooked in several ways, much as we would cook potatoes. However, the skin is never eaten. The breadfruit may be peeled and cored, then cut up and boiled, or it may be baked whole with the skin on, either over coals or in the um. A favorite way, especially of older women, is to peel and core the breadfruit, then slice it perpendicularly to the long axis, salt lightly, and deep-fry. This produces a product resembling fried pineapple rings, but somewhat larger, and is a good snack food, a sort of Marshallese equivalent of potato chips. Once cooked, breadfruit can be covered and kept for several days.

Another method of preparing breadfruit is to peel and core about a dozen fruits and let them soak about 24 hr in a coconut-frond basket in the lagoon. They are then rinsed in fresh water and kneaded together on a rock or board until the product resembles orange-colored bread dough. This is then divided into "loaves" of a kilogram or so apiece, wrapped in breadfruit leaves, and stored underground in a pit as already described. It is said to keep several months this way, and may be used like fresh breadfruit after another rinse in fresh water. This product is usually mixed with grated coconut and baked in the um.

Arrowroot grows all over Ujilang and is the principal undergrowth in the coconut forest. In July, the tubers were small because the harvest season begins around November. The preparation of arrowroot has been described by Tobin and consists of digging, then washing and grating the tubers, and placing the pulp in a burlap sack or one woven of coconut roots. The sack is immersed in salt water, squeezed out by hand, and the milky extract, consisting of a fine suspension of starch, is collected. In an hour or so the starch coagulates and is washed several times by decantation with salt water, then fresh water. The starch is then spread in the sun to dry, ground lightly to break up lumps, and stored away where it will keep indefinitely. Arrowroot starch is not at all like wheat flour and is only used as a thickening agent in soups or stews. It resembles our familiar cornstarch. When questioned, the Ujilangese all stated a preference for wheat flour over arrowroot starch. Flour can be used as a thickener, as well as for other purposes. They said that given both, they would use up the flour first and then fall back on the arrowroot. From start to finish, arrowroot production is a long, tedious process, resulting in a product which has no flavor and limited usefulness.

Pandanus was just coming into season during the July trip. When questioned, most adults said that they eat hardly any pandanus. It is consumed mostly by the children. Tobin reports a method of sun-drying pandanus on coconut fronds; the Ujilangese acknowledged this, but claimed that they do not make it often. Pandanus is not abundant on Ujilang and probably will not be on Enewetak either.

About the only other native food consumed in any quantity on Ujilang was pork and, in even lesser amounts, chicken. The quantity of pork consumed varies greatly from family to family, because pigs are private property, and there is no obligation to share them. Some families have many pigs and may eat pork two or three times per week, replacing fish on a gram-for-gram basis, while other people have few or no pigs and hence eat little or no pork. Chickens are in the same category but are very scarce. The reason for this seems to be that the cats, originally imported to control the rats, did such a good job that they had to move on to the chickens. All animals are free-roaming and forage anywhere on the island.

Little need be said for other native foods. Coconut crabs and wild birds have been essentially wiped out on Ujilang but may be important at Enewetak, especially for the first year or two. The coconut crabs are highly prized for food. Their legs and claws are broken off and cooked immediately; then the crab is force-fed until the tail doubles in size, when it is used for soup. Almost all of the sea birds are eaten except the golden plover, which is believed to contain spirits of departed souls. The young birds just getting feathers are a favorite food item. Again, the Marshallese recipe is simple: catch the bird, wring its neck, and cook it over an open fire, entrails, feathers, and all. The liver and heart are eaten. Bird eggs are eaten but are not a favorite food item.

The only garden vegetables growing on Ujilang were two pumpkin vines, neither of which had any pumpkins, but one was in blossom. The lack of agriculture is explained first by the fact that there is practically no soil, just rocks, and second, that the pigs are free-roaming and fond of anything edible. The latter fact, when combined with the cat-chicken situation, provides a real insight into the Marshallese philosophy of life, "play it where it lies."

Methods of cooking imported foods have been described as they accompanied the native diet. Flour, in addition to the products mentioned, is also made into bread, baked in the um. Rice is exclusively boiled with the standard proportions of two parts of water to one of rice. Tea is drunk hot and is much preferred to coffee. In fact, the order of preference in beverages is tea, coffee, water, soft drinks, and ni. Sugar is added to several foods, and almost everyone uses sugar in tea and coffee. Canned meats such as corned beef, tuna, salmon, and mackerel are eaten with no more preparation than heating, and they replace fresh fish on a gram-for-gram basis.

Medicines and Remedies

This was the only area where there seemed to be a definite desire for secrecy. Apparently the Marshallese medicine, like the folk medicine in parts of the United States, is a family secret and not shared extensively, especially with outsiders. Part of this reticence may be due to the fact that the Marshallese realize the sophistication of American medicine and are afraid of ridicule. It was inferred that many of the Marshallese themselves did not have much faith in their medicine, but it was worth a try, particularly if the American version did not work or was unavailable. Held's article (op.cit.) contains some information regarding the local remedies of Rongelap. The reported uses of Messerschmidia and Scaevola were confirmed on Ujilang. The use of Messerschmidia is particularly important with regard to dose assessment, because leaves are used as a first-aid bandage and as a poultice to cover open wounds.

A few general remarks regarding health care should be made. Ujilang is the most remote of the Marshall Islands and as such, suffers even more than the others from a lack of readily available first aid, much less real medical care. The dispensary stock consisted of aspirin, tetracycline capsules, penicillin, dextrose solution, normal saline solution, and miscellaneous odds and ends of patent medicines. A Marshallese medical attendant was in charge. A kerosene refrigerator was operable but out of fuel, and there was no other medical equipment or furniture of any kind. In case of a medical emergency, the usual procedure is to divert a Trust Territory ship and take the victim to Majuro. Usually this means a minimum of three days' delay. The people all appeared very healthy and vigorous, and there seemed to be no evidence of malnutrition or illness. However, it was reported that all through the Marshall Islands a baby's first birthday is a big event and a cause for celebration.

Agricultural Considerations

Just what the level of agriculture will be in Enewetak is very difficult to say. Certainly the two staples, coconut and breadfruit, will be grown, especially on the islands of Medren, Japtan, and Engebi. Some pandanus and arrowroot will also be raised. The fact that no agriculture is practiced on Ujilang and the reasons why have already been mentioned. Whether things will be different at Enewetak remains to be seen. Many Ujilangese interviewed remembered that the Japanese raised a variety of vegetables as row crops on Engebi and Enewetak. These were irrigated with either cistern or well water containing human waste. No one knew whether vegetables could be grown on any other islands (probably Japtan) but, since irrigation is necessary, the availability of fresh water would be a crucial factor. The implication is that, given some effort and perhaps some fertilizer, a variety of crops could be grown. One Ujilangese, Balik by name, worked as a Trust Territory agriculturalist on Majuro for a year. He also lived on Enewetak at the time of the Japanese occupation and recalls their growing pumpkins, cucumbers, watermelons, potatoes, sweet potatoes, green onions, cabbage (bok choi), carrots, and maybe soybeans. Thus there is certainly a potential for augmenting the standard diet of coconut, breadfruit, and fish. It is reported by Tobin and confirmed by others that the Ujilangese are quite industrious and will probably grow at least some vegetables, but will probably not practice American-style truck farming.

Pigs and chickens will remain the only domestic animals raised for food; no one interviewed indicated otherwise. However, Tobin says that Muscovy ducks and turkeys do well in this part of the Marshalls. As on Ujilang, livestock will be allowed to forage on their own, although it would seem that for at least a few years after return, some sort of food supplement would be necessary. On Ujilang the pigs ate coconuts at all stages of ripeness, grass, the leaves of the trumpet morning glory (Ipomoea), fallen breadfruit, family garbage, and small crabs and snails from the lagoon beach. Presumably the chickens consume a similar diet. It would seem that on Enewetak the confining of either the animals or the vegetables would be beneficial.

Marine Resources at Enewetak

During conversations and fishing trips with Smith Gideon, Ujilang magistrate, in a two-week period at Enewetak Atoll in July 1973, some information on the food habits of the Ujilang people was gained which may be used to help estimate dose rates from food intake. In general, the data gathered concern the use of fish in the Ujilang diet and specifically include data on meals eaten during fishing trips while on Enewetak.

Generally, it can be stated that the Ujilang people are opportunists and will eat most types of fish which they happen to catch. However, certain fish are preferred and special efforts are made to

Table 6. Average wet weights of tissues from common edible nearshore fish at Enewetak Atoll.

Common name	Tissue	No. of fish	Average wet weight	Wet/dry
Goatfish	Eviscerated whole	61	145	3.4
Goatfish	Viscera	61	13	3.5
Goatfish	Muscle		45-50[a]	4.8[a]
Mullet	Muscle	32	57	3
Mullet	Eviscerated whole	32	167	3
Mullet	Viscera	32	44	2
Rabbitfish	Muscle	9	200	3.9
Convict surgeon	Eviscerated whole	47	54	3.5
	Viscera	47	10	5.3
	Muscle		15[b]	4.0[b]
Parrotfish	Muscle	17	144	4.9

[a]Estimated from similarity to size and body shape of mullet.
[b]Estimated.

capture the preferred species. Also, certain fish are avoided either because they are known to be poisonous (ciguatera), difficult to prepare, or simply because they are not as flavorable as other species.

