2 of 3

11-18 NOVEMBER 00 - Midway IV 447 421

BALAZS Mead 2000

COMPOSITION

MIDWAY II Book

"NAVAL AIR FACILITY"

NAF

George Balazs

395-4409

100 sheets • 200 pages • 100 hojas
9¾ x 7½ in/24.7 x 19.0 cm
wide ruled/réglage large/rayado ancho

ME 429

FRIENDS OF MIDWAY ATOLL NATIONAL WILDLIFE REFUGE

WH6BLQ
George H. Balazs
992-A Awaawaanoa Place
Honolulu, Hawaii 96825

82

(33) End Days 5 (MT #56)

5:15PM

CAPTURE DATE, LOCATION AND METHOD: 11/16/00 Scoop Net outer side of NW Harbor Seawall
Midway-Sand Isl.

PERSON RECORDING DATA: Katie H.

OLD TAGS:

NEW TAGS: LHF 414B0D7334
RHF 414B682450

TUMOR SCORE: 0

OTHER NEW TAGS:

STRAIGHT CARAPACE-LENGTH:	50.1	WIDTH:	41.9
NOTCH LENGTH:	49.5	DB: L.O.	VB: L
CURVED CARAPACE LENGTH:	53	WIDTH:	48
HEAD WIDTH:	8.1	SEX: MALE, FEMALE OR UNDETERMINED	U
PPS: YES OR NO OR NE	Y		
TAIL LENGTH: T	11	C	8
RIGHT FRONT FLIPPER WIDTH:	9.1	SAMPLES COLLE	
PLASTRON LENGTH:	40.4		
WEIGHT:	36 lbs.		

DESCRIPTIVE REMARKS:
small extra scale, seam of plastron line cut, left front flipper, healed
Old line injury, left hind flipper 5 bumps-soft palette →
2.3 cc Liq. mototooled #56
left eye pic. - #5 axial - 18.5 esophagus flush sample collected
right eye pic. - #6 lateral - 17.8 full body pic - digital - #7

Digital
Mototoot 56

LEYE ..... MT 56 REYE ..... MT 56 DORSAL ..... MT 56

56LT	FAIR	MED	Very earliest sign we've been able to pick up on honu. That white banding along the corneal edge. Extremely subtle but enough to call up the Amber Light.	FP VULNERABLE
56RT	EXC	HI	Tissue normal –no problems	NORMAL

86

(25) MT29 Westwall Inner Harbor

15/17/00 Scoop Net Midway Sand Island

old TAGS LHF 41370C237D new TAGS
RHF41360F591C

R EYE MT29

SCL = 38.0 cm SCW = 31.9 cm

Notch 37.8 cm DB = VB = 8
CCL = 41 cm CCW = 37 cm
Head = 6.2 cm Axial - 15.4 cm
~~lateral - 14.9 cm~~
re-mototooled #29

PPS - Yes
TAIL 7 cm. C 4.5 cm
RFF 6.5 cm.
PLASTRON 30.1 cm full body pic. - #5 - print
D4 left eye pic. - #11
WT = 17 lbs. right eye pic - #12

~~8 ventral barnacles~~ - pic. #10 - collected, put in alcoho
3.0 cm. 3.0 cm 2.5 cm 3.0 cm
2.9 cm 2.5 cm 3.0 cm 3.0 cm

numerous large skin barnacles
some collected, alcoho

9-23-99
Tug Pier
SCL = 38.0
CCL = 41.0
FL = 30.3


✓BARNS...., MT29 ✓EYE..... MT29

wrong page

27RT	POOR	LOW	Poor focus –but if I had to call it the posterior looks suspicious enough to call a problem with that eye. Looks to have warping and white through it.	"something happening posterior. Possibly FP. Get better pic

goes on p.

27LT	GOOD	HI	Posterior looks fine	NORMAL

29RT	GOOD	HIGH	Connective tissue looks even gray, flat	NORMAL
29LT	EXC	HIGH	Pink/red caste to pic makes the connective tissue a tad suspicious but there's zero warping/veining or hint of white must call this normal especially along with RTEYE	NORMAL

(26)

MT 58

11/17/00 Scoop net Midway, Sand Island west wall INNER Harbor

old TAGS

NEW TAGS LHF 41351F5D79

RHF 41360C6077

SCL = 38.6 cm

SCW = 32.9 cm

NOTCH - 38.2 cm

CCL = 41.0 cm

Head = 6.3 cm

DB =

VB =

CCW = 38.5 cm

axial - 16.1 cm

lateral - 15.5 cm

PPS - yes

TAIL 7.5 cm c 4.5 cm

RFF - 6.5 cm

PLASTRON - 30.1 cm

WT = 18 lbs.

1.7 cc liq.

D4 left eye pic. - #13

right eye pic. - #14

Blood & DNA

~~mototooled - #58~~

LEYE.... MT58 REYE.... MT58

Mr Rice saw
[51] 8:00 [illegible]
at fishing

11/17/00 (27) FUEL PIER
~~[illegible]~~ fuel pier 3:00pm
SCUBA hand capture
Midway, Sand Island


none — 2 TAGS

LH 41351A476D

RH 41360E471E

LEYE..... MT59 REYE... MT59 ✓

SCL = 50.4

SCW = 42.0

59LT	AVE	MED	No detail to tissue but all looks ok	NORMAL
59RT	POOR	LOW	Lots of shadow in pic and tough to bring out detail. Still nothing threatening	NORMAL

NoTch = 50.0

DB = VB

CCL = 53.0

CCW = 49.0

Head = 7.8

PPS N

TAIL + 10 L 7

RFF 8.7

PLASTRON [illegible] length 39.9

Axial 17.9

WT = 36 lbs lateral 18.7

Tip of left front flipper injured slightly necrotic

PCA 2/3/00

samples stomach flush blood dots DNA

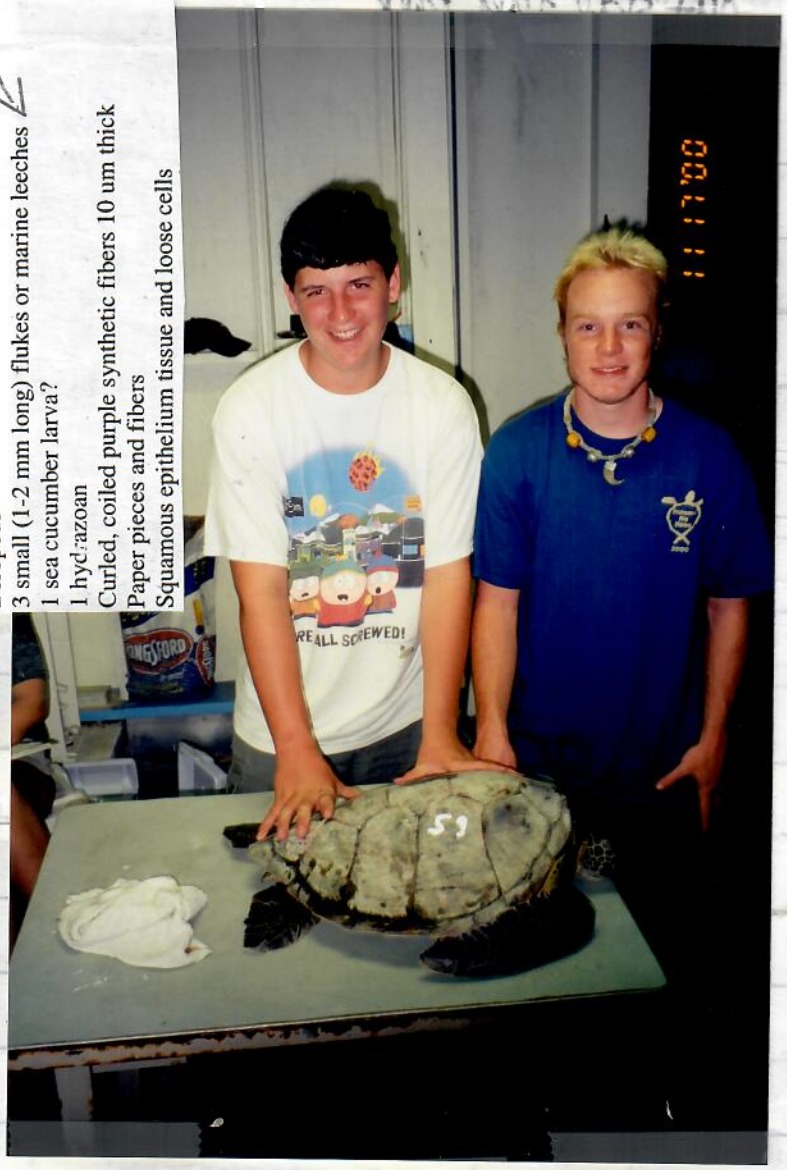
- left eye-15
- right eye-16

very mild fish

Mobtool #5

11-17-00 Midway Atoll, #41351A476D, MT #59, stomach flush

Centroceros clavulatum	Trace
Jania capillacea	Trace
Masses of jellyfish tissue with nematocysts	
2 amphipods	
2 isopods	
3 small (1-2 mm long) flukes or marine leeches	
1 sea cucumber larva?	
1 hydrozoan	
Curled, coiled purple synthetic fibers 10 um thick	
Paper pieces and fibers	
Squamous epithelium tissue and loose cells	



George,

1-4-01 from Dennis Russell

Attached are the results of the October / November 2000 turtle samples.

I will be sending you a hard copy of these results by mail (takes two weeks) along with a bill for these samples plus one other (the Mauna Lani fish pond sample), total nine samples.

Sample MT #59 had small flukes or marine leeches in it. I've seen these in other samples. Could there be small flukes or leeches in the esophagus of Green Turtles? They could be dislodged by the tubing during the flushing process. They are definitely parasitic worms with a sucker on the abdomen, a sucker mouth and it looks like a sucker at the tip of the tail (like a leech). Flukes have two suckers, one on the abdomen and one around the mouth. I'll send you a sketch of the thing.

glass float for barbra

11/17/00 ~~roadside~~ fuel pier 3:00

(28) SCUBA ~~road~~ hand capture

Midway, Sand Island

old tags none

New tags LH 413639640E

RH 413E486F5B

SCL = 58.0

SCW = 44.9

Notch = 58.0

DB = _____ VB = _____

CCL 61.5

CCW = 55.5

Head 1.3

PPS yes

Tail x 13.0 c 9.0

RFF 10.4

Plastron ~~46.8~~ length 46.8

weight ~~WT~~ = 54 lbs

full body - 10 print film

17 - digital left

18 - right digital

3.0 lig

Axial 32.2

Lateral 22.4

PLA

predominately dark carapace

~~fine scutes~~ thin scutes

sample fish

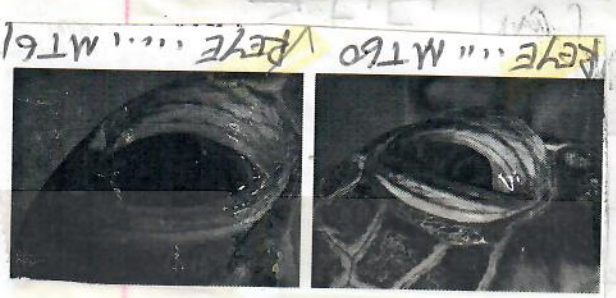
fish smell

stomach contents

blood dots

DNA

Mototag



60LT	GOOD	HIGH	Connective tissue looks dark and flat but what is that white at the corner? Magnifying doesn't help. Can't make it out. Would want a closer shot of this eye	NORMAL
60RT	EXC	HIGH	Posterior and tissue look fine.	NORMAL

11-17-00 Midway Atoll, #413639640E, MT #60, stomach flush

Laurencia nidifica	90%
Codium cuniatum	5
Laurencia sp.	4
Centroceros clavulatum	1
Ceramium sp.	Trace
Griffithsia sp.	Trace
Halophila hawaiiana	Trace
Polysiphonia sp.	Trace
Sphacelaria tribuloides	Trace
Spyridia filamentosa	Trace

Squamous epithelia cells abundant

94 11/17/00 Cargo pier 4:00 END DAY 6

29 Turtles Total This Trip // SCUBA hand capture

Midway/Sand Island

END Midway 11-

413E0E025

RH 413572C7

LEYE.... MT 61

Ntags= LH

SCL= 77.2

SCW= 63.2

Notch= 76.9

CCL 83.0

Head 10.6

DB= VB=

CCW 77.5

61LT	GOOD	HIGH	Connective tissue looks fine. The very posterior near corner of eye is a lighter colour than I'd like to see. But tissue looks flat and even	NORMAL
61RT	POOR	LOW	Shot wrong angle when I need to see as much of posterior as possible. Very little here to asses. Nothing obvious.	NORMAL