One apparently favorite fish is the goatfish, either "Jo" (Mulloidichthys) or "Jome" (M. auriflamma). The whole fish is laid on a grill (if available) and roasted over a bed of hot coals for about 10 minutes. The skin is then peeled off and the flesh eaten. The head of the goatfish is considered a delicacy and is often offered to a guest as a courtesy. The soft parts (brain, eyes) of the head are eaten, but the bones and viscera are discarded. All organic waste from a meal is placed in the fire and burned. This is a garbage disposal method and serves to keep the fly population down. One goatfish or mullet (see Table 6 for average weight of fish) is a reasonable intake at one meal; however, some people may eat three goatfish. The remainder of the meal usually consists of one-third of a copra coconut and a drinking coconut.

Another apparent favorite is the rabbitfish, "bejrok" (Siganus). Rabbitfish of other species are also known as "mole" or "molle" and are referred to several times in Tobin's 1955 journal as a favorite fish of the Ujilang people. The rabbitfish are cooked in the same manner as the goatfish. In fact, it appears that most fish are cooked in this manner, except for occasions when the um is used. Only the flesh of the rabbitfish is eaten, and one fish is the usual intake for a meal. One-fourth of a copra-type coconut (the kind usually sold in the U.S., with the meat dry), coconut crab legs (100 g, wet), and a drinking coconut completed this meal as prepared at Enewetak.

Other fish which were captured on fishing trips and which are said to be eaten are mullet, convict surgeon, parrotfish, grouper, surgeonfish, and damselfish. These fish, along with the goatfish and rabbitfish, probably comprise the most common fish found in the nearshore water around the island of Enewetak, and hence will probably be the most common fish in the diet. Seven or eight convict surgeon, some copra, and a drinking coconut, or two to three convict surgeon, copra, rice, and a drinking coconut are typical meals.

There seems to be some conflicting opinion as to whether or not the Ujilang people eat mullet and parrotfish. Tobin, in one conversation, stated that the Ujilang people do not eat either mullet or parrotfish. However, Smith Gideon, when shown specimens of mullet and parrotfish, indicated that at least three different species of the smaller (<12 in.) mullet, both "ikare" (Chelon vaigiensis or Neomyxus chaptalii) and "jomou" (Mugil sp.), and three species of parrotfish are eaten on occasion. The conflicting opinions may be due to the fact that one genus of mullet, "iol" (Crenimugel sp.), is considered to be poisonous and therefore is not eaten. Furthermore, parrotfish from the northern end of the Enewetak Atoll are also considered to be poisonous and are not eaten. Parrotfish from the David to James area of the Atoll are eaten. In addition, the fact that other species of fish (goatfish and rabbitfish) are preferred may have led to the confusion on this point. However, it seems clear that the Ujilang people, on occasion, will eat both mullet and parrotfish.

Of the fish actually captured and shown to Smith, his preference in descending order seemed to be goatfish, rabbitfish, mullet, convict surgeon, and parrotfish, with grouper, surgeon and damselfish occupying indefinite intermediate positions between rabbitfish and parrotfish. These nearshore fish are captured by several methods, including use of thrownets, gillnets, and a surround technique by which the fish are driven into shallow water where they are hand-captured or dip-netted. Additional thrownets and gillnets, along with appropriate mending materials, might be considered as a part of the rehabilitation program for the Enewetak people.

A fish not actually captured but indicated to be very good to eat is the flying fish, "jojo" (Exocoetidae). These fish are captured at night by building a fire in a boat and attracting them to within a range where they may be netted. Some flying fish also fall into the boat during their flight toward the attracting light. Small hooks on a line are also used in a manner similar to the jigging of herring or smelt which bite on the bare hooks that simulate the planktonic organisms they feed on.

Other fish which reportedly are eaten are barracuda with four gill rakers, "nidwa," tunas, and other similar lagoon fish such as jacks, mackerel, and dolphin. Although larger sharks (probably gray sharks but not thresher or nurse sharks) are eaten, they probably are a minor portion of the diet due to the length of time required in the preparation of the flesh to make it edible. This lengthy preparation is due to the urea in the flesh which renders the fresh fish unpalatable: "a shark has a big smell."

In the preparation of shark flesh, the fish is boiled in hot water for about 10 minutes, after which the skin is removed. The flesh is then boiled for several hours, presumably until the smell goes away. Next, the boiled meat is fried or steamed (um) and then placed in the sun until it is dry. This process takes most of a day, but the finished product is considered good.

The capture of large lagoon fish requires boats and fairly heavy fishing lines, feathered jigs, and large hooks. Hence, the use of these fish in the diet is highly dependent on these items and is probably less than the utilization of the nearshore fish because of the present scarcity of adequate fishing gear and because the nearshore fish are so abundant and easily captured at most times. In general, at the present time, deepwater lagoon fish are probably not as abundant in the diet as they would be if more fishing gear were available to the people.

Other marine organisms which may be eaten include porpoise, tridacna clams, ("kabwur"), shore crabs, and large gastropods (en). Other smaller gastropods are also called en, but they are not eaten. These include spider snails and smaller Strombus species.

Porpoise are captured by surrounding them as they enter the wide pass or deep channel and herding them into shallow water. Herding is accomplished by banging rocks together underwater and splashing on the surface.

Three types of Tridacna are distinguished by the Enewetak people: (1) the large killer clam, Tridacna gigas; (2) a white-mantle, medium-sized clam; and (3) small clams with colored mantles which are embedded in the reef. All types are called kabwar. No information was obtained on how these clams are prepared, but it is known that other Marshallese people do not eat the kidney, due to its very bitter flavor, and it may be presumed that this is the case for the Enewetak people until different information is obtained.

Another organism which will certainly be eaten by the returning Enewetak people, unless advised to the contrary, is the coconut crab, "baru lip" (Birgus latro). The first step in preparing this crab is to knock the pincer legs and the largest walking legs off with a machete. The legs appear to break off near the body at a natural breaking point, which quickly heals over. By doing this the crabs can be easily contained without causing damage to themselves or to their captors. Also, crabs can be held alive like this for several weeks. The legs and the bodies of crabs not to be saved are then roasted over a bed of coals.

From discussions with Smith Gideon, I would conclude that the diet of the Ujilang people is very similar to diets of the Bikini people, the Rongelap people, and other northern island groups in the Marshall Islands. This is true because the basic foods are the same in all these areas. Breadfruit, pandanus, arrowroot, and coconut are the chief natural terrestrially grown vegetative foods, with imported rice and flour supplementing this portion of the diet to a degree which is very dependent upon the length of time from the visit of the last field-trip ship.

Fish, clams, and langousta from the lagoon and reef; birds and bird eggs from bird-nesting islands; domestic pigs and chickens raised on the village island; and imported meats (corned beef, sardines) provide the animal protein in the diet. Again, the proportions vary greatly with the availability of specific items; however, fish are indicated as being an important part of the diet at Ujilang and will probably be more important at Enewetak Atoll where the fish supply is greater.

It should be remembered that a diet determined for the Ujilang people over one short time period may differ greatly from a diet determined over another time period in a different season or at a different length of time from the last visit of a trade ship. I feel, therefore, that a composite diet, based on all available diet information for the Ujilang, Bikini, and Rongelap people, is the best information to be used in the calculation of dose rates from food intake.

or bone doses has been ignored. To convert from free-air dose (rads) to gonadal dose (rem), a body-shielding factor of 0.8 may be used.*

The free-air dose will be additionally enhanced by the presence of beta rays, originating primarily from ^{90}Sr-^{90}Y in the soil. In radiation fields produced by global fallout, where the $^{90}Sr/^{137}Cs$ activity ratio in the soil is normally about 0.67, the free-air beta dose at 1 m above the ground is expected to be about four times that due to the ^{137}Cs gamma rays. At Enewetak, however, the $^{90}Sr/^{137}Cs$ activity ratios in the soil samples showed a wide range of values with an average ratio of about three. Thus, the free-air beta dose rates may average about 800 μrad/hr in the interior of JANET and about 200 μrad/hr in the village area. The resulting beta-ray doses to the skin, eye lenses, and gonads will be about 50, 25 and 1%, respectively, of the free-air values.† Thus, appreciable increases in skin and eye-lens doses due to the beta contribution could be expected. The gonadal dose, on the other hand, would be insignificant.

Very little information is available to verify these calculated beta-ray air doses, but indications are that they may be unrealistically high. This is based upon data obtained from two LiF TLD badges that were equipped with aluminum shields, one of which was situated within the interior of JANET. These shielded badges only showed an approximate 10% reduction in exposure rates from those measured by the unshielded badges at the same location, thus leading one to suspect that the beta air doses are considerably less than the calculated values.

MARINE PROGRAM

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Purpose

The mission of the aquatic survey was to collect enough sufficiently representative samples to define and quantify the contributing radioactivities in the lagoon and reef areas of the Atoll. The radiological data are needed to assess both the exposure pathways to persons utilizing the aquatic environment and to determine the distribution of selected radionuclides in the Enewetak marine environment. Fish, invertebrates, plankton, and water and marine sediment were collected and other marine observations conducted during October, November, and December, 1972. This section of the report describes the kinds and quantities of samples obtained, the methods of collecting and processing, and the details pertinent to each kind of sample or program.

General Program Description

Ships and Capabilities

A 17-ft Boston Whaler was flown from LLL to Enewetak for the survey of the

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* Report of the United Nations Scientific Committee on The Effects of Atomic Radiation, 27th Session, Vol. 1, Supplement No. 25 (1975).

† K. O'Brien, Health and Safety Laboratory, USAEC, New York, private communication (1973).

lagoon. It was powered by a 65-hp outboard engine and carried a 7.5-hp outboard for emergency use. It was equipped with a depth sounder and davit with a hand-operated winch and 500 ft of 3/32-in. steel cable, sufficient to reach any depth in the lagoon.

This boat was used chiefly for sampling near the shore; its range was limited because it was necessary to remain within sight of land to fix the station locations, which was done with a sighting compass. We sampled the lagoon between FRED and PEARL, no more than 6 km from shore; additional collections were made between LEROY and FRED, including stations in the Wide Passage.

Sampling by the Whaler crew included water collection, sediment collection, plankton-tow and mid-lagoon trolling with rod and reel. This small boat proved very satisfactory for these collections. In all, 43 of the 126 sediment grabs, 21 water samples, many open lagoon fish, and several plankton samples were collected by the whaler during the survey in spite of bad weather which seriously hampered its operation in the lagoon. On a number of days, operations were curtailed because of wind and sea conditions.

A landing craft utility (LCU) was provided for the survey and used to support all survey programs. Its use for the marine program was on an availability basis, but the time allotted was sufficient to complete the program. A portable winch powered by a gasoline engine was mounted on the stern of the vehicle deck. The winch contained 1000 ft of 3/32-in. stainless steel hydrographic cable which passed through a metering sheave secured to the port-side davit of the vessel. All sampling operations were conducted from the port side with equipment attached to the hydrowire.

The bridge-height of the LCU was sufficient to sight on land from any location in the lagoon and the Navy crew provided all fixes necessary for locating station positions. Sample depths were determined from the wire-out readings recorded on the sheave. Water samples, sediment samples, and fish and plankton samples were obtained. Bad weather limited many operations from the LCU.

A 24-ft launch belonging to the USAEC has been stored and used at Enewetak since May 1972. It is powered by two 120-hp inboard-outboard engines and is equipped with a depth sounder.

This boat was used for transportation between sampling locations during all portions of the Enewetak Survey and for the <u>in situ</u> gamma probe work. The boat was adequate for both purposes, since it was large enough to handle the normal wind and wave conditions found in the lagoon, yet maneuverable enough to work in the shallow near-shore waters.

<u>Equipment and Other Facilities</u>

Both the Whaler and the LCU had complete pumping systems aboard. Surface and subsurface water samples were collected with battery-operated pumps through a weighted hose-line which was lowered to the desired depth. Each sampling operation was preceded by pumping for at least 10 min to flush out the entire system. The 55 liter black (D... polyethylene collection barrels were first rinsed with the sample water and then filled at the rate of 8 liters per min.

Sediment grab samples were collected with either Shipek, Ponar, or Ekman samplers. Plankton were collected in No. 6 or No. 10 nets, 1 m in diam. Fish were collected by trolling with rod and reel in the lagoon or with nets in the shallow near-shore areas. Invertebrates were hand collected. Crater sediments in MIKE and KOA craters were sampled with a "Benthos" model 3-in.-diam gravity corer.

Every precaution was taken to ensure against contamination of the samples. All samples were placed in plastic bags, jars, or barrels, immediately after collection. After each day's cruise, all decks and equipment were washed to remove any sediment debris accidentally spilled and overlooked.

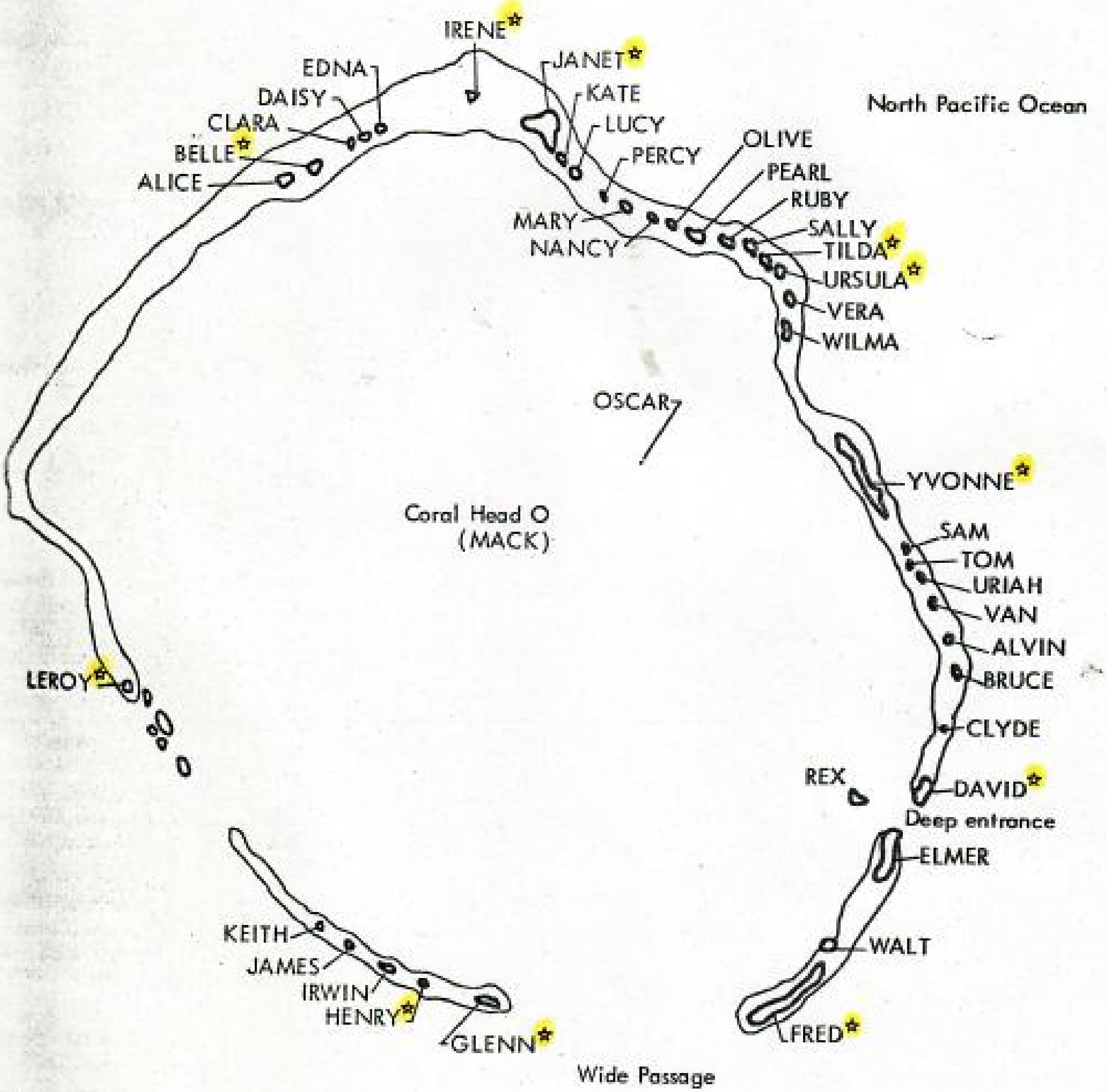

Fig. 41. Major collection locations (starred) of marine biological samples at Enewetak Atoll, October to December, 1972.

Fish

Introduction

There are more than 700 species of fish at Enewetak Atoll, but only a few species of reef, benthic, and pelagic fishes were selected for use in this study. The common anglicized names of the fishes are used in the text, but the scientific names and the Enewetakese common names, when known, are listed in Table 25. The Enewetakese names were those used by Smith Gideon, Enewetak magistrate, in his conversations with Victor Nelson at Enewetak in July 1973, and from Goo and Banner (1963).

The species selected were chosen for one or more of the following reasons: (1) they are commonly eaten by the Marshallese; (2) they are relatively abundant at most of the collection sites; (3) they are representative of a feeding habit; or (4) there is previous relevant radiometric information about the species. The species of reef fishes selected as being representative of feeding habits include the mullet (a plankton and detritus feeder), convict surgeon (a grazing herbivore), goatfish (a bottom-feeding carnivore) and parrot-fish (a coral eater). The tunas, jacks, and dolphins – pelagic fish – and the snappers and groupers – benthic fish – are carnivores of high order in the food chain leading to man. Information about the radioactivity in Enewetak fish during the last 25 yr, including the species selected for this study, can be found in the reports of the University of Washington, Laboratory of Radiation Ecology, which include the following: Held, 1973[a]; Beasley and Held, 1972[b]; Held, 1971[c]; Welander, 1967[d]; Welander et al., 1967[e]; Seymour, 1963[f]; Held, 1963[g]; Lowman, 1960[h].