PPS N

TailT 24 C 16

RFF injured

Plastron ~~Width~~ → length 63.5

weight 141 lbs

Axial 31.0

Lateral 31.1

21, 19 - digital right eye } end of circ 4

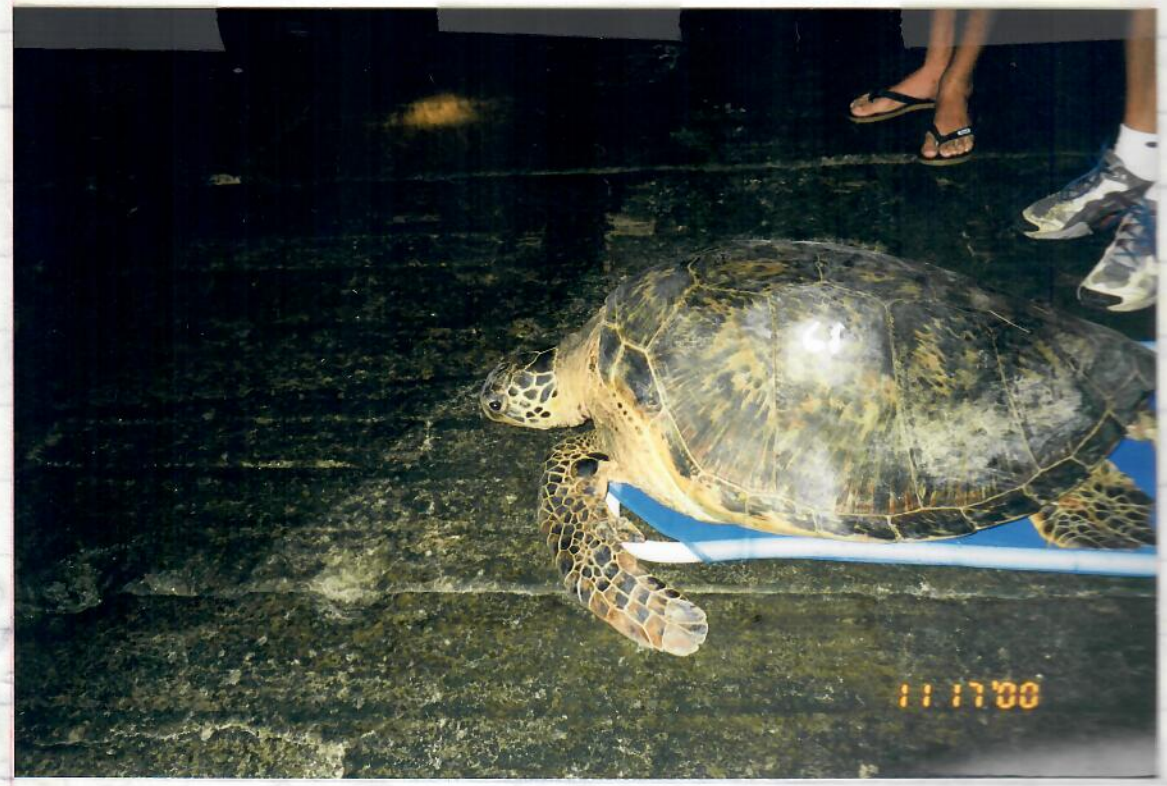
20 - digital left eye }

5.6 kg Pallet

5 soft jumps

sample blood clots DNA

Mototool #


11 17 00

MOTOTOOL #22 Recovery 1-17-01

SEA TURTLE TAGGING FORM

CAPTURE DATE, LOCATION AND METHOD:

29 APRIL 1999 SAND ISLAND MIDWAY ATOLL TURTLE BEACH BASKING

PERSON RECORDING DATA: BRUCE ROGERS

OLD TAGS:

NEW TAGS: HRF 411C710056

HLF 411C3D1C4E

TUMOR SCORE: 0

OTHER NEW TAGS:

STRAIGHT CARAPACE-LENGTH: 80.3 WIDTH: 64.5

NOTCH LENGTH: 79.5 DB: L.O. VB: L.O.

CURVED CARAPACE LENGTH: 86.0 WIDTH: 79.0

HEAD WIDTH: 11.5

SEX: MALE, FEMALE OR UNDETERMINED: U

PPS: YES OR NO OR NE: Y

TAIL LENGTH: T 18.0 C 10.0

RIGHT FRONT FLIPPER WIDTH: 12.4 SAMPLES COLLECTED:

PLASTRON LENGTH:

WEIGHT:

DESCRIPTIVE REMARKS:

MOTOTOOL # 22 2nd lateral RF. + left

01/17/01 recaptured: Curved carapace length: 91.5 width: 84.

Straight carapace length: 85.3

Notch length: 84.6

number was engraved again & new paint applied on 17 Jan 01

1/17/01 = 85.3

4/29/99 80.3

5.0cm

2.8cm/year

04/29/00 = 12 +9 =

AN outstanding turtle doing something better than the others!

Range = 38.0 - 91.5 cm SCL (But missing 2 my subadults 65-81 cm)

Date

Date Rec.

Growth Summary Midway IV

MT #	orig TAG	SCL	WT		SCL	WT	
29	9/23/99	38.0	—	11/17/00	38.0 J	17 lbs	0 cm No growth
				14 months = 1.2 years			
~~05~~	10/18/98	47.6	43 lbs	11/14/00	53.2 J	56 lbs	5.6 cm
				25 months = 2.1 years			2.7 cm/year
~~08~~	4/12/99	91.5	—	11/14/00	91.9 Adult	—	0.4 cm
				19 months = 1.6 years			Nil - no growth
33	"99-10-8"	~~83.8~~	—	11/13/00	83.4 Adult	—	0.4 cm ?
				13 months? = 2.1 years			Nil No growth
16	10/16/98	42.5	20 lbs	11/13/00	~~43.4~~ 43.4 J	25 lbs	0.9 cm
				25 months = 2.1 years			0.4 cm/year
27	~~9/23/99~~	~~44.5~~	26 lbs	11/12/00	44.8 J	26 lbs	0.3 cm
				~~14~~ months = 1.2 years			0.3 cm/year
13	3/27/99	40.7	—	11/12/00	41.4 J	19 lbs	0.7 cm
				20 months = 1.8 years			0.4 cm/yr
"20" Mistake	10/18/98	46.7	31 lbs	11/12/00	48.3 J	33 lbs	1.6 cm
				25 months = 2.1 years			0.8 cm/year
14	4/4/99	45.5	—	11/12/00	45.7 J	25 lbs	0.2 cm
				19 months = 1.6 years			Nil No growth

Interval 14 - 25 months (1.2 - 2.1 years)

Adults = 2
Subadults = 0
Juveniles = 7

N = 9

4 = No growth
4 = 0.3 - 0.8 cm/year (1/8" - 5/16"/year)
1 = 2.7 cm/year

Equal to main islands MT 15

Nancy Type? 30 Oct. 00 CYNTHIA VANDERLIP necropsy

(98)

SEA TURTLE TAGGING FORM

All samples brought to NMFS by GHB 11/18/00

Dead = Buried Cynthia showed me the spot 11-18-00

CAPTURE DATE, LOCATION AND METHOD: 10/30/00 Found floating off turtle beach 1-2 days old
First seen @ 1515 Sand Is, Midway

PERSON RECORDING DATA: Anja Schiller

OLD TAGS: No tags
NO PIT TAGS (Scanned w/monk seal reader)

NEW TAGS: RFL
LFL

TUMOR SCORE: 0

OTHER NEW TAGS:

STRAIGHT CARAPACE-LENGTH: 62.5 WIDTH: 50.3

NOTCH LENGTH: 61.8 DB: L.O. VB: L.O.

CURVED CARAPACE LENGTH: 69.0 WIDTH: 64.0

HEAD WIDTH: 9.0

SEX: MALE, FEMALE OR UNDETERMINED: ?

PPS: YES OR NO OR NE

TAIL LENGTH: T C 7 28

RIGHT FRONT FLIPPER WIDTH: 11.0

SAMPLES COLLECTED:

PLASTRON LENGTH: 50.5

WEIGHT: ~40 lbs

DESCRIPTIVE REMARKS:

Need copy

Notes: Photo taken with Cynthea's camera.
Cynthia Vanderlip did a partial necropsy
Took samples from throat (contents) sand
Lower throat algae

Took sample of stm
Frozen stomach contents @ OSE freezer

NMFS Survival factor #204

Also
(SKIN sample for DNA preserved)

ID 10-30-00 Midway fatality

ID
10-30-00
Midway fatality

BAG A

BAG B

Based on these contents, Halophila must still be present off Sand Turtle Beach 10/00 11/00

	DNA	Whole MT Blood
41356E0318	✓	48 N=
413E0E0254	✓	61 SKIN IN Alcohol N=2
4135090963	✓	46 Total
413E330454	✓	50 N
~~4136329938~~	✓	44 Duplicate
4135 1F5D79	✓	58 Fedex # 11-27-09
413E374C7D	✓	57
~~413B2647 6C~~	✓	18 Duplicate

4136342335 ✓ SKIN IN Alcohol MT= 5
cryotube

Marine Turtle Research
NMFS HONOLULU LAB
2570 Dole Street
Honolulu, HI 96822-2396

"O" = sorted confirmed by GHB 11/26/00 in AR

ID PIT TAGS	MOTOTOOL NO.	Leeches and or Tumors	DNA Blood N=12	Feces of Mouth or Esophagus FLUSH	BARNS
413E3A4763 O ✓	43		O ✓		✓ (1)
4Ø7A45387B O ✓	44		O ✓		✓ (1)
41363F315B O ✓	45	✓L	O ✓		
413E2DØ127 O ✓	47		O ✓		✓ (1)
41Ø4134854 O ✓	16		O ✓		✓ (4)
4Ø77597E29 O ✓	33	✓ T x2	O ✓		
414BØØ5762	18		✓		
413596EØE O ✓	51	✓L	O ✓	O ✓	
1F71572178 O ✓	15		O ✓		✓ (1)
41361345Ø9 O ✓	None		O ✓		
413574 7E3F O ✓	52		O ✓		✓ (1)
4135Ø87C4A O ✓	53		O ✓		✓ (4)
413566 3E4D O ✓	54		O ✓		✓ (1)
* 4136342335 O	55	in alcohol	O ✓	O ✓ feces	✓ (2)
414BØD7334 O ✓	56		O ✓	✓	
41370C237D O ✓	29		O ✓		✓ (2)
41351A476D O ✓	59		O ✓	O ✓	
4136396 4ØE O ✓	60		O ✓	O ✓	
ID 10-30-ØØ Midway — Necropsy see p. 98 Vial			O ✓ skin in alcohol	2 packets ✓ stomach	

Sample ID List Peter

MiDwAy Green Turtle Samples

Fedex to Peter Dutton 11-27-00

#8215-1157-9800 ON BLUE ICE

Whole Blood N=18 and N=2 IN Alcohol

Date	ID PIT TAGS	MT
11-12-00	413E3A4763	43
11-13-00	41363F315B	45
11-13-00	4077597E29	33
11-14-00	4135796E0E	51
11-14-00	4136134509	None
11-15-00	4135747E3F	52
11-15-00	4135087C4A	53
11-15-00	4135663E4D	54
11-16-00	4136342335 Alcohol	55
11-16-00	41430D7334	56
11-17-00	41370C237D	29
11-17-00	41351A476D	59
11-17-00	41363964dE	60
ID 10-30-00	Midway (Alcohol) seep98	Necropsy

	ID	MT
	41356E0318	48
	413E0E0254	61
RHF	4135090963	46
	413E330454	50
	41351F5D79	58
	413E3740?D	57

28°15' N

20 Samples enclosed

177°25' W

Marine Turtle Research
NMFS HONOLULU LAB
2570 Dole Street
Honolulu, HI 96822-2396

101

Marine Turtle Research
NMFS HONOLULU LAB
2570 Dole Street
Honolulu, HI 96822-2396

MIDWAY GREEN TURTLES ~~to Dennis~~ Russell

Mouth Sample Vials and Flush and Stomach and Fecal

NOV. ØØ

PIT TAG	DATE	MT #
4135796EØE mouth	11-14-00	51
414B682450 Flush	11-16-00	56
41351A476D Flush	11-17-00	59
41363964ØE Flush	11-17-00	60
1F6D676D2Ø mouth	11-14-00	15
4136342335 Fecal	11-16-00	55

N=6

+N=2 (below for one Turtle - Cynthia necropsy)

ID 10-30-ØØ A Stomach Necropsy MIDWAY ALSO

ID 10-30-00 B Stomach

Xerox of this page sent w/ Fedex.