Sample Collections

Reef Fishes – The nine major collection stations are shown in Fig. 41. They are listed in clockwise order around the Atoll, and beginning with the most northern station are as follows: BELLE, IRENE, JANET, TILDA-URSULA, YVONNE,

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[a] E. E. Held "Fallout Radionuclides in Pacific Ocean Tuna," in Proc. Third National Symposium on Radioecology, 10-12 May 1971 (Oak Ridge, Tennessee) CONF 710501, p. 689.

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Table 25. Common, scientific, and Marshallese names and wet weight to dry weight ratios of tissues from aquatic organisms collected at Enewetak and Kwajalein Atolls, October to December 1972.

Common name	Scientific name	Marshallese[a] name	Tissue	Number of samples	Wet/dry ratio
		Fishes			
Barracuda	Sphyraena barracuda	Nidwa	Muscle	1	4.36
			Bone	1	
Bonefish	Albula vulpes		Muscle	1	3.38
			Viscera (solids and lipids)	1	1.57
Skipjack	Euthynnus yaito	Loj	Light muscle	9	3.51
			Dark muscle	9	3.58
			Liver	9	3.60
			Bone	9	
Butterflyfish	Chaetodon auriga	Dribob	Evisc. whole	1	3.06
			Viscera	1	4.38
Convict surgeon	Acanthurus triostegus	Kuban	Evisc. whole	30	3.54
			Viscera	28	5.26
Damselfish	Abudefduf sp.		Entire	1	3.09
Dolphin	Coryphaena hippurus		Muscle	2	4.01
			Liver	2	3.47
Flagtail	Kuhlia taeniura	Jerot	Evis. whole	1	2.76
			Viscera	1	3.09
			Entire	2	3.29
Goatfish	Mulloidichthys auriflamma	Jome	Evisc. whole	1	3.26
			Viscera	1	3.65
Goatfish	Mulloidichthys samoensis	Jo	Evisc. whole	13	3.38
			Viscera	13	3.50
Goatfish	Parapeneus barberinus	Jerrobe	Evisc. whole	4	3.78
			Viscera	3	4.31
Goatfish	Parapeneus cyclostomus	Jerrobe	Evisc. whole	2	3.29
			Viscera	2	4.03
Goatfish	M. samoensis & M. auriflamma		Evisc. whole	1	3.24
			Viscera	1	3.82
Grouper	Epinephelus merra	Momo	Evisc. whole	1	3.28
			Viscera	2	3.63
			Muscle	1	4.98
			Entire	1	3.37
			Bone	1	
Grouper	Epinephelus spilotoceps	Momo	Muscle	1	4.03
			Liver	1	2.16
Grouper	Epinephelus sp.	Momo	Evisc. whole	1	3.50
			Viscera	1	3.52
Grouper	Variola louti	Kaikbet	Muscle	1	4.76
			Liver	1	3.04
			Bone	1	
Halfbeak	Hemirhamphus laticeps	Kibu	Entire	1	4.57

Table 25 (continued).

Common name	Scientific name	Marshallese[a] name	Tissue	Number of samples	Wet/dry ratio
		Fishes (continued)			
Jack	Caranx melampygus	Deltokrok	Muscle	4	4.36
			Viscera	4	3.73
			Bone	2	
Jack	Caranx sexfasciatus		Evisc. whole	1	3.88
			Viscera	1	4.26
Mackerel	Grammatorcymus bilineatus		Muscle	3	4.10
			Viscera	2	3.72
			Bone	1	
Mullet	Crenimugil crenilabis	Iōl	Evisc. whole	3	2.88
			Viscera	4	2.68
			Muscle	1	3.94
			Remainder	1	2.40
Mullet	Plicomugil labiosus	Ikari	Evisc. whole	1	3.25
			Viscera	1	3.06
Mullett	Mugil sp.	Jomou	Evisc. whole	3	3.76
			Viscera	3	2.32
Mullet	Neomyxus chaptalii	Ikari	Evisc. whole	13	2.97
			Viscera	13	2.83
			Muscle	6	3.86
Needlefish	Strongylura incisa	Tak	Muscle	1	4.41
			Viscera	1	3.67
Parrotfish	Scarus sordidus	Mao	Evisc. whole	2	3.85
			Viscera	10	2.95
			Muscle	9	4.92
			Bone	9	
Rabbitfish	Siganus rostratus	Elik	Evisc. whole	1	3.91
Rudderfish	Kyphosus cinerascens	Bagrok	Muscle	1	4.95
			Viscera	1	5.69
			Remainder	1	3.15
Skipjack tuna	Euthynnus pelamis	Chilu	Light muscle	2	3.51
			Dark muscle	2	3.55
			Liver	2	3.52
			Bone	1	
Snapper	Aphaerus furcatus		Muscle	1	4.62
			Viscera	1	3.69
Snapper	Aprion virescens	Eowae	Muscle	1	4.34
			Viscera	1	4.18
Snapper	Lethrinus kallopterus	Jalia	Muscle	2	4.78
			Liver	1	3.38
			Viscera	1	3.71
			Bone	1	
Snapper	Lutjanus monostigmus	Ban	Muscle	2	4.34
			Viscera	2	3.20
			Liver	1	3.09
			Skin	1	1.91
			Remainder	1	2.90
			Bone	1	

Table 25 (continued).

Common name	Scientific name	Marshallese[a] name	Tissue	Number of samples	Wet/dry ratio
			Fishes (continued)		
Snapper	Lutjanus vaigiensis	Ban	Evisc. whole	1	3.41
Snapper	L. monostogmus & L. vaigiensis		Muscle	1	4.71
			Remainder	1	3.05
Surgeonfish	Ctenochaetus striatus		Evisc. whole	1	3.97
			Viscera	1	3.16
Surgeonfish	Naso lituratus	Balak	Muscle	1	4.70
			Viscera	1	5.97
			Remainder	1	2.42
Wahoo	Acanthocybium solanderi		Muscle	3	3.88
			Liver	3	2.97
Wrasse	Goris sp.		Muscle	1	4.83
			Viscera	1	3.22
			Bone	1	
Yellowfin tuna	Thunnus albacares	Pwepwe	Light muscle	5	3.78
			Dark muscle	4	3.75
			Liver	5	3.80
			Bone	3	
			Invertebrates		
Pencil urchin			Soft parts	1	2.92
			Hard parts	1	
Sea cucumber	Actinopygia mauritiana		Evisc. whole	2	6.49
			Viscera	2	5.51
Sea cucumber	Holothuria atra		Evisc. whole	2	8.21
			Viscera	2	2.92
Sea cucumber	Holothuria leucospilota		Evisc. whole	3	9.02
			Viscera	3	3.32
Sea cucumber	Holothuria sp.		Evisc. whole	5	7.56
			Viscera	5	5.31
Sea cucumber	Unidentified		Entire	1	2.26
Spiney lobster	Panulirus penicillatus		Muscle	1	4.32
			Hepatopancreas	1	2.94
			Exoskeleton	1	7.61
Top snail	Trochus sp.		Soft parts	1	4.57
Tridacna	Tridacna gigas	Kabwur	Muscle	2	4.29
			Mantle	2	7.43
			Muscle & mantle	4	6.44
			Kidney	5	3.36
			Viscera	5	6.79
			Kidney & viscera	1	4.78
			Gills	1	7.82

Table 25 (continued).

Common name	Scientific name	Marshallese[a] name	Tissue	Number of samples	Wet/dry ratio
		Invertebrates (continued)			
Tridacna	Tridacna sp.		Muscle & mantle	11	6.17
			Viscera & kidney	4	5.02
			Viscera	7	6.85
			Kidney	6	4.37
			Entire	3	5.03
		Algae			
Calcareous algae	Halimeda		Entire	2	2.59
		Turtle			
Sea turtle	Chelonia sp.		Muscle	1	7.43
			Liver	1	4.33
			Kidney	1	6.64
			Lungs	1	8.85
			Heart	1	6.49
			Mesenteries	1	24.37

[a]Marshallese names from the 1963 unpublished manuscript, "A preliminary compilation of Marshallese animal and plant names," by F. C. Goo and A. H. Banner, Hawaii Marine Laboratory, University of Hawaii, Honolulu, and from personal communications with Smith Gideon, Ujilang Magistrate in 1973.

DAVID, FRED, GLENN-HENRY and LEROY. These areas were selected because they are potential resettlement sites and/or were previous collection sites. In addition, "control" fish from a noncontaminated area were obtained from Enewetak, Kwajalein, and Meck Islands in Kwajalein Atoll.

Most of the reef fish were caught in variable mesh monofilament gillnets 25 to 125 ft in length and 6 ft deep. Gillnets were watched closely and unwanted fish were usually released alive. Thrownets were also used in some instances. In most cases, these methods of capture allowed us to collect only fish which were needed for analysis.

The total catch was about 200 mullet (4 species), 100 goatfish (4 species), 400 convict surgeon (1 species), 40 parrotfish (1 species), and 40 other reef fish (12 species). The miscellaneous species included flagtail, rabbitfish, wrasse, surgeon, butterflyfish, damselfish, and bonefish. The catch of reef fish by species and location is given in Table 26.

Pelagic and Benethic Fishes – Large pelagic fishes (tuna, jacks, dolphins) and benthic fishes (snapper, grouper) were collected, since they will presumably be captured and eaten by the Enewetak people and they represent carnivores of high order in the food chain leading to man. They were collected primarily on sport-fishing gear, using feathered jigs and spoons as lures while trolling in the lagoon and in the passes leading to the ocean. Most of the large yellowfin tuna and dolphins were caught in the passes between the

Table 26. Number of organisms collected at Enewetak Atoll and Kwajalein Atoll near-shore sites, October to December 1972.

Collection site	Organism								
	Mullet	Goatfish	Convict surgeon	Parrot-fish	Other reef fish	Tridacna	Sea cucumber[a]	Other inverte-brates	Approx total
Enewetak Atoll									
GLENN-HENRY	~25	11	~50	2	10	6	4	6[b]	114
LEROY	~50	9	34	3	1	1	0	~10[c]	108
FRED	0	~20	~50	9	7	3	2		91
DAVID	0	25	~50	12	2	4	1		94
BELLE	~50	3	30	1	3	10	0		97
IRENE	2	3	12	0	8	0	0		25
JANET	~50	3	~40	1	0	4	0		98
TILDA-URSULA	~35	11	~50	2	3	3	3		107
YVONNE	10	~15	~55	10	3	0	3	9[d]	105
Kwajalein Atoll	–	–	~30	1	5	5			41
Approximate Total	~220	~100	~400	41	42	36	13	25	870

[a]The number given is the number of collections from a given site.

[b]Pencil urchins.

[c]Top snails.

[d]Spiny lobster.

lagoon and the ocean, while the smaller skipjack, mackerel, and ulua were caught in the lagoon proper. The snappers and groupers were caught in both the shallow water of the reef and the deep lagoon waters. The number of large carnivorous fish caught is given in Table 27.

Sample Analyses

Field Processing – After capture, fish were segregated by type (e.g., goatfish, mullet, etc.), placed in plastic bags, and transferred to ice chests containing dry ice as soon as practical (1 to 4 hr after collection). At the main camp, most fish were frozen, either in dry ice or in freezer units. Occasionally, fish were dissected fresh, the tissue dried, and then frozen.

Originally, it was planned that most of the marine biological samples would be processed at Enewetak by people from the Laboratory of Radiation Ecology. However, the disruption to the program caused by Typhoon Olga made sample processing at Enewetak impractical; therefore, the majority of the samples were processed at the home laboratory in Seattle, Washington.

Laboratory Preparation – The samples were frozen at Enewetak and remained frozen until processed at the Seattle laboratory. To begin preparation of the samples for analyses, the fish were partially thawed and dissected into the tissue types shown in Table 25. Tissue types chosen were those most useful for estimation of the radiation dose and were of sufficient size to yield a dried sample of adequate size for gamma spectroscopy or radiochemical analyses. After

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ENEWETAK RADIOLOGICAL SURVEY

OCTOBER 1973

UNITED STATES ATOMIC ENERGY COMMISSION

NEVADA OPERATIONS OFFICE

LAS VEGAS, NEVADA

ENEWETAK

Lisa Bourke

"~40 taken at Christmas 1983
greens + hawks + 3rd species?"

^{210}Po AND ^{239}Pu, ^{240}Pu IN BIOLOGICAL AND WATER SAMPLES FROM THE BIKINI AND ENIWETOK ATOLLS

By

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^{210}Po and ^{239}Pu, ^{240}Pu in biological and water samples from the Bikini and Eniwetok atolls

MEASUREMENTS of the radioactivity in water and biological samples from Bikini and Eniwetok lagoons indicate that although the samples were collected from the most plutonium-polluted waters of the world, the values of the naturally produced radionuclide, polonium-210 were usually greater than the values of plutonium-239 and 240, which are produced by nuclear detonations by factors as great as 100.

With the advent of nuclear testing at the Bikini and Eniwetok atolls in the central Pacific, an environmental laboratory became available for investigating the concentrations of many radionuclides in the marine environment and their uptake by biota. Over the 16 years since the conclusion of nuclear testing, the long lived radionuclides created during the tests and deposited in sediments have had time to approach equilibrium with biota and with natural radionuclides present.

It is of particular interest to compare the concentrations of natural radionuclides, such as ^{210}Po, with concentration of ^{239}Pu and ^{240}Pu produced by nuclear bombs, in that part of the world which has been subject to most radioactive fallout. Both radionuclides decay by α-particle emission of approximately equal energy and both become concentrated in biota. The amount of plutonium to be used in nuclear power reactors is expected to increase by a factor of 1,000 in the next 30 years[1] and with this increased use comes the possibility of accidental or planned releases of plutonium into the food chain of man. The uptake of plutonium by biota in the marine environment is not well understood and a full evaluation of their potential hazard cannot yet be made.

Natural waters contain ^{210}Po as a member of the ^{238}U decay chain. Atmospheric aerosols also contain ^{210}Po which are scavenged[2] by precipitation and enter the hydrosphere. Once in the aquatic environment, polonium and plutonium undergo processes such as precipitation, redistribution, and changes in physical–chemical and oxidation states which may not be similar for the two elements. Both, however, are apparently available biologically as they are accumulated by algae, phytoplankton, zooplankton, vertebrates and invertebrates[3–8].

The samples discussed here were collected by the Laboratory of Radiation Ecology (LRE) during the 1972 joint expedition with the Puerto Rico Nuclear Center and the Lawrence Livermore Laboratory to Bikini and Eniwetok atolls. The locations of the collecting stations are shown in Fig. 1. The analytical results and collection locations of both biological and water samples, and the number of individual species of biological samples measured, are given in Table 1. Samples labelled as 'eviscerated whole' are whole fish which have had the viscera (liver, kidney, gonads, gut contents, and gastrointestinal tract) removed.

As several months elapsed between the collection and analysis of samples, the disintegration rate of ^{210}Po was corrected to allow for decay between the date of counting and the date of collection. The lower and upper limits given in Table 1 indicate the possible range of values if, first, ^{210}Po was derived entirely from the decay of ^{210}Pb in the sample (the lower limit) or, second, no ^{210}Pb was present

Table 1 ^{210}Po, ^{239}Pu and ^{240}Pu values in biological and water samples, and the corresponding concentration factors for samples collected in October, 1972 at Bikini and Eniwetok atolls

	Biological samples			Water samples			Concentration factor	
Species and tissue	Location	^{210}Po range* (d.p.m. g^{-1}, wet)	^{239,240}Pu* (d.p.m. g^{-1}, wet)	Location	^{210}Po (d.p.m. m^{-3})	^{239,240}Pu (d.p.m. m^{-3})	^{210}Po range	^{239,240}Pu
Turtle liver (1)†	Eniwetok rubbish dump dock	0.20– 0.69	0.200	Runit dock	188 ±40	190 ±11	(1.1–3.7) × 10³	1.1 × 10³
Goatfish viscera (6)	Eniwetok, Runit seaward reef	2.60– 9.27	0.650	200 yards off Runit	146 ±20	190 ±11	(1.8–6.3) × 10⁴	3.4 × 10³
Wavyback skipjack (1), dark muscle	Eniwetok Lagoon off Runit	2.50– 8.94	0.280	" "	146 ±20	190 ±11	(1.7–6.1) × 10⁴	1.5 × 10³
Mullet (2) eviscerated whole	Eniwetok, Runit seaward reef	0.50– 1.90	0.003	" "	146 ±20	190 ±11	(3.4–13) × 10³	16
Surgeon fish (3), bone	Bikini *a*–6	8.15-49.70	<0.001	*b*–15	107 ±10	73 ±9	(7.6–46.0) × 10⁴	<20
Surgeon fish (3), muscle	Bikini *a*–6	0.02– 0.15	<0.001	*b*–15	107 ±10	73 ±9	(1.9–14.0) × 10²	<20
Surgeon fish (1), eviscerated whole	Bikini *a*–2	0.40– 2.50	0.018	*b*–2	124 ±13	138 ±9	(3.2–20.0) × 10³	130
Surgeon fish (3), viscera	Bikini *a*–6	0.51– 3.09	1.330	*b*–15	107 ±10	73 ±9	(4.7–29.0) × 10³	1.8 × 10⁴
Convict surgeon (3), muscle	Bikini *a*–3	0.10– 0.59	<0.001	*b*–6	125 ±13	51 ±7	(8.0–47.0) × 10²	<20
Convict surgeon (17), muscle	Bikini *a*–7	0.06– 0.34	<0.001	*b*–18	145 ±14	102 ±9	(4.1–23.5) × 10²	<20
Convict surgeon (13), muscle	Bikini *a*–4	0.13– 0.77	<0.001	*c*–12	135 ±14	45 ±5	(9.6–57.0) × 10²	<20
Convict surgeon (6), muscle	Bikini *a*–5	0.09– 0.56	<0.001	*b*–10	153 ±15	7 ±2	(5.9–36.5) × 10²	<20
Convict surgeon (13), eviscerated whole	Eniwetok, Runit seaward reef	0.80– 2.75	0.005	200 yards off Runit	146 ±20	190 ±11	(5.5–19) × 10³	26
Convict surgeon (21), eviscerated whole	Eniwetok, Runit	0.20– 3.31	0.025	" "	146 ±20	190 ±11	(1.4–22.6) × 10³	130
Convict surgeon (4), eviscerated whole	Bikini *a*–2	1.40– 8.28	0.028	*b*–2	124 ±13	138 ±9	(1.1–6.7) × 10⁴	200
Convict surgeon (1), eviscerated whole	Bikini *a*–1	0.46– 2.82	0.010	*c*–3	141 ±15	138 ±9	(3.3–21.7) × 10³	72
Convict surgeon (4), eviscerated whole	Bikini *a*–1	0.34– 2.06	0.017	*c*–3	141 ±15	138 ±9	(2.4–14.6) × 10³	120
Convict surgeon (17), vliver	Bikini *a*–7	2.04–12.50	0.913	*b*–18	145 ±14	102 ±9	(1.4–8.6) × 10⁴	9 × 10³
Convict surgeon (21), iscera	Eniwetok, Runit seaward reef	1.20– 4.20	0.140	200 yards off Runit	146 ±20	190 ±11	(8.2–28.7) × 10³	7.4 × 10²
Convict surgeon (13), viscera minus livee	Bikini *a*–4	1.67–10.21	0.350	*c*–12	135 ±14	45 ±5	(1.2–7.6) × 10⁴	7.8 × 10²