Fedex 11-27-00 To Dennis UAE # 8249 7221 9382

Fedex 12/7/00 # 8215-1157-9487

DMSO Cryo Vial to Dutton "10-31-99" A219 "heart, live, skin" 2ml DMSO cryo vial.

12-6-00 Fedex TO Peter Dutton
MIDWAY g.t. STRN Biopsies

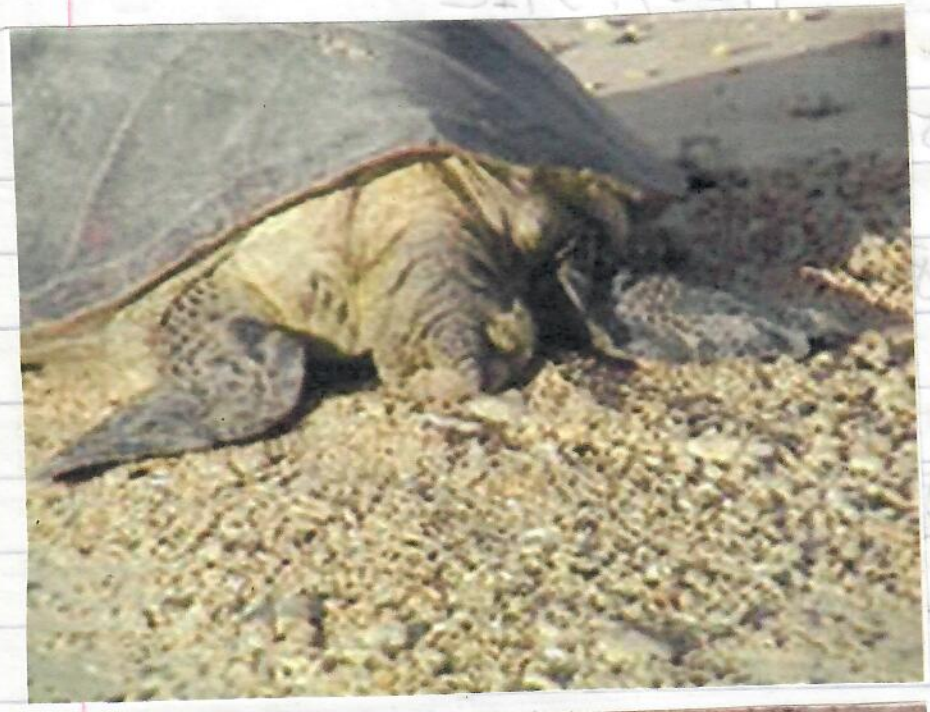
Marine Turtle Research
NMFS HONOLULU LAB
2570 Dole Street
Honolulu, HI 96822-2396

DATE	ID#	PIT TAG
9-23-99	MT27	413533ØA3F
9-23-99	MT29	4136ØF591C
9-23-99	MT25	41345FØØØ4
9-23-99	MT28	413643195F

28°15'N, 177°25'W

<STYLE></STYLE>
</HEAD>
<BODY><DEFANGED-BODY bgColor=#ffffff>
<DIV><FONT face=Arial size=2>George, hey dude! We had five turtles on turtle beach yesterday. #34, 41, 22, and two untagged. We boxed one female and gave (#62. In the process the other untagged turtle went back in the water. got #22 and freshened up it's number and took a few measurements. Attached few photos of #62. This turtle had a prolapsed cloaca. Why? Diet? Stress It other wise looked healthy. I will send off the data sheet and photos you on the Sat flight. Please let me know what you think about this female's prolapse. hope all is well, later, Nancy PS I will have to send the photo's separate emails because of their size.</FONT></DIV></BODY></HTML>

Nancy 18JAN01 #62



#62?

#62

Date: Sat, 25 Nov 2000 09:28:52 -1000 (HST)
From: "George H. Balazs" <gbalazs@honlab.nmfs.hawaii.edu>
To: Ron <ranglin@midwayisland.net>, Nancy <nhoffman@midwayisland.net>,
Ken <kniethammer@midwayisland.net>,
Jennifer <jschramm@midwayisland.net>
Subject: Re: Freezer for turtle fatalities at Midway

To maximize the research value (leading to management value) of any and all dead turtles or turtle parts found at Midway, it's occurred to me that a lift-top freezer (22 cuft) would be very valuable to have on-site. A freezer dedicated for sea turtles, no matter what stage of decomposition. We regularly purchase these fairly cheap ($700) in my program for long-term loan placement on the neighbor island (NOAA sanctuary Maui office, DLNR, HPA in Waimea, UH Hilo, etc). Having such a freezer at Midway would not preclude on-site necropsies (fresh tissues into formalin) if/when the carcass is Very Fresh, and there are personnel with time available to do the cutting. For less-than-fresh carcasses, freezing them will make eventual shipment to Honolulu a much easier task. The alternative now, of burying a carcass, is certainly better than nothing (humeri bones can be collected later for aging studies). However, having a turtle-dedicated freezer on-site would be vastly improved circumstance.

If such a freezer was bought for Midway by my program, would FWS be able to arrange for shipment to Midway, and have a place in your offices where it can be installed? I'm eager to hear your thoughts. Aloha, George

Date: Sun, 26 Nov 2000 13:41:05 -1000 (HST)
From: "George H. Balazs" <gbalazs@honlab.nmfs.hawaii.edu>
To: Ron <ranglin@midwayisland.net>, Nancy <nhoffman@midwayisland.net>,
Ken <kniethammer@midwayisland.net>,
Jennifer <jschramm@midwayisland.net>
Subject: Jumbo Animal Carrier at Midway?

Can you please confirm for me that there is still a jumbo animal carrier at Midway, that I previous sent up there for potentially severe cases of live tumored turtles encountered. I don't recall see one at the FWS storage area during our recent visit. However, many it's being kept elsewhere. Let me know, please, if there isn't one there I'll make arrangement to ship on up to you. Aloha, George

SEA TURTLE TAGGING FORM

MOTOTOOL #62

CAPTURE DATE, LOCATION AND METHOD:

9/7/01 Sand Island, Midway Atoll NWR, Turtle Beach, ~~Hard~~ BASKING
1/17/01

PERSON RECORDING DATA: Amy Martin

OLD TAGS: No tags / No Pit tags

NEW TAGS: ~~RPF~~ RHF 4136356E27

~~LFF~~ LHF 4135704F6D

TUMOR SCORE: 0

OTHER NEW TAGS:

STRAIGHT CARAPACE-LENGTH: 91 WIDTH: 72

NOTCH LENGTH: 90.4 DB: — L.O. VB: — L.O.

CURVED CARAPACE LENGTH: 95.4 WIDTH: 95.5

HEAD WIDTH: 13.5

SEX: MALE, FEMALE OR UNDETERMINED: F

PPS: YES OR NO OR NE: NE

TAIL LENGTH: T 26 C 21

RIGHT FRONT FLIPPER WIDTH: 15.2

SAMPLES COLLECTED:

PLASTRON LENGTH: —

photo on p. 114

WEIGHT: —

DESCRIPTIVE REMARKS:

Prolapsed cloaca, A lot of white discharge from eyes
Mototool #62

Midway Atoll Green Turtle Algae Samples

Results of identifications done by Dennis J. Russell on December 30, 2000

11-14-00 Midway Atoll, #4135796E0E, MT #51, mouth sample

Spyridia filamentosa	All

11-16-00 Midway Atoll, #414B682450, MT #56, stomach flush

Halophila hawaiiana	95%
Spyridia filamentosa	3
Zonaria sp.	2
Hypnea sp.	1
Centroceros clavulatum	Trace
Cladophora sp.	Trace
Sargassum sp.	Trace

1 micromollusc snail
1 amphipod

11-17-00 Midway Atoll, #41351A476D, MT #59, stomach flush

Centroceros clavulatum	Trace
Jania capillacea	Trace

Masses of jellyfish tissue with nematocystes
2 amphipods
2 isopods
3 small (1-2 mm long) flukes or marine leeches
1 sea cucumber larva?
1 hydrazoan
Curled, coiled purple synthetic fibers 10 um thick
Paper pieces and fibers
Squamous epithelium tissue and loose cells

11-17-00 Midway Atoll, #413639640E, MT #60, stomach flush

Laurencia nidifica	90%
Codium cuniatum	5
Laurencia sp.	4
Centroceros clavulatum	1
Ceramium sp.	Trace
Griffithsia sp.	Trace
Halophila hawaiiana	Trace
Polysiphonia sp.	Trace
Sphacelaria tribuloides	Trace
Spyridia filamentosa	Trace

Squamous epithelia cells abundant

(5)

11-14-00 Midway Atoll, #1F6D676D20, MT #15, mouth sample

Hypnea nidifica	Trace
Dictyota crenulata	Trace

(6)

11-16-00 Midway Atoll, #4136342335, MT #55, fecal samples

Halimeda sp.	Trace
Lyngbya majuscula	Trace

Terrestrial vegetation (trace)
Spong spicules, masses and major bulk of sample contents
Turquois blue paint chips

(7)

10-30-00 Midway Atoll, Stomach necropsy sample A

Halophila hawaiiana (with nice flowers)	90%
Codium cuneatum	10
Laurencia sp.	Trace
Microdictyon setchellianum	Trace

Orange sponge spicules and small chunks

10-30-00 Midway Atoll, Stomach necropsy sample B

Halophila hawaiiana	99%
Tufts of filamentous meshwork red algae (looks like the tips off *Galaxaura* sp.)	1

Bright orange sponge, 2 cm^3

Summary of species found in these samples:

Chlorophyta

Cladophora sp.
Codium cuniatum
Halimeda sp.
Microdictyon setchellianum

Sea Grass

Halophila hawaiiana

Phaeophyta

Dictyota crenulata
Sargassum sp.
Sphacelaria tribuloides
Zonaria sp.

Rhodophyta

Ceramium sp.
Griffithsia sp.
Galaxaura ?
Hypnea nidifica
Hypnea sp.
Jania capillacea
Laurencia nidifica
Laurencia sp.
Polysiphonia sp.
Spyridia filamentosa

Cyanophyta

Lyngbya majuscula

Midway Island, U. S. A.

By E. H. Bryan, Jr.

MIDWAY atoll crowns the summit of the next to the last peak from the northwest end of Hawaii's submerged mountain range. It is 1,150 miles northwest of Honolulu, 90 miles beyond Pearl and Hermes Reef, and 50 miles east of Kure, the final island of the chain. It consists of a nearly circular rim of coral reef, about 5 miles in diameter, enclosing a lagoon, the central portion of which ranges in depth from 25 to 50 feet, surrounded by a considerable expanse of shallower water. Much of the reef, especially on the northeast, forms a continuous flat-topped wall, standing some 5 feet out of the water and 6 to 15 feet wide. Some of it consists of irregular rocks, just about reaching the surface, and the west side, to the north of Seward Road, which gives entrance to Welles Harbor, is open, with only a few patches of reef.

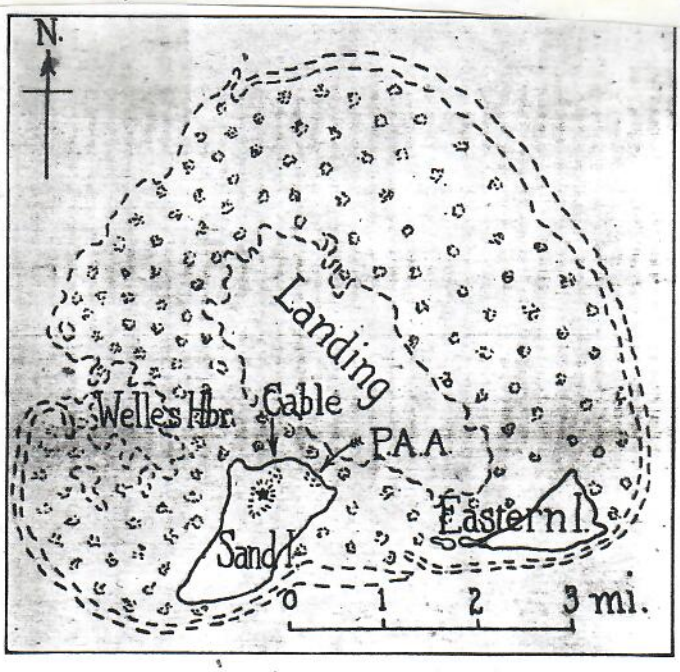
Close to the southern rim of the atoll lie two low islands. Sand Island, the larger, measures a mile and a half long by a mile wide, and has a hill which reaches a maximum elevation of 43 feet, topped by a light. Formerly composed of nearly bare sand, now grass, shrubs, and trees have been planted on it by man until it is well wooded. Eastern Island is triangular in shape, about a mile and a quarter long by three-quarters of a mile wide. Of more compact soil, it has supported a growth of low scrub, including native species, since long before its discovery, and consequently has been called Green Island. Between these two islands there is a small passage, with a break in the south reef, such that a row boat can get through into the lagoon.