*Analytical error is ±10% for polonium and ±20% for plutonium.

†Numbers in parentheses indicate the number of fish or organs combined in a given sample. Concentration factors are calculated as a ratio of activity per gram of wet tissue to activity per gram of water.

and the ^{210}Po measured was the true concentration present at the sampling time (the upper limit). The real value is expected to be near the upper limit for most samples since, in pelagic fish, the ^{210}Po is obtained by direct uptake and not as much by ingrowth from ^{210}Pb; measurements showed 1–5 times more ^{210}Po than ^{210}Pb (refs 8–10).

Table 1 shows that ^{210}Po activity is highest in bone, decreasing in order in liver, viscera and muscle. Although bone and liver have been reported as the major repositories for plutonium[10], the plutonium content of the single bone samples reported was at the detection limit of 0.001 d.p.m. per g. wet weight. The high concentrations of both ^{210}Po and ^{239}Pu and ^{240}Pu in viscera and viscera minus liver (convict surgeon), together with the fact that algae in the diet of these species concentrates those radionuclides from seawater, seems to support the idea that both radionuclides enter the fish during the ingestion of food.

Values of plutonium radioactivity have been reported in a large number of biological samples from Eniwetok Atoll[11]. These data also show that the highest plutonium concentrations occur in the viscera of fish. The food contents of the digestive organs were not separated, however, so it is not possible to estimate what fraction of the activity is associated with food and how much occurs in the tissues or organs of the fish.

The convict surgeon and surgeon fish were selected for ^{239}Pu, ^{240}Pu and ^{210}Po analysis because they are local feeders and would concentrate radionuclides from nearby waters. The concentrations of ^{239}Pu, ^{240}Pu and ^{210}Po measured in water from near the sites of the fish collection were used to determine the concentration factors shown in Table 1. The ^{210}Po concentration in the water was calculated from the ^{210}Pb concentration measured in the samples after most of the ^{210}Po had decayed. The error on the ^{210}Po calculation is expected to be small, as the ratio of ^{210}Po/^{210}Pb is approximately 1 : 2 in seawater[4,5]; thus, the ^{210}Pb and ^{210}Po would be near secular equilibrium in the marine environment at Bikini and Eniwetok atolls. The highest ^{239}Pu and ^{240}Pu contents in the water column were found in areas where the highest activity of those radionuclides occurred in sediments, as reported already for Bikini[12]. The highest ^{210}Po concentration was found outside the lagoon in the deep ocean waters, and one possible explanation could be that biological uptake results in a shorter resident time of ^{210}Po–^{210}Pb in the lagoon. The concentration of ^{210}Pb in the particulate phase, (>0.3 μm in size) was less than 10% of the total: the concentrations of ^{239}Pu and ^{240}Pu in the particulate phase varied from 2 to 60% of the total depending on where it was collected from[12]. The overall result indicates that inside the lagoon the radioactivity values of plutonium were more variable than those of ^{210}Po.

Concentration factors of ^{210}Po, ^{239}Pu and ^{240}Pu in organisms (Table 1) are calculated using the total concentrations (particulate plus soluble) measured in the water. All specimens measured have concentration factors for ^{210}Po that are greater (as much as 100 times greater) than those for ^{239}Pu and ^{240}Pu with the exception of samples of turtle liver and surgeon fish viscera. Although these samples were collected in the most plutonium-polluted waters of the world we conclude that the plutonium radioactivity is only a fraction of the natural polonium radioactivity, and that a greater radiation dose to the marine organisms of Bikini and Eniwetok lagoons would be received from ^{210}Po than from ^{239}Pu and ^{240}Pu. This conclusion should not, however, lead to neglect in studies of plutonium concentrations in the higher trophic levels and of its transport through the food web to man.

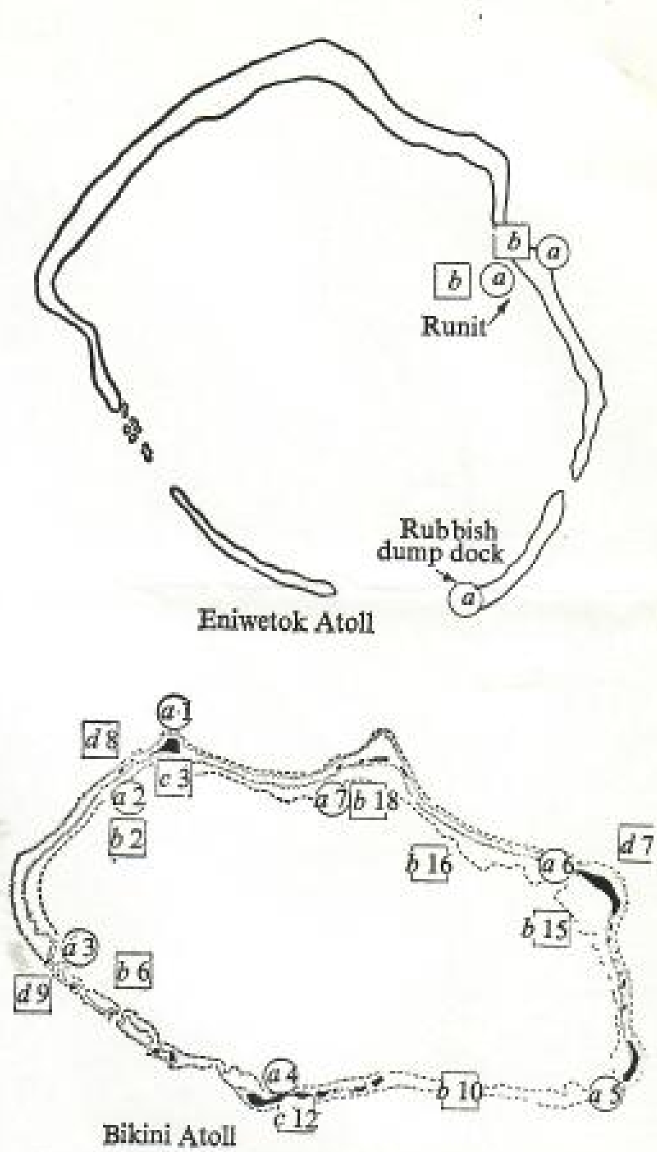

Fig. 1 Sampling stations at Bikini and Eniwetok atolls. *a*, Intertidal zone, biological stations; *b*, lagoon stations; *c*, crater stations; *d*, ocean stations.

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ARNO AND MILI TOP COPRA PRODUCERS

Majuro Aug. 22 Tobolar Copra Processing Plant in Majuro has released the figures for copra production during the first six months of 1985, and while Arno and Mili Atolls led the way in tonnage produced, copra prices have fallen dramatically in the past six months lowering the already small returns for the copra-makers.

Since January, when the price was at 18½ cents a pound, the price has dropped more than fifty percent to just nine cents a pound for outer islands producers. Copra-makers in the district centers are paid 10½ cents a pound as they incur no costs for shipping.

Arno people gathered 416 tons of copra between January and July, while Mili was a close second with 365 tons produced.

An obvious incentive for high production from these islands is that they are both close to Majuro and have regular transportation to get their dried coconut to the Tobolar processing plant in Majuro.