Page 1

On Sand Island, near the north end, are now located a relay station of the Commercial Pacific Cable Company, established in 1902, and installations of the Pan American Airways. The lagoon provides a spacious landing place for the Trans-Pacific clippers at the end of their first jump from Honolulu toward Wake, Guam, Manila, and China. Midway is the only island in the "little end of Hawaii" which at present has permanent residents. On January 20, 1903, Midway was placed under the jurisdiction of the U. S. Navy Department, not being an official part of the Territory of Hawaii.

Midway was discovered July 8, 1859, by Captain N. C. Brooks of the Hawaiian bark *Gambia*, and by him called Middlebrook Islands. An account of this discovery, reprinted from the Polynesian of August 13, 1859, appears in the Paradise of the Pacific for October, 1936, on page 23. Captain Brooks took possession of the two islands in the name of the United States, a peculiar proceeding in view of the flag of his vessel, owned by B. F. Snow of Honolulu. Had he given the editors of the Polynesian a less glowing account of the new discovery, we would be inclined to believe the story that Captain Brooks kept the discovery secret so that he might sell the information to the North Pacific Mail and Steamship Company, who were on the lookout for a mid-Pacific coal depot for their vessels on the oriental run.

However that may be, the Pacific Mail Steamship Company learned about the atoll, and eight years later succeeded in having the American government send the U. S. S. *Lackawanna* to make a careful survey. With considerable cere-



Midway Islands—Drawn by E. H. Bryan, Jr.

mony, on Wednesday, August 28, 1867, in compliance with the orders of the Secretary of the Navy, formal possession was taken of what was termed Brooks' Island. Wrote Captain William Reynolds, commander of the *Lackawanna*: "It is exceedingly gratifying to me to have been thus concerned in taking possession of the first island ever added to the dominion of the United States beyond our shores, and I sincerely hope that this will by no means be the last of our insular annexations. I ventured to name the only harbor at this island after the present Honorable Secretary of the Navy (Welles), and to call its roadstead after the present Honorable Secretary of State (Seward)."

In 1870 the United States Congress appropriated $50,000 to be spent in blasting a 600-foot wide ship channel through the reef into the lagoon, doubtless at the insistence of the Pacific Mail Steamship Co., and based on observations made by the *Lackawanna*. The U. S. S. *Saginaw* was detailed to carry divers and equipment to Midway, arriving there on March 24, 1870. Dredging proceeded during the summer of 1870, but the weather was so bad that at the end of seven months little had been accomplished, the funds nearly exhausted, and the project was given up. The story of how the *Saginaw* was wrecked on Kure Island on its way back to Honolulu, has no place here, as we discussed it in our article on Kure Island. A full account of it has been given by George H. Read, in his "Last cruise of the *Saginaw*."

On November 16, 1886, the little fishing schooner *General Seigel*, at anchor in Welles Harbor, was hit by a sudden gale and went to pieces on the reef. The gruesome adventures of its seven castaways, and how one of their number, Adolph Jorgensen, was left behind by his companions, is a well-known story, made famous by John Cameron's Odyssey. So also is the story of the manner in which, when he was about to be rescued by the 467-ton schooner *Wandering*

Continued on Page Twenty-Nine

MIDWAY ISLAND, U. S. A.

Continued from Page Seven

Minstrel, that vessel also was wrecked in almost the same spot. Five of the crew made off in one of the boats and were never heard of again. John Cameron, Jorgensen, and a Chinese boy, in another of the boats, succeeded in making the trip from there to Jaluit in the Marshall Islands. Captain F. D. Walker, his wife, three sons, and the remainder of the crew, who didn't die, lived for 14 months on the island until rescued by the fishing schooner *Norma*, March 16, 1889, and returned to Honolulu, April 7, 1889. If one believes John Cameron's Odyssey, Captain Walker appeared to have intentionally wrecked the *Wandering Minstrel* on Midway, and Jorgenson was not such a bad fellow, just little *pupule*. If, on the other hand, we accept the statements of Captain and Mrs. Walker (one account appears in the Paradise of the Pacific for November, 1936, pages 27-29), Jorgensen was a killer, and Cameron was little better.

Several naturalists visited Midway around the turn of the century: Henry Palmer, bird collector for Hon. Walter Rothschild, in July, 1891, and William Alanson Bryan, in August, 1902. The latter gives the last account of observations made on the island prior to the Cable Company installations, made later the same year and during 1903. (Oc-

casional Papers of B. P. Bishop Museum, vol. II, no. 4, pp. 291-299, 1906) The schooner *Julia E. Whalen* was wrecked on Midway, October 22, 1903, while bringing supplies to the newly established cable station. The British bark *Carrollton*, with a load of coal from Newcastle for Honolulu, was lost on Midway, December 28, 1906. The crew was rescued by the cable ship *Restorer*. The Pacific Mail S. S. *Mongolia* went aground on the western side September 16, 1906, but succeeded in getting off again even before the arrival of the *Buford, Iroquois*, and *Restorer*, which went to her aid from Honolulu.

One might ask why so many wrecks have occurred on Midway. The answer is that the atoll is very low and hard to see, and also that it is subject, especially in the winter, to sudden and severe storms. Midway, although only about 400 miles further north than Honolulu, is no longer in the tropics, and has a much more temperate climate, which in winter becomes quite cold. This, together with the heavy winds, which drive the loose sand into every nook and corner, rule out this island as a winter resort. But in summer the climate is delightful. The position of Midway is 28 degrees 12 minutes 52 seconds north, 177 degrees 22 minutes 46 seconds west of Greenwich.

Perhaps the outstanding fact about the natural history of Midway is the great change which Sand Island has undergone through the efforts of man. When the cable station was established, there were no trees and shrubs, and scarcely any herbs to keep the shifting sand in place. Daniel Morrison went to Midway as superintendent of the cable station in 1906, remaining until 1921. He imported a coarse grass (*Ammophila arenaria*) from the windswept beaches near San Francisco, and with it succeeded in holding the sand in place. He set out ironwood trees (*Casuarina equisetifolia*) as windbreaks, and numerous other kinds of ornamental and useful trees, shrubs, and herbs. Ship loads of soil were brought from Honolulu and used to encourage gardens and other plant growth. Mr. Morrison also imported canary birds and Laysan finches in 1906, and fostered the flightless rails which had also been introduced from Laysan. The island has been turned into quite a beauty spot, with livestock, poultry, lawns, and airy, spacious quarters, and now a good hotel, to attract the visitor, who might also be interested in splendid fishing.

The *Tanager* expedition, which explored the northwest Hawaiian islands in 1923, obtained a few specimens from Midway, to which have been added notes and specimens by Dr. D. R. Chisholm and others. The writer has a lengthy record of the plants, birds, insects, and fishes of the island and its adjacent waters, some of which have been published in Bishop Museum Bulletins 26, 27, 31, and 81, and other publications.

Now we read of a sudden awakening of interest in Midway on the part of the U. S. Navy and Army, and plans on foot to improve the harbor facilities of the atoll. This is not the first time such improvements have been contemplated. It is to be hoped that this will be more successful than earlier efforts. Edwin North McClellan, present editor of the Paradise of the Pacific, writing in the Honolulu Advertiser of September 16, 1927, reminds us that in March, 1904, Marines were ordered to Midway to "protect property and guard the cable employees from marauders who might visit the islands to kill the sea birds." A detachment arrived on Midway May 2, 1904, and set up two six-pounders; but they were withdrawn in the spring of 1908.

Of considerable value to the interests of Hawaii at present, with rapid and direct means of transportation from the Orient, is the "insect filter" which was established when F. C. Hadden, entomologist, was stationed on Midway, on November 24, 1936. His duty is to inspect and fumigate the clipper planes going in both directions. Already he has headed off insect pests which might have done considerable damage to the agriculture of Hawaii, (See Paradise of the Pacific for Jan. 1937, pp. 16, 30).

Weather observations were started on Midway in May, 1917. Now, with trans-Pacific flying, much more detailed weather data is being collected and sent to Honolulu. As many of the storms approach Hawaii from that direction, these observations are of great value in helping local weather forcasters.

Thus, with clipper landing facilities, cable relay station, insect filter, weather station, and potential advantages as a summer resort, Midway is a very useful and desirable little neighbor, and a valuable asset to the U.S.A., even though it isn't an official part of the Territory of Hawaii, and of the City and County of Honolulu, as it has frequently been considered.

PARADISE
OF THE PACIFIC
HAWAII'S ILLUSTRATED MONTHLY MAGAZINE
June 1938 50(6)

See p.109

Mototool 62

Thanks Mr. Balazs for a wonderful trip. I hope to have many more in the future. Mahalo. Katie Harrington

Thank You for teaching me so much. I had a great time

John,

Dear Mr. Balazs,

Thank you very much for giving us the opportunity to accompany you to Midway Atoll. We all learned a tremendous amount and had a great time.

Thank you Mr. Balazs. I had a great time.
Jilly

Thank you so much for the wonderful experience.
Dylan

Thank you so much for helping us tag and realese the turtles. I learned a lot.
Kelly

Many thanks for everything you did for us. You are a truly great guy and a joy to work with. Thanks Again,
Alika Brooks

Thanks,
M

24 March 01

Hi George!

Attached are data from three new turtles. It was a stellary day on Friday for basking Turtles on turtle beach. We had five turtles on the beach (two marked - #41 & #62). We had one leave before we get our equipment together. But, while finishing up the second turtle, a huge male pulled out onto the beach about 10 meters from us! So, once finished w/#64, we boxed the future #65! Then, another male started to haul out - it had a old # on the carapace & a red, right eye. But, it got almost totally out of the water & decided it was a little to close to us (≈5m) & swam away slowly.

Sorry about photo of turtle #63 - it is an action shot of a turtle flying!

More later! Nancy

P.S, We only have 8 more PIT tags. Would you please send us more OR do we need to purchase them? Would you please send me a replacement dermel tool bit? Ours is a very dull/worn

U

SEA TURTLE TAGGING FORM

#63

CAPTURE DATE, LOCATION AND METHOD:

Sand Island, Midway Atoll NWR - Turtle Beach 23 March 2001 Basking Hand/Box

PERSON RECORDING DATA: Kat Hokamura

OLD TAGS:

NEW TAGS: LFF ~~RFF~~ 413E3B7E6F

~~LFL~~ LHF 4136412D5F

TUMOR SCORE: 0

OTHER NEW TAGS:

STRAIGHT CARAPACE-LENGTH: 69.7 WIDTH: 55.0

NOTCH LENGTH: 69.5 DB: L.O. VB: L.O.

CURVED CARAPACE LENGTH: 73.6 WIDTH: 68.5

HEAD WIDTH: 10.3

SEX: MALE, FEMALE OR UNDETERMINED: U

PS: YES OR NO OR NE: YES

TAIL LENGTH: T 15.5 C 12.0

RIGHT FRONT FLIPPER WIDTH: 12.2

SAMPLES COLLECTED:

PLASTRON LENGTH: U

WEIGHT: -

DESCRIPTIVE REMARKS:

MOTO TOOL #63

SEA TURTLE TAGGING FORM #64

CAPTURE DATE, LOCATION AND METHOD:

SAND ISLAND- TURTLE BEACH 23 MARCH 2001
Midway Atoll NWR
Basking/Hand

PERSON RECORDING DATA: Kat Hokama

OLD TAGS:

NEW TAGS: LFF ~~RFF~~ 413E2B0C33
LHF ~~LHF~~ 41363A2F55

TUMOR SCORE: 0

OTHER NEW TAGS:

STRAIGHT CARAPACE-LENGTH: 61.0 WIDTH: 51.5

NOTCH LENGTH: 60.8 DB: L.O. VB: L.O.

CURVED CARAPACE LENGTH: 64.3 WIDTH: 61.8

HEAD WIDTH: 9.3 SEX: MALE, FEMALE OR UNDETERMINED

PS: YES OR NO OR NE

TAIL LENGTH: T 9.0 C 7.0

RIGHT FRONT FLIPPER WIDTH: 9.9 SAMPLES COLLECTED:

PLASTRON LENGTH: 4

WEIGHT: —

DESCRIPTIVE REMARKS: Notch on (L)-hind side of carapace

MOTO TOOL #64

U

SEA TURTLE TAGGING FORM

#65

CAPTURE DATE, LOCATION AND METHOD:

Sand Island - Turtle Beach, Midway Atoll NWR — 23 March 2003

Basking/hand box

PERSON RECORDING DATA: Kat Hokama

OLD TAGS:

NEW TAGS: LHF ~~[illegible]~~ 413D7F2547

RHF ~~[illegible]~~ 4136421A5C

TUMOR SCORE:

OTHER NEW TAGS:

STRAIGHT CARAPACE-LENGTH: 87.1 WIDTH: 63.4

NOTCH LENGTH: 86.8 DB: L.O. VB: L.O.

CURVED CARAPACE-LENGTH: 90.5 WIDTH: 84.2

HEAD WIDTH: 12.1

SEX: MALE, FEMALE OR UNDETERMINED: M

'S: YES OR NO OR NE: U

TAIL LENGTH: T 42.0 C ~32.0

RIGHT FRONT FLIPPER WIDTH: 14.5

SAMPLES COLLECTED:

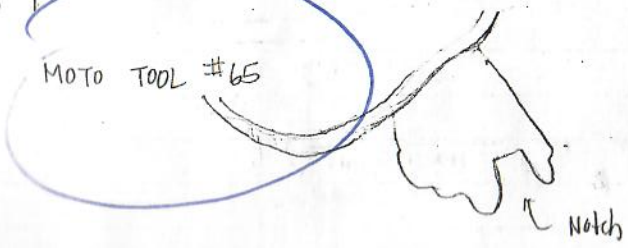
PLASTRON LENGTH: U

WEIGHT: —

Notch on (R) hind flipper

DESCRIPTIVE REMARKS:

MOTO TOOL #65



(R) Hind Flipper

121

NoLT	EXC	HIGH	Posterior and tissue look fine.	NORMAL
NoRT	FAIR	MED	Shadow and no detail in posterior but still nothing obvious seen	NORMAL

UNABLE TO ASSESS Turtle 43, 44, 58

TOTAL ASSESSED 29-3 = 26

See pp. 72-73

See p. 23 Note bitten-off barnacles by turtle

(24)

See p. 4, 5

USFWS

Date: Sun, 26 Sep 1999 23:28:48 -1000 (HST)
From: "George H. Balazs" <gbalazs@honlab.nmfs.hawaii.edu>
To: Nancy Hoffman <nhoffma@aloha.net>,
Robert Shallenberger <rshall@aloha.net>
Subject: What a trip!

TO: ROB and NANCY

Rob and Nancy- Just about as successful as one could imagine. Let me tell you that when our time got cut to 3 workings days, due to flight schedule changes, I had no hope of doing what we just did. Great credit once again goes to my FWS partners (you two and your colleagues) for collaborative help and logistical support (a vehicle, among other vital items).

To recap, we captured 8 turtles ranging from 38.0 to 88.8 cm carapace length. Mototool white id numbers are now up to 32 (recall that mototooling didn't start until I came up in March of this year).

Four of the eight turtles were fitted with expensive electronic gagetry to help us learn more about 1) the habitats they are using, and 2) their behavior in that habitat. All four now have sonic tags each with a different id signal. We left a receiver and hydrophone with Nancy (long term loan like the other stuff) for use in locating the animals as time allows. Rob, ask her to teach you how to use it. Easy. The hardest part is being careful not to drop it in the ocean. The receiver needs a shoulder-strap carrying bag, my apologies for not bringing one with me.

Three of the four turtles with sonic tags also have Time-Depth recorders (TDR's), as follows:

An adult male mototool (MT) "25" with sonic tag 3-5-7 Recovered by Nancy & Bruce (Rob Pier photo)

A subadult male MT "26" with sonic tag 4-4-7

An adult female MT "31" with sonic tag 4-6-9 "Nancy"

MT "32" is a 58cm immature (sex unknown) with only a sonic tag (4-5-6)

In spite of uncooperative weather conditions for two of our three working days, we were still able to test and validate the effectiveness of using a small turtle net along the inside of the inner harbor seawall (resulting in the capture of MT "31" our largest turtle. This happened on the morning of our last day, in spite of waves breaking Over the seawall. I'm eager now to try this technique again under better conditions. If you know the plane schedule for January and February, please send it to me so we can start scoping out plans for the "next step" in this dandy little cooperative project. Yes, I know weather can be bad in those months, but we accept the gamble.

Let me know how it's going (and where you are seeing (hearing) the turtles at. We know that 357 was living under the fuel pier. Aloha, George

****
* George H. Balazs, Leader *
* Marine Turtle Research Program *
* National Marine Fisheries Service *
* SWFSC Honolulu Laboratory *
* 2570 Dole Street *
* Honolulu, Hawaii 96822-2396 USA *
* Tel:(808) 983-5733 *
* Fax:(808) 983-2902 *
* gbalazs@honlab.nmfs.hawaii.edu *

Date: Fri, 24 Dec 1999 18:35:17 EST
From: RussDenn@aol.com
To: gbalazs@honlab.nmfs.hawaii.edu
Subject: Midway Codium

Codium Midway

Dear George,

Please send me several samples from their crop/stomach, there is no telling what else besides Codium could be in there. I can make a thorough analysis of the sample contents and even look for microscopic components. Codium, as far as I know, is never toxic. Maybe there is a lot of Caulerpa in there too and we know it can be toxic.

I identified the algae from the Kiholo Ponds as Cladophora hemisphaerica and Cladophora sericea. It is mostly C. hemisphaerica, (a very good fit), but Abbott does not have this species in her latest keys, so I have asked Celia Smith about the taxonomic status of C. hemisphaerica. Cladophora is a genus that is in need of a lot of taxonomic revision, but I have madé drawings of it, however, so we will be able to put a permanent name to it regardless of any future changes in nomenclature.

Dennis J. Russell
P.O. Box 210-435
Auke Bay, Alaska 99821
(907) 789-1621 Juneau, AK
E-mail: RussDenn@aol.com

George Balazs
Marine Turtle Research Program
National Marine Fisheries Service
SWFSC Honolulu Laboratory
2570 Dole Street
Honolulu, Hawaii 96822-2396

January 17, 2000

Dear George,

Here are the results from the two samples you sent to me from Midway Atoll.

Results:

10-22-99 Midway, Nancy Hoffman, crop-greenturtle, forestomach.

Codium cuneatum 100%

10-31-99 Midway, Nancy Hoffman, #A219, Inner Harbor, crop ID, forestomach.

Codium cuneatum 100%

We have also identified this species from two former samples:

06-28-78 #GB 147 – no location given

and

05-79 French Frigate Shoals

Aloha,

Dennis J. Russell

Date: Sat, 8 Jan 2000 12:28:13 EST
From: RussDenn@aol.com
To: gbalazs@honlab.nmfs.hawaii.edu
Subject: Codium cuneatum

Midway Pollute

Dear George,

I have positively identified the Codium you found on Midway as Codium cuneatum Setchell & Gardner. It fits P. Silva's (1950) description exactly. I've made drawings of it for our manual (future edition) and see from my notes that we had found it before.

Results:

10-22-99 Midway, Nancy Hoffman, crop - green turtle, forestomach.

Codium cuneatum 100%

10-31-99 Midway, Nancy Hoffman, #A219, Inner Harbor, crop ID, forestomach.

Codium cuneatum 100%

The former samples we had this in were:

06-28-78 #GB 147 -- (no location given)

and

05-79 French Frigate Shoals

I will send this information to you by formal letter later today,

Date: Fri, 4 Feb 2000 08:36:42 -1100
From: Nancy Hoffman <nhoffma@aloha.net>
To: "George H. Balazs" <gbalazs@honlab.nmfs.hawaii.edu>
Subject: Re: Electro-bionic cyber sea turtles at Midway

MOTO Tool #36

[The following text is in the "iso-8859-1" character set]
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[Some characters may be displayed incorrectly]

George, we see large turtles in the inner harbor and at the mouth of the inner harbor, but not on the beach lately. Did Suzanne talk to you about #36 and how it swims? Interesting. we will keep an eye out for it and keep watching to make sure nothing happens to the beast. The hydrophone receiver is acting strange....we think there is a short in the switch so I will have the guys in electronics take a look at it. When was the last time you got the hydrophone monitoring data? We look for turtles often, not everyday, but visitors (OSE types) are looking also, because I told them if they find a no numbered turtle on the beach they could watch and see what we do with them. So, our coverage is fair. Starting May through September there will be one Wednesday flight per month. They are asking for input as to which Wednesday in the month would be best.....do you have a Wednesday that you would prefer? Please let me know ASAP so I can get your input back to Aloha. Got to run! Are you busy! Did Mark's grandchild arrive? later, Nancy

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Date: Tue, 7 Mar 2000 07:19:06 -1100
From: Nancy Hoffman <nhoffma@aloha.net>
Reply to: Nancy Hoffman <nhoffman@midwayisland.net>
To: "George H. Balazs" <gbalazs@honlab.nmfs.hawaii.edu>
Subject: Re: Back from the seaturtle symposium

[The following text is in the "iso-8859-1" character set]
[Your display is set for the "US-ASCII" character set]
[Some characters may be displayed incorrectly]

George, welcome back to the islands. I did not receive the temperature data. We have not had a plane in two weeks, so maybe this Sat we will receive the information. I will relay the info on to the turtle-heads. Bruce and I saw two turtles mating in the inner harbor on Sunday. They were both un-numbered! No, we have not seen any TDR's basking in the beach. I am still looking! Relax and get that body grounded again! later, Nancy
>

Date: Mon, 27 Mar 2000 15:11:51 -1100
From: Nancy Hoffman <nhoffma@aloha.net>
Reply to: Nancy Hoffman <nhoffman@midwayisland.net>
To: "George H. Balazs" <gbalazs@honlab.nmfs.hawaii.edu>
Subject: Re: ears

[The following text is in the "iso-8859-1" character set]
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[Some characters may be displayed incorrectly]

George! Hi Guy!! How's tricks? I loan my earphones to the project, but if you get some new ones you should bring them out with you on a WEDNESDAY flight or something. During the months of May through September there will be ONE Wednesday flight in addition to the normal Sat. flight: May 17, June 7, July 12, August 2, September 20. So, plan your trip my friend! I will be off island 6-27 May for meetings and workshops. talk to you later, Nancy PS the dip net is still working!
>

Date: Tue, 20 Jun 2000 08:37:50 -1100
From: Nancy Hoffman <nhoffman@midwayisland.net>
To: "George H. Balazs" <gbalazs@honlab.nmfs.hawaii.edu>
Subject: Re: Nice...

[The following text is in the "iso-8859-1" character set]
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Hi George! Sorry for the delay in my response. I am not mad at you, silly man!
Here are the details of the attack and turtle stats. On 11 June 2000 at about 0600 a large (>12ft) tiger shark was seen (by Bill Boagey, manager of the fishing operations) attacking a un-numbered, 84.8cm straight carapace length, 68.2cm width green sea turtle in the inner harbor between the first and second finger pier at the sport fishing and diving operations. Two other tiger sharks dis-membered the turtles head, flippers, and tail. These sharks were smaller (<12ft). So, we pulled it out of the harbor and did a necropsy on the beast. WE collected spleen, liver, heart, lung, pancreas, gonads, and stomach contents. It had a gut of Halafala (sorry about my spelling)(sea grass). The limbs were gone, so I did not collect the humerus. The carapace had four deep (through the carapace into the body cavity) shark teeth slices. These samples were frozen and another set were put in formalin. The samples are labeled specimen #4.
The specimens I brought into your lab a few weeks ago were from turtle number 23, PIT tagged on August 24, 1999. It had old tag numbers N28 (LF) and N27 (RF). It's carapace with missing limbs, head, and tail were found on Spit Island's beach 6 Jan. 2000. It was seen alive on turtle beach 5 Jan. 2000.
Now, I will be gone with Bruce after 8 October for about 6 weeks....I think you don't want to visit and work here when I am on island!!! Please let me know how I can help with your plans for the visit in Oct. Sept is nice also...majority of the birds are gone. got to run, later dude! Nancy

Date: Tue, 5 Sep 2000 06:23:39 -1100
From: Nancy Hoffman <nhoffman@midwayisland.net>
To: "George H. Balazs" <gbalazs@honlab.nmfs.hawaii.edu>
Subject: Re: Hearing things UW at Midway??