Continued page 6

THE BIKINI/KILI COUNCIL, pictured here, sent a delegation to visit Bikini Atoll last month, the first time they had set foot on Bikini in nearly 10 years. Minus three islands from the testing, Bikini is nevertheless overflowing with fish, turtles and lobsters report the Bikinians who reviewed ongoing Bikini radiation experiments.

RETURN TO BIKINI — 1985

Majuro Aug. 20 A large contingent of Bikinians returned to their former home for a brief visit last month for the first time in nearly 10 years.

The delegation of 17 Bikinians was led by Mayor Tamaki Juda and joined by numerous scientists and Department of Energy logistics people for a visit to review ongoing radiation studies on the atoll.

The people left after a week's stay extremely impressed with the professionalism of the scientists and the studies they are working on, said Bikini/Kili Liaison Officer Ralph Waltz.

Scientific issues aside, there was a definite feeling of excitement when the Bikinians, many of whom are older and remembered the islands as they were before the nuclear tests of the 1940's, set foot on the islands.

They found marine life in abundance; Waltz estimat-

Continued page 6

WET-Chemistry

TRANSURAMICS Plutonium americium Strontium-90

#180-#190

SDgrams

Gamma

BIKINIANS MAKE BRIEF RETURN TO BIKINI

From page 1

ed that there are 2,000 turtles on the atoll, and in one night they caught more than 100 lobsters.

Lawrence Livermore Laboratory scientists, led by Dr. William Robison, are conducting three major studies designed to find out ways to lower radiation levels in the soil and plants on Bikini.

In one three acre plot, the scientists have drenched the soil with salt water from the lagoon using plastic pipes and a sprinkler system to "wash out" the radionuclides. A tremendous amount of salt water has been used, and the scientists estimate that it has resulted in about a 15% reduction in the level of radiation in this area.

The drenching has now stopped, and two areas have been planted, one using fertilizer and the other without. This study should indicate whether the remaining radionuclides are "attached" to the soil and will not be taken up by the plants through their roots.

Waltz noted that the plants in the fertilized area have grown quickly and the soil seems to have recovered from the salt water.

In another plot of land, 18 inches of top soil were scrapped off and piled up at the end of the area. 20 different fruits and vegetables have been planted, again in both fertilized and non-fertilized sections of the scraped land. This study should help determine the extent of radiation contamination in the soil below the 18 inches.

In addition, Konou trees, the wood of which are used for Marshallese carvings, have been planted in the pile of contaminated soil.

In a third experiment the scientists are looking at a large coconut grove that was planted back in the late 1960's when the first Bikini resettlement was being considered. They are experimenting with different kinds of fertilizer, particularly potassium fertilizer, to see what is effective in lowering the coconut trees' uptake of radiation.

The particular grove of coconuts is in one of the most heavily contaminated areas, so if the experiments are successful in lowering or eliminating radiation uptake it will be a major shot in the arm for the resettlement attempts.

According to the scientists, potassium and radioactive cesium 137 have similar properties, and in areas where there is no potassium fertilizer, the coconut trees absorb the cesium "thinking" it is actually potassium.

After the fact-finding trip to Bikini, the people came away with an appreciation for the work the scientists are doing and a sense of trust between the scientists and the people is developing, said Waltz.

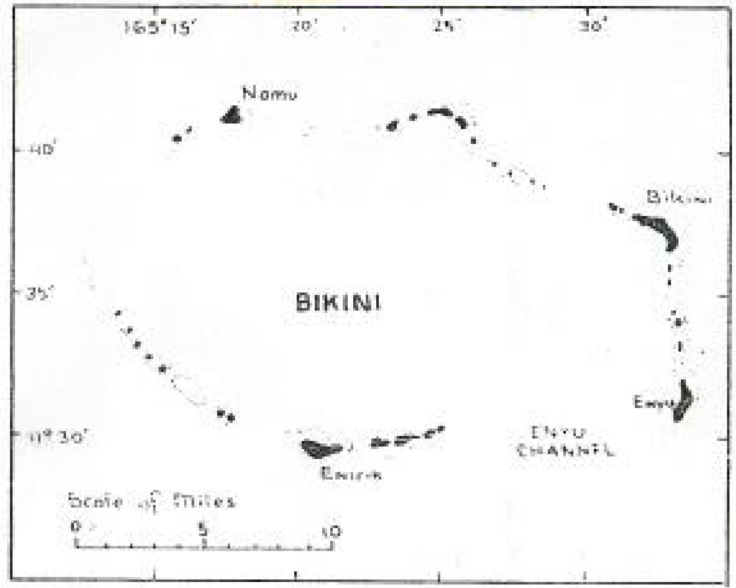
During the visit, they traveled to all remaing 26 islands in the atoll. Before the tests there were 29; three were blown off the face of the earth by the tests.

Motoring across the immense crater from the Bravo shot gave people an eerie feeling, said Waltz, who pointed out that the crater is a mile and a half long and nearly 500 feet deep – a huge black hole in the reef where the three islands once were.

Members of the Congressionally-funded Bikini Atoll Rehabilitation Committee (BARC) were involved in the trip, in addition to the DOE and Lawrence Livermore representatives. Waltz said that before their tour around the atoll, the BARC committee members had not been aware of the extent of the damage to Bikini from the tests before and after the infamous Bravo hydrogen bomb test.

The island by island inspection, which had many of the Bikinians remembering back to the 1940's of the good fishing or crabbing spots, or where an island used to be, was made possible by Bill Tolkes and his ship the William T, said Waltz.

The Bikinians will be returning later in the year for a follow up visit and to review progress made in these now preliminary planting experiments.



Copra Production

From page 1

Ebon islanders made 267 tons, while Ailinglaplap brought in 244 tons. On the low end of the scale, Kili produced just one ton,

The 1,748 people on Arno earned nearly $75,000 from copra which translates into an income of $42.83 per person on the atoll.

Coop School Sets Fundraiser

Majuro Aug. 22 The Majuro Cooperative Elementary School will begin its 1985-86 school term on September 3 in new and remodelled classrooms on a refurbished campus in Delap.

Instruction will be provided from pre-school through eighth grade by a staff of eight experienced teachers headed by David Glen Wright.

Buildings will be painted and cleaned, playground equipment installed, furniture placed into position, flagpole erected and the grounds cleaned by a parent's work party Saturday August 24.

"Participants should bring rakes, hoes, shovels, white paint, rollers or brushes, mechanic and carpenter tools, wheel barrows, trash bags, lunches and drinking water, plus a lot of enthusiastic energy," Wright announced.

"If we start at 8:00 am, we should go home early."

A "Monte Carlo Night" fundraiser will be staged the following Saturday, August 31 at the Yacht Club in Rita. Tickets for this event are now being sold.

Scheduled for 7 pm to midnight, this affair will feature games of chance, entertainment, pupus, acitivities for children and the like. Admission prices are $3 for children, $5 singles and $7.50 couples.

Atomic Shrimp: An Ominous Legacy Surfaces

TOM SUCHANEK

By MRILL INGRAM

THE CALLIANASSID ghost shrimp, an industrious creature that digs labyrinthine burrows in ocean sediments around the world, was never deemed particularly worthy of scientific attention. But this summer marine scientists Thomas Suchanek and Patrick Colin and three teams of EARTHWATCH divers will be carefully studying the shrimp and its activities in the warm waters off Papua New Guinea. The ghost shrimp systematically stores larger sand grains and coral and shell rubble in the chambers of its burrows, which are up to two meters deep, and pumps the finer grains to the surface, forming volcanic heaps at the burrow entrances. Bulldozing at the rate of five pounds of sand per square meter per day, these 2½-inch-long diggers rearrange entire ocean sediment layers and can profoundly affect neighboring plants and animals.

The seemingly innocuous habits of these marine burrowers may have ominous implications for the people of the Marshall Islands, where Suchanek and Colin have discovered them dredging up a piece of history better left buried. Ghost shrimp off Enewetak Atoll, they have found, are bringing up buried radioactive fallout particles from atomic tests the United States conducted there more than 25 years ago. Suchanek and Colin hope that their research in New Guinea, 1,900 miles away, will answer some of the disturbing questions raised by this discovery.

TOM SUCHANEK

Signs like this on Runit warn people of radioactive soil but don't impress shrimp (above).

The U.S. acquired Enewetak from the United Nations Trust Territory of the Pacific Islands in 1947. A year later, U.S. officials relocated the 143 people of Enewetak to Ujelang Atoll, about 124 miles away, so that the U.S. government could institute a program of atomic and hydrogen bomb testing that lasted until 1958. During that period the U.S. conducted 44 bomb tests on Enewetak, contaminating some islands with radioactive elements and littering others with debris.

The effects of the explosions were de-

[continued on page 11]

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Atomic Shrimp: An Ominous

[continued from page 1]

scribed as follows in "The Meaning of Radiation for the Northern Marshall Island Atolls," published by the U.S. Department of Energy (DOE) in 1982: "When an atomic bomb explodes, it takes up soil, rocks, coral heads, water and other such things. These things join with the radioactive atoms from the bomb. All of these things rise quickly high into the air and then later fall back down. At Bikini and Enewetak Atoll, the radioactive atoms and tiny particles from the bombs that were tested fell on the islands, in the lagoons, in the ocean, and the winds blew some to the United States and other countries far away."