[The following text is in the "iso-8859-1" character set]
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[Some characters may be displayed incorrectly]

George, yes, they are being located every three days or so. A boat captain saw the tug-boat pier turtle near the inner harbor jetty on last Friday evening heading out of the harbor. Suzanne will be leaving this weekend and so the monitoring will be reduced to once a week. Are you and Marc still interested in coming out in November. I will be leaving on the Cromwell cruise in Oct and not returning until late Nov so I would like to get you guys set-up before I leave the atoll for two months. hope all is well, later, Nancy
>

Date: Thu, 2 Nov 2000 07:23:26 -1000
From: "Marc R. Rice" <mrice@hpa.edu>
To: gbalazs@honlab.nmfs.hawaii.edu
Subject: Fwd: Midway Trip

George,
I spent quite a bit of time on the phone with the midway folks and they were very accomodating. it seems that Masakai will be on island and we can get air and make a dive or two outside if the weather permits... note the reference to COLD water.
Hope all is well. If you have a moment, please give me some ideas about what to do with the hawksbill hatchlings in Pohnpei.
Marc

>From: Eileen Davie <EDavie@PHOENIXAIR.COM>
>To: "'mrice@hpa.edu'" <mrice@hpa.edu>
>Subject: Midway Trip
>Date: Thu, 2 Nov 2000 12:00:37 -0500
>Status:
>
>Marc --
>
> Please note excerpt from a message I received from Marla Kelly
>(Director of Marketing & Guest Relations for Midway Phoenix, resident in
>Hawaii). Masaki will be on island for the time you will be there. Please
>note -- all bases seem to be covered. If I can do anything else, please let
>me know.
>
>Eileen
>
>Midway team.....
>
>Please note the following group will be on island 11/11-18 and although they
>are focusing efforts on turtle research, they also want to get some dives
>in. I have confirmed the following to them through Eileen:
>
>Diving is on a weather-permitting basis. They have been told to bring full
>wetsuits since the water is now cold. They've been told a maximum of 6
>divers at any given time. We can use the Atlanta; just need to advise
>Freddie when to put it in the water. Bob can serve as captain; just need to
>give him advance notice to be available. Masaki will be on island and can
>serve as divemaster; advance notice also. (Masaki, they'll want tanks, air
>refills)
>
>FYI to Guest Services - they will need to request dive time through you and
>you'll convey to Masaki, Bob, Freddie.
>
>- Marla

>---------- Forwarded message ----------
>Date: Thu, 18 Nov 99 10:47:48 -0800
>From: Anja <missanja@wildmail.com>
>To: gbalazs@honlab.nmfs.hawaii.edu
>Subject: turtle data
>
>George,
>
>After some trouble with the computer I finally got that data for you on disk. At the moment I am going out atleast every second day. Nancy said 3 times a week is good. The other day was the only day I've ever found all four turtles at once. However, I've never actualy seen any of these turtles. I see unmarked ones all the time. I've decided to stay on Midway for another couple of weeks. So maybe you'll be in Hawaii when I am? I hear your always away! You wouldn't believe but a male golden gooney just came in today and is about 1km away from the female! I'm not sure if they are going to try to get them together but we are all hoping some golden love starts happening :)
>
>Have fun on your trip.

Date: Mon, 22 Nov 1999 08:06:34 -1000
From: Marc Rice <mrice@hpa.edu>
To: "George H. Balazs" <gbalazs@honlab.nmfs.hawaii.edu>
Subject: Re: turtle data (fwd)

Thanks, I got the file. It certainly appears that the 4 animals are doing as we expected. The two associated with the outter piers are spending time there and the harbor critters are spending time in that area. While it won't guarantee success at recapture, it will certainly give us a place to look.

Need keys

TURTLE SONIC TRACKING

DATE	TURTLE#	SONIC#	LOCATION	TIME	COMMENTS	
9/27/99	7	N/A	sea plane ramp	1312	basking at foot of ramp	NH, SR
9/27/99	25	357	beneath fuel pier	1500	freq 73	NH, SR
9/27/99	32	456	beneath tug pier	1530	freq 73	NH, SR
10/1/99	26	447		1045/1415	freq 75	SR, NG
10/1/99	25	357	beneath end of fuel pier	1035/1415	freq 73	SR, NG
10/1/99	30		tug pier	1436/1455	plus 2 unmarked on surface	SR, NG
10/1/99	32	456	center harbor	1458/1508/1531	freq 73	SR, NG
10/5/99	25	357	beneath cargo pier	1333/1356	freq 73	SR, NG
10/11/99	26	447	from fuel pier	740	weak signal	SR
10/11/99	25	357	beneath fuel pier	740		SR
10/17/99	25	357	beneath cargo pier	1200/1217		SR
10/28/99	25	357	beneath cargo pier	1321/1334		NG, AS
10/28/99	31	469	inner harbor floating dock	1345/1349	freq 74	NG, AS
11/2/99	32	456	tug boat pier	1320/1330	freq 73	AS
11/2/99	26	447	b/n cargo and fuel piers	1355/1410	freq 69	AS
11/5/99	26	447	near fuel pier	0830/0845		AS
11/5/99	25	357	b/n cargo and fuel piers	0830/0845		AS
11/8/99	25	357	b/n cargo and fuel piers	1530/1555	freq 72	AS
11/8/99	26	447	under fuel pier	1530/1555	freq 73	AS
11/10/99	32	456	mouth of harbor	920	freq 73, weak signal	AS
11/10/99	25	357	b/n cargo and fuel piers	0935/0950	freq 72	AS
11/10/99	26	447	b/n cargo and fuel piers	0935/0950	freq 73	AS
11/12/99	25	357	b/n cargo and fuel piers	1305/1320	freq 73	AS
11/12/99	26	447	b/n cargo and fuel piers	1305/1320	freq 73	AS
11/12/99	31	469	near tug boat pier	1340/1435	freq 72, strong signal	AS
11/15/99	25	357	b/n cargo and fuel piers	1335/1342	freq 73, high pitch	AS
11/15/99	26	447	b/n cargo and fuel piers	1335/1342	freq 73, low pitch	AS
11/15/99	31	469	east side of tug boat pier	1400/1415	freq 72	AS
11/16/99	31	469	mouth of harbor	1510/1555	freq 73	AS
11/16/99	32	456	under tug pier	1540/1547	freq 72	AS
11/16/99	25	357	under fuel pier, near end	1605/1610	freq 73	AS
11/16/99	26	447	under fuel pier, near end	1605/1610	freq 73	AS

Date: Thu, 3 Aug 2000 11:09:26 -1100
From: Nancy Hoffman <nhoffman@midwayisland.net>
To: "George H. Balazs" <gbalazs@honlab.nmfs.hawaii.edu>
Subject: turtle

[Part 1, Latin 1 text (ISO-8859-1) 8 lines]
[Unable to print this part]

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[Your display is set for the "US-ASCII" character set]
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<DEFANGED-META content="MSHTML 5.00.2314.1000" name=GENERATOR>
<STYLE></STYLE>
</HEAD>
<BODY><DEFANGED-BODY bgColor=#ffffff>
<DIV><FONT face=Arial size=2>George, Guess what! Bruce saved a turtle from entanglement and death. He was doing a reef survey for monk seals and found a T2 entangled in a cargo net near the reef. It was enveloped in the net, twisted badly and attached to coral. He removed the net from the coral and un-wrapped the little green thing! He has pictures of the net and turtle on his kayak. I will send you photos when we get them developed. Cool! A great save!   Question! Why do turtles bask or haul out of the water (besides nesting)? Thanks for the head set!! it is great! later, Nancy</FONT></DIV></BODY></HTML>

Need Photos

Date: Tue, 5 Sep 2000 06:23:39 -1100
From: Nancy Hoffman <nhoffman@midwayisland.net>
To: "George H. Balazs" <gbalazs@honlab.nmfs.hawaii.edu>
Subject: Re: Hearing things UW at Midway??

[The following text is in the "iso-8859-1" character set]
[Your display is set for the "US-ASCII" character set]
[Some characters may be displayed incorrectly]

George, yes, they are being located every three days or so. A boat captain saw the tug-boat pier turtle near the inner harbor jetty on last Friday evening heading out of the harbor. Suzanne will be leaving this weekend and so the monitoring will be reduced to once a week. Are you and Marc still interested in coming out in November. I will be leaving on the Cromwell cruise in Oct and not returning until late Nov so I would like to get you guys set-up before I leave the atoll for two months. hope all is well, later, Nancy

Date: Thu, 26 Oct 2000 07:33:04 -1000
From: "Marc R. Rice" <mrice@hpa.edu>
To: "George H. Balazs" <gbalazs@honlab.nmfs.hawaii.edu>
Subject: Re: 10 + 1

I fully understand your concern. The numbers are a large. The number of students, however, has not increased. What has increased is the number of adults. The primary focus will be 1. safety, 2. capturing the TDR turtles and 3. increasing the database of tagged turtles... is that reasonable.

If we are going to go under the cargo pier, for example, we will assigned the number of divers that we want to go and the rest of the people will stay out of the way and help... if that means only two people diving, that is the way it will be. I expect we will assign jobs based on the needs of the situation and not so we can get everyone in the water.

I hope that you will not feel too much additional pressure because of the numbers. We will be available to do what you want us to do, when you want it. That is the reason I have George and Arjun along. They can take care of the students and do things with/for them if you/we want/need to work on something that is too dangerous or too complex for them. I do hope it will work out ok.

>Frankly it's a little scary for me now with the group so large, well
>rather I should say "not as relaxed" in my mind. How many of the folks
>are 1) scuba divers, 2) Snorkelers, of each how many do we plan to have in
>the water at one time? I could be wrong, but I don't think even a large
>van can get us all around at once.
>
>I think it would be good to pick a day now (early in the project time up
>there rather than later?) for the non-turtle activities. In the meantime
>I'll be working on a schedule of daily efforts, all weather conditional
>of course.

Date: Sat, 28 Oct 2000 10:25:47 -1000
From: "Marc R. Rice" <mrice@hpa.edu>
To: "George H. Balazs" <gbalazs@honlab.nmfs.hawaii.edu>
Subject: Re: www.turtles.org/toon.htm

Midway travelers:
Marc Rice
Roy Harrington
George Watson
Arjun Clarry
Katie Harrington
Jill Quaintance
Alika Brooks
Dylan Boyle
John Alexander
Kelly Davis
--
Marc R. Rice
Assistant Headmaster
Hawaii Preparatory Academy
65-1692 Kohala Mt. Road
Kamuela, Hawaii 96743
phone: 808 881 4004
cell: 808 987 6903
fax: 808 881 4003

Pergamon

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Distribution Patterns of Polychlorinated Biphenyl Congeners in Water, Sediment and Biota from Midway Atoll (North Pacific Ocean)

BRUCE HOPE*, SUSAN SCATOLINI, ERIC TITUS† and JEFF COTTER

Ogden Environmental and Energy Services Company, Inc., 680 Iwilei Road, Suite 660, Honolulu, HI 96817, USA

To increase our understanding of critical pathways of polychlorinated biphenyl (PCB) transfer from abiotic media into marine organisms, this study quantified 20 PCB congeners in surface water, sediment and tissues of marine biota (macrophytes, snails, urchins, bivalves, sea cucumbers, fishes) taken from Midway Atoll. PCBs 138, 153, 170, 180 and 187 were the most abundant congeners in all samples analysed. Distribution of PCB congeners was shifted in favour of higher (hexa- and above) chlorinated congeners in all species; only aquatic macrophytes displayed significant bioaccumulation of lower (tri- and tetra-) chlorinated congeners. Evidence is presented for the differential metabolism of congeners by marine species. Non-*ortho* substituted congeners (PCBs 77, 126) with elevated toxic potency were not present at significant levels in the sampled species. Certain mono-*ortho* congeners (PCBs 105, 118), implicated in marine mammal toxicity, comprised only ≈4.5% of total congener load in prey for piscivorous birds and marine mammals. © 1997 Elsevier Science Ltd

Midway Atoll is in the North Pacific Ocean 1100 miles northwest of Pearl Harbour, Hawaii, approximately 178°W longitude, 28°N latitude (Fig. 1). The atoll consists of two main islands, Sand and Eastern, surrounded by a fringing coral reef. Although heavily modified by human activity over the previous 90 years, the islands provide breeding and feeding habitat for more than one million migratory seabirds; a total of 45 migratory bird species have been recorded at the atoll. Midway also provides habitat for terrestrial and marine mammals, sea turtles and other reptiles, and a rich diversity of reef fishes and invertebrates. Pacific green sea turtles (*Chelonia mydas agassizi*) and the protected spinner dolphin (*Stenella longirostris*) both frequent the lagoon. US Federally-listed endangered Hawaiian monk seals (*Monachus schauinslandi*) are present in small numbers and known to pup on the atoll's beaches. The atoll is considered critical habitat for this species. In 1988, the atoll was designated as an overlay National Wildlife Refuge, under the full control of the US Fish and Wildlife Service in May 1996.