Ujelang Atoll, one-third the size of Enewetak, was too small to grow enough food on, so the Enewetakese who arrived there in 1948 had to depend entirely on irregular U.S. supply ships. In 1956 the Marshall Islanders first petitioned the United Nations to give them back their land. "Land means a great deal," they wrote, "more than just a place where you can plant your food. . . . It is the very life of the people. Take away their land and their spirits go also."

The U.S. response was a statement to the United Nations Trusteeship Council: "It is the conviction of the United States that it has the responsibility . . . to maintain at a maximum its capacity to deter aggression and preserve peace. Thus . . . further tests are absolutely necessary for the eventual well being of all the people of this world."

In 1967 a group of Enewetakese boarded a U.S. supply ship at Ujelang and demanded assistance. Their people were starving, they said, and the psychological hardship of losing their land and the social status and family unity that the land represented was becoming harder and harder to bear.

The situation on Ujelang continued to deteriorate, and in 1969 the leaders made another plea: "We cannot make enough copra [a cash crop]. The reason is that the people have to eat it, and the rats also eat it. . . . The conditions on Ujelang are worse now . . . there are more people now. . . . We did not complain when the Navy told us we had to leave our atoll of Enewetak . . . Now we need help badly. We ask America for help in our suffering. Help us, or send us home."

Finally, under pressure from the Marshall Islanders' increasing protests, a nascent independence movement, and threats to return to Enewetak, radioactive or not, the U.S. government allotted $1 million to clean up the atoll and compensate its people. The cleanup program, run by the Department of Defense, involved scraping off 125,000 cubic yards of Enewetak's topsoil and encasing it in a cement crypt on the uninhabited island of Runit, about 12 miles away. Runit remains off limits for the next 240,000 years.

Five hundred Enewetakese returned to their native atoll in 1980, when the cleanup was officially complete. But within a matter of months, one hundred of them went back to Ujelang, complaining of boredom, lack of food, and fear of radiation. Theodore Mitchell, a counsel for the Enewetakese, testified on their situation before a U.S. Congressional subcommittee in 1983. "The soil is poor," he said, "and constantly disrupted by buildings, concrete, and activity. We need a supplementary food program to replace the fish, pandanus, breadfruit, and lime that are not available on Enewetak now. Not only are the crops planted after the cleanup immature, but everything is having difficulty growing." Enewetak, he concluded from a recent visit, "looks like a newly completed housing project in Scottsdale, Arizona. It is desolate."

Mitchell also told the subcommittee that many of the islanders' traditional ways of preparing food and building boats had been lost during their 32 years of exile. "Now they want outboard motors to chase the tuna," he said. Readjusting to life on Enewetak, however, may be the least of their problems.

Runit, the cement-capped depot for Enewetak's radioactive soil, remains off limits for the next 240,000 years.

Enewetak Atoll in the Marshall Islands, about halfway between Hawaii and New Guinea, was the site of 44 nuclear tests in the 1940s and 1950s. Shaded areas show island lagoons with highly radioactive sediment.

DURING the cleanup of Enewetak, the DOE engaged a team of scientists from the Lawrence Livermore Laboratory in Berkeley, California to conduct radiological surveys of the atoll. According to Dr. Ernst Reese, who was director of the marine research laboratory on Enewetak from 1977 to 1980, the DOE decided in 1979 to conduct "one last study using outside scientists"—marine specialists who would look under the ocean. "The DOE had made a mistake," says Reese. "They had all these fancy chemists studying the soil on the atoll but no one had really looked at the lagoon. The outside team uncovered a lot of new information."

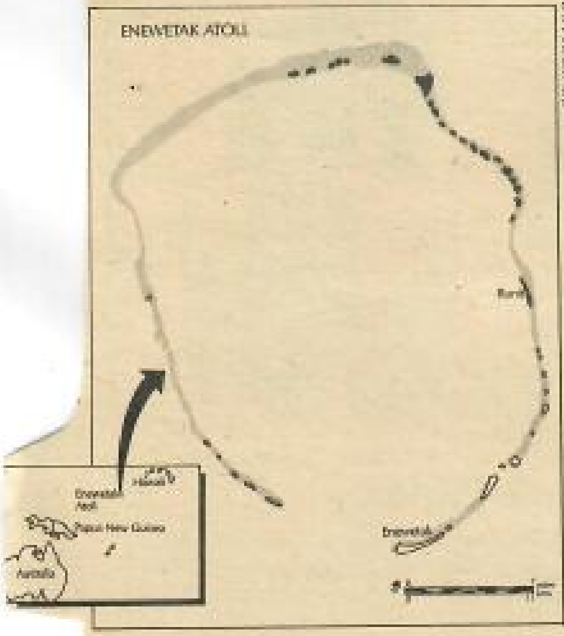
The agency brought in Patrick Colin to carry out the study. He became Reese's successor, running the laboratory from 1980 to 1983. Noting the high levels of radioactive elements in the lagoon and the presence of very active burrowing organisms, he recruited other scientists to work on the project, including Tom Suchanek, who was stud-

Legacy Surfaces off Enewetak Atoll

ying similar burrowers in the Virgin Islands.

"First we took core samples of the lagoon floor down to two meters," says Suchanek, "eighty centimeters lower than almost all the previous DOE tests. We found high levels of radionuclides such as plutonium 239 and 240, cobalt, and cesium, particularly between sixty and two-hundred centimeters deep. Second, we found many callianassid or ghost shrimp and other burrowers in the lagoon, and we saw that they were burrowing as deep as eighty centimeters."

The shrimp burrows, it turned out, intersected the core samples at the level of the highest concentration of radioactive particles, between 60 and 80 centimeters deep. While digging their burrows the shrimp were pumping the buried fallout particles up toward the lagoon floor. No one yet knows whether these particles find their way into the food chain and thus present a threat to



TINA HARNED

humans who might eat fish, crabs, or other marine organisms from the lagoon. The green turtle, for instance, feeds on certain types of green algae that are known to take up and concentrate plutonium 239 and 240.

Colin and Suchanek's work "was significant as the one main study done *besides* those done by DOE people," says Ernst Reese. But it came at a time when the department was already phasing out its radiological research on Enewetak, and in 1983 the laboratory was largely shut down. "Someone in the DOE made the decision that the research did not reveal a sufficient threat," says Reese. "But the agency has massive problems, like where to put tons of nuclear waste, that make Enewetak look like peanuts."

Dr. Roger Ray of the DOE explains that, as the U.S. military presence on Enewetak withdrew and the cleanup operation ended, "we changed the nature of our presence. When the cleanup was finished there was no other basis for us to be there. The area is 99-plus percent being turned back to its owners, who don't have the money or equipment to keep a lab active."

Robert Buddemeier, a radiologist from the Lawrence Livermore Lab who worked at Enewetak, questions the importance of the shrimp research. He calls it "a latter-day attempt at combining relevance with basic science. It's more a matter of interest than concern." He believes that the laboratory was not doing enough research "of primary use to the agency," and that budget considerations forced the DOE to make the "narrow but understandable decision to close it down."

But Dr. Phillip Helfrich, another scientist who worked at Enewetak, has a different view. "We thought we had something pretty exciting," he says, "but it got funneled into this vast machine where it was shoved in the back." The research team reported its findings to the DOE and asked for support to continue. "Their response was a lack of response," says Helfrich. "They just said, 'Thanks for the nice proposal.'"

NOW, despite all the risks, the Enewetakese are back on their atoll. The Marshall Islanders voted for the Compact of Free Association in 1983, gaining independence but leaving military jurisdiction to the U.S. The DOE lab is little more than empty buildings, visited occasionally by DOE ships that still monitor the lagoon's radioactivity. Although Roger Ray claims that "scientists are welcome on Enewetak," each researcher must raise his own money for transportation, food, and equipment on an island in the middle of the Pacific Ocean.

Although some have gone back to tiny Ujelang (where alcoholism and suicide are major killers), most of the Enewetakese remain on their home island. Other Pacific Islanders who were displaced by atomic testing—the people of Bikini, for instance—have not been allowed to return home. Although the Reagan administration in March pledged support for cleaning up Bikini, the DOE has estimated that "Bikini is 80 times more contaminated than Eneu, which is 30 times more contaminated than Enewetak." The administration approved $42 million for the Bikini cleanup, but the decision doesn't affect a lawsuit pending in U.S. Claims Court in which Bikini's tribal leaders are demanding $450 million from the U.S. government for destruction of the atoll's environment and their way of life.

Meanwhile, with Enewetak's lab effectively closed, Patrick Colin and Tom Suchanek turned to EARTHWATCH for support of their continuing shrimp research in the clear, nonradioactive waters off Papua New Guinea. Understanding how this little shrimp operates will help determine whether it poses a real threat to the people of Enewetak. Does the sediment-mixing actually introduce radioactive elements into the food chain? And if so, what is the ultimate fate of those particles?