As a result of historical use in industrialized countries and current use in the rapidly industrializing countries of low-latitude tropical and subtropical Asia and Oceania, PCBs have entered and are still being eased into the global environment (Iwata *et al.*, 1994; Tanabe *et al.*, 1994). Atmospheric transport and ocean circulation are primary mechanisms for circum-global dispersion of these organochlorine compounds (Tanabe and Tatsukawa, 1986). Their wide dispersal, along with their great capacity to bioaccumulate, have allowed PCBs to attain 'steady-state' in some ecological and biological systems (Bauman and Whittle, 1988; Falandysz *et al.*, 1994; Harris *et al.*, 1993). They are currently recognized as ubiquitous in marine, estuarine and freshwater food chains, with the largest biological concentrations occurring in fish-eating aquatic seabirds and marine mammals, making them an ecotoxicological concern to these species (Tanabe *et al.*, 1994).

Air samples collected in the North Pacific Ocean, along a track that passed immediately south of Midway Atoll, contained ΣPCB concentrations in the range of 0.012 0.390 ng m^{-3}, with a mean of 0.130 ng m^{-3} (Iwata *et al.*, 1993). Iwata *et al.* (1993, 1994) also investigated PCB contamination in seawater along the route followed by the Kuroshio current from the low-latitude rapidly industrializing regions, where PCBs are still used, past the Northwestern Hawaiian Islands (including Midway Atoll), and northward into the Gulf of Alaska and the Bering Sea. Seawater samples taken along this route contained ΣPCB levels ranging from 0.0091 to 0.063 μg l^{-1}, with a mean of 0.024 μg l^{-1}.

*Current address: Oregon Department of Environmental Quality, Waste Management and Cleanup Division, P.O. Box 8099, Portland, OR 97207-8099, USA.

†Current address: Ogden Environmental and Energy Services Company, Inc., 343 Sansome Street, Suite 700, San Francisco, CA 94104, USA.

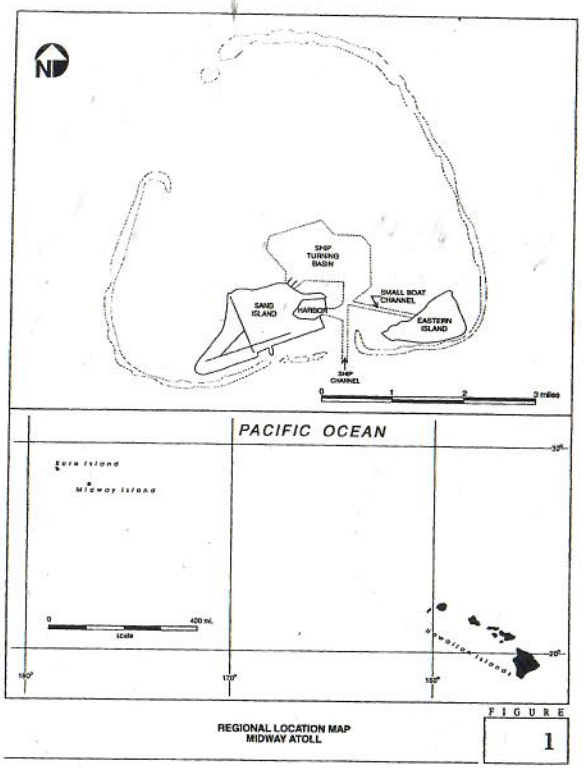

Fig. 1 Regional location map Midway Atoll.

These findings suggest that Midway Atoll may be receiving ambient environmental PCB exposures from atmospheric deposition and ocean surface water circulation.

To increase our understanding of critical pathways of PCB transfer from sediment or water into lower trophic level organisms and, subsequently, to higher order consumers, particularly for the North Pacific Ocean, this study measured the concentration and distribution of 20 PCB congeners (PCBs 8, 18, 28, 44, 52, 66, 77, 101, 105, 118, 126, 128, 138, 153, 170, 180, 187, 195, 206 and 209 (congeners numbered according to Ballschmiter

and Zell (1980)) in marine sediments, surface waters, and tissues of 12 species of marine biota from near-shore waters at Midway Atoll. PCB congeners 28, 52, 101, 118, 138, 153 and 180 are among those recommended by the International Council for Exploration of the Seas (ICES) for assessing marine pollution by PCBs (Duinker *et al.*, 1988; Porte and Albaigés, 1993).

PCBs are lipophilic and thus are expected to associate with benthic and suspended sediments, phytoplankton, zooplankton and natural surface oil films. Assimilation of PCBs into aquatic food chains generally begins with these sediments, planktons, or films being incidentally ingested by fish and invertebrates, or taken up by aquatic macrophytes. Therefore, species analysed in this study included two macroalgaes (*Dictyota acutiloba*; *Giffordia breviarticulata*), a sea grass (*Halophila ovalis*), a bivalve mollusk (*Chama iostoma*), a sea urchin (*Echinometra mathaei*), a snail (*Nerita picea*), two holothurians (*Bohadschia obesus*; *Holothuria atra*), and four fishes: striped convict tang (*Acanthurus triostegus*), goatfish (*Mulloidichthys flavolineatus*), Pacific gregory (*Stegastes fasciolatus*) and blacktail wrasse (*Thalassoma ballieui*). Based on limited life history information, these species were grouped into broad trophic levels as follows: primary producers (*D. acutiloba*; *G. breviarticulata*, *H. ovalis*); herbivores (*C. iostoma*, *E. mathaei*, *A. triostegus*, *S. fasciolatus*); omnivores (*B. obesus*; *H. atra*); and carnivores (*N. picea*, *M. flavolineatus*, *T. ballieui*).

In this paper, we report on: *1.* concentrations of individual PCB congener associated with marine biota near the base of the food chain in near-shore, North Pacific waters; *2.* distribution of PCB congeners in these marine biota as a function of trophic level and congener chemistry; *3.* patterns of PCB bioconcentration and bioaccumulation in these biota with respect to surface water and sediments; *4.* the influence of stereochemistry on each species capacity to metabolize specific congeners; and *5.* the distribution and potential toxicity of non-*ortho*-substituted (PCBs 77 and 126) and selected mono-*ortho*-substituted (PCBs 105 and 118) congeners.

Materials and Methods

Sample collection

Samples of marine sediment were collected from locations in nearshore areas around Sand and Eastern Islands using horizontal and vertical cores. Sediment, water and biota samples were collected subtidally. Horizontal sediment cores were collected at all stations, vertical sediment cores were only collected at a small subset of the stations. Aluminium core tubes with a diameter of 5 cm and a length of 60 cm were used to collect both core orientations. Horizontal cores were collected by pushing the tubes though the upper 6 inches of sediment and capping both ends. Vertical samples were collected with the use of a weighted slide hammer to pound the full depth of the tube into the sediment. The top of the vertical core was marked at the time of sampling. Each core was processed by removing the cap, decanting the water, measuring the head space, and cutting the tube at a point 25% below the sediment surface. The lower 75% of the sleeve (45 cm of sleeve depending on head space) was retained as the sample, the top 25% was discarded. Resulting horizontal and vertical samples were homogenized in decontaminated stainless steel bowls, placed in new, laboratory-certified clean glass jars, sealed, cooled to 4°C, and shipped to the laboratory for analysis of low level PCBs.

All sediment sleeves were decontaminated prior to use by washing in Alconox®, rinsing twice with bottled water, spraying with isopropyl alcohol and rinsing again. Teflon® sheets were placed over the ends of the sleeves to reduce the possibility of outside contamination. The sleeves with Teflon® were then capped, taped at the ends and placed on ice until homogenization. Seawater samples were also collected from locations in nearshore areas around Sand and Eastern Islands. Samples were collected by removing the container lid just below the water surface, filling a 2-l amber glass bottle, and resealing lids with the bottle still submerged. All glassware used for water samples were new laboratory-certified clean bottles provided by the analytical laboratory. Samples were then cooled to 4°C, and shipped off-atoll for low level PCB analyses.

A biological reconnaissance of the lagoon at Midway Atoll and most nearshore areas was completed prior to initiating sampling for biota. All habitats, substrate types and species were identified to the extent feasible, and appropriate species for collection identified. Organisms collected for tissue analysis were selected based on trophic level, specificity of location, and availability. The goal was to collect representatives from a wide range of trophic levels, especially species that may be prey for endangered Hawaiian monk seals and threatened green sea turtles. Fish species were collected using a spear, invertebrates and algae were collected by hand. Species collected were placed in new, food grade, resealable plastic storage bags, and frozen at −10°C until shipped to the laboratory for analysis. Due to the mass requirements for PCB analysis, samples were sometimes composites of several individuals, depending on wet wt of the organisms.

All samples were shipped on ice in coolers, with custody seals and chain of custody forms to track sample access. Temperature of samples was recorded by the laboratory upon receipt and samples greater than 6°C were qualified as estimated values. All holding times were met for all samples.

Sample preparation and analysis

The off-atoll laboratory performing the PCB analyses on seawater, sediment and biotic material was Arthur D. Little, Inc., (ADL) Cambridge, Massachusetts. Low-level PCB analysis was performed in accordance with the National Oceanic and Atmospheric Administration's Status and Trends Program Methods. In preparation for low level analyses for PCBs, seawater samples were spiked with a calibration surrogate (PCB 103), then extracted with methylene chloride in a separatory funnel. This extract was dried with sodium sulphate, concentrated, and an aliquot of the sample weighed, then analysed by gas chromatography-electron detection (GC-ECD) technique (ADL, 1994). Sediment samples were first spiked with surrogates, then extracted with a solution of methylene chloride/acetone (1:1 ratio) using a sonication/shaking technique, then dried with sodium sulphate, followed by concentration, centrifugation and weighing. Sediment sample extracts were analysed with a GC-ECD technique (ADL, 1994).

Tissue samples were homogenized, an aliquot removed, weighed and placed in a Teflon® jar, after which they were dried with sodium sulphate and spiked with surrogates. Samples were then serially extracted with methylene chloride, the solvent and matrix having been mixed through maceration; the extract was then concentrated for clean-up and fractionation. Total extractable (lipid) weight was calculated as part of the clean-up process. Tissue sample extracts were analysed using the GC-ECD technique employed for surface water and sediment samples (ADL, 1994).

Method detection limits were determined in accordance with US Environmental Protection Agency criteria (40 CFR 136, Appendix B). Congener-specific detection limits were 0.00022–0.003 μg l^{-1} for seawater, 0.011–0.21 μg kg^{-1} for sediments and tissues. The gas chromatograph was calibrated prior to PCB analyses, then daily or after every 10 samples analysed. Concentrations of all analytes were determined relative to that of the internal standard spiked just prior to analysis. Recovery of surrogates were also determined relative to the internal standard. Individual compounds were then identified by their retention time in the gas chromatograph, and the concentration of each analyte computed on the basis of sample volume or weight. Standard reference materials (SRMs) were used for precision and accuracy tests and performance evaluation samples were submitted to laboratory. All data were validated to US Navy Level D criteria.

Results and Discussion

Individual congener concentrations

The geometric mean and the 95th percentile upper and lower confidence intervals about the mean for concentrations of individual congeners in surface water, sediments, and each species (on a dry wt basis) are summarized in Table 1. Means and confidence intervals were calculated using log-transformed data to normalize residuals; non-detects were included in these calculations at one-half the detection limit. All congeners were present in marine sediments at mean concentrations from 0.03 to 0.20 μg kg^{-1}. Mean congener concentrations in surface water were 0.0003 to 0.001 μg l^{-1}, and generally 1–2 orders of magnitude lower than concentrations in sediments. Individual congener mean concentrations in biota were 0.02 μg kg^{-1} in *H. atra* to 3300 μg kg^{-1} in *Mulloidichthys*; with the majority, however, in the range of 0.1–50 μg kg^{-1}. Three species, *Bohadschia*, *Mulloidichthys*, and *Stegastes*, had elevated (> 50 μg kg^{-1}) mean concentrations of several congeners, particularly hexa- and heptachlorobiphenyls. Interpretations based on data for *Nerita* and *Mulloidichthys* were made with caution owing to the high heterogeneity in these data as reflected in the broad confidence intervals.

Congener distribution patterns

Shifts in the proportion of each individual congener concentration relative to the sum of the mean concentration of all 20 congeners are represented graphically (Figs 2–5). For biota, total congener concentrations were calculated on a dry wt basis. In all samples, contributions to total PCB concentrations were not evenly distributed across the 20 congeners. In both marine sediments and surface water (Fig. 2), congeners making the proportionally largest individual contributions to total congener concentration were the hexa- and heptachlorobiphenyls PCBs 138, 153, 170, 180 and 187. These five collectively accounted for approximately 52% and 36% of total congener concentration in sediments and surface water, respectively. The deca-chlorinated congener PCB 209 comprised approximately 3–5% of the total. Lower chlorinated congeners (PCB 101 and below) generally made small (< 10%) individual contributions to total loading. This observed skewing of congener distribution towards more highly chlorinated compounds is consistent with previously published findings indicating the preferential retention of these less volatile, more lipophilic compounds in aquatic systems (De Voogt *et al.*, 1990).

Major congeners detected in all biota samples (Figs 3–5) were very similar to those dominating the abiotic media: two hexa- (PCBs 138 and 153) and three heptachlorobiphenyls (PCBs 170, 180 and 187). These five collectively accounted for approximately 46–87% and 67–80% of the total congener concentration in invertebrates and fishes, respectively (Figs 4 and 5). These isomers have in common, chlorine atoms in positions 2,4,5- in one (PCB 187) or both rings (PCB 153 and 180), *para* positions on both biphenyl rings, and a lack of adjacent unsubstituted *meta* and *para* positions, making these congeners particularly recalcitrant to degradation by invertebrates or fishes (Bright *et al.*, 1995; Zell *et al.*, 1978). Borlakoglu *et al.* (1990) have also shown that these same congeners are not readily metabolized by vertebrates and tend to accumulate in the adipose tissue of seabirds. In aquatic macrophytes (Fig. 3), these five congeners collectively accounted for 43–50% of the total congener concentration. However, plant species exhibited higher proportions of lower

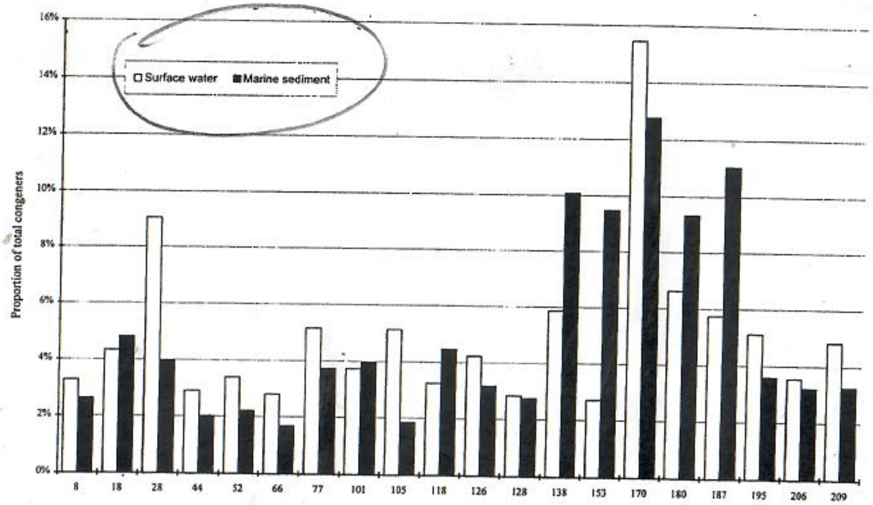

Fig. 2 Distribution of individual congeners in marine sediments and surface water.

TABLE 1

Mean (dry wt) concentrations (with 95% confidence limits) of individual PCB congeners sampled in abiotic media and marine species from Midway Atoll.

Congener	Marine sediment µg kg⁻¹ [a]	Surface water µg l⁻¹	*Dictyota acutiloba* µg kg⁻¹	*Giffordia breviarticulata* µg kg⁻¹	*Halophila ovalis* µg kg⁻¹	*Chama iostoma* µg kg⁻¹	*Echinometra mathaei* µg kg⁻¹	*Nerita picea* µg kg⁻¹	*Bohadschia* µg kg⁻¹	*Holothuria atra* µg kg⁻¹	*Acanthurus triostegus* µg kg⁻¹	*Mulloidichthys flavolineatus* µg kg⁻¹	*Stegastes fasciolatus* µg kg⁻¹	*Thalassoma ballieui* µg kg⁻¹
	Abiotic media or species sampled							Species sampled						
8	0.04 0.03–0.05	0.0004 0.0003–0.0004	0.31 0.16–0.6	0.36 0.1–1.0	0.18 0.08–0.41	0.45 0.2–1.01	0.11 0.05–0.23	0.08 0.02–0.33	0.24 0.12–0.54	0.15 0.12–0.2	0.49 0.23–1.08	2.40[c]	0.73 0.23–2.37	0.23 0.09–0.52
18	0.08 0.06–0.09	0.0005 0.0005–0.0005	2.14 1.43–3.2	1.03 0.55–1.95	2.20 0.34–14.22	0.49 0.31–0.79	0.08 0.05–0.12	0.44 0–40100.75	0.46 0.14–1.47	0.20 0.15–0.26	0.44 0.38–0.52	3.07[c]	1.39 0.39–4.93	0.27 0.11–0.66
28	0.06 0.05–0.08	0.0010 0.0009–0.001	0.20 0.17–0.25	0.36 0.2–0.65	0.29 0.11–0.82	1.12 0.42–2.98	0.12 0.07–0.19	0.21 0–323.48	0.45 0.1–1.99	0.19 0.15–0.25	1.31 0.22–7.87	2.93[c]	3.29 0.44–24.4	0.26 0.1–0.65
44	0.03 0.02–0.04	0.0003 0.0003–0.0003	0.40 0.16–1.01	0.43 0.24–0.75	0.15 0.11–0.2	0.31 0.25–0.38	0.06 0.04–0.08	0.18 0–106.53	0.41 0.13–1.28	0.16 0.12–0.21	0.36 0.31–0.42	2.30[c]	2.61 0.38–17.86	0.22 0.09–0.54
52	0.04 0.03–0.05	0.0004 0.0004–0.0004	7.35 2.87–18.83	0.93 0.53–1.79	0.36 0.18–0.71	0.77 0.57–1.04	0.30 0.18–0.84	0.24 0.11–0.53	1.04 0.25–4.33	0.32 0.12–0.47	4.55 2.0–10.0	3.05[c]	7.65 1.06–54.95	0.90 0.02–36.14
66	0.03 0.02–0.03	0.0003 0.0003–0.0003	0.28 0.23–0.35	0.63 0.38–1.06	0.24 0.18–0.32	0.45 0.41–0.57	0.13 0.09–0.24	0.19 0.1–0.37	0.26 0.22–0.31	0.27 0.2–0.36	0.85 0.31–2.35	4.11[c]	2.44 0.63–9.43	0.36 0.2–1.0
77	0.06 0.04–0.08	0.0006 0.0005–0.0006	0.38 0.3–0.46	0.83 0.5–1.42	0.48 0.24–0.99	0.64 0.55–0.76	0.11 0.11–0.12	0.25 0.09–0.69	0.34 0.29–0.41	0.36 0.27–0.47	1.14 0.39–3.32	5.47[c]	2.19 0.6–8.05	0.42 0.11–1.61
101	0.04 0.04–0.1	0.0004 0.0004–0.0004	1.14 0.75–1.74	2.73 1.2–6.2	0.42 0.23–0.77	1.82 1.28–2.58	0.59 0.3–2.0	0.50 0.18–1.38	5.12 0.95–27.52	0.93 0.82–1.05	4.70 1.54–14.35	32.58[c]	29.01 3.55–221.05	1.36 0.23–8.01
105	0.03 0.02–0.04	0.0005 0.0005–0.0006	0.47 0.14–1.6	0.69 0.33–1.46	0.20 0.13–0.3	0.72 0.42–1.23	0.25 0.12–0.5	0.26 0–1717.42	2.89 1.03–8.06	0.24 0.15–0.39	1.70 0.36–8.55	7.82[c]	5.51 0.69–43.91	0.79 0.05–10.76
118	0.07 0.05–0.1	0.0003 0.0003–0.0004	0.80 0.4–1.6	2.51 1.46–4.34	0.77 0.6–1.0	1.87 1.23–2.86	0.63 0.34–1.16	0.70 0.18–2.72	7.70 1.73–34.36	0.94 0.71–1.22	7.18 1.62–31.86	30.66[c]	24.04 3.6–160.49	1.60 0.21–12.11
126	0.03 0.03–0.03	0.0005 0.0004–0.0005	0.31 0.25–0.38	0.69 0.41–1.14	0.28 0.19–0.54	0.53 0.45–0.62	0.09 0–0	0.33 0.08–0.52	0.28 0.24–0.34	0.29 0.22–0.38	0.65 0.56–0.76	4.52[c]	1.45 0.38–5.51	0.40 0.16–1
128	0.04 0.03–0.06	0.0003 0.0003–0.0003	0.52 0.31–0.89	1.14 0.68–1.9	0.33 0.24–0.45	0.77 0.6–0.99	0.28 0.16–0.47	0.16 0–18439.84	0.58 0.31–1.1	0.36 0.19–0.7	2.09 0.84–5.21	13.21[c]	5.95 1.5–23.66	0.74 0.21–2.55
138	0.16 0.1–0.26	0.0006 0.0005–0.0007	6.38 4.16–9.8	3.35 0.78–14.35	1.30 0.69–2.47	7.26 4.04–13.05	1.89 0.62–5.78	0.61 0–53785.97	43.38 4.51–417.13	1.61 0.66–3.92	17.37 3.31–91.16	111.88[c]	89.40 11.28–708.32	4.03 0.32–50.32
153	0.15 0.09–0.27	0.0003 0.0002–0.0004	6.01 3.85–9.37	4.15 1.14–15.14	1.94 1.05–3.6	12.22 6.79–21.97	2.42 0.85–6.89	0.21[c]	59.06 4.81–725.18	0.74 0.18–3	24.29 0.92–641.72	205.24[c]	132.86 10.93–1615.02	2.06 0–352.74
170	0.20 0.14–0.3	0.0017 0.0001–0.0028	1.67 1.07–2.59	0.69 0.09–5.41	0.31 0.13–0.73	3.41 1.65–7.08	0.19 0.1–0.38	0.28 0–11597.5	2.07 0.26–16.11	0.23 0.14–0.38	5.12 0.13–200.17	40.64[c]	47.82 3.21–712.88	2.07 0.03–168.9
180	0.13 0.08–0.26	0.0007 0.0006–0.0009	4.22 1.57–6.92	2.65 0.49–14.7	0.46 0.08–2.75	8.53 4.05–17.96	0.96 0.49–1.88	2.19 0–4597.36	4.71 0.74–30.67	0.29 0.17–0.47	16.11 0.77–338.88	74.83[c]	142.22 10.32–1922.19	5.82 0.07–483.3
187	0.18 0.11–0.28	0.0006 0.0005–0.0007	2.70 0.84–8.7	4.21 1.18–15.08	0.98 0.45–2.12	3.40 1.72–6.73	1.34 0.44–4.07	0.96 0–19728.18	12.15 2–1358	1.52 0.37–6.35	11.68 0.66–207.84	48.73[c]	91.53 7.55–1309.22	3.85 0.1–155.93
195	0.06 0.04–0.09	0.0005 0.0005–0.0006	0.99 0.7–1.39	1.29 0.46–3.62	0.36 0.24–0.53	0.75 0.32–1.77	0.16 0.11–0.21	0.65 0.5–0.89	1.11 0.23–5.46	0.29 0.2–0.43	2.23 0.6–8.26	12.30[c]	20.15 1.58–256.75	0.47 0.01–29.81
206	0.03 0.03–0.04	0.0004 0.0003–0.0004	1.43 0.87–2.11	0.57 0.16–2.11	0.19 0.11–0.32	1.13 0.67–1.91	0.08 0.06–0.11	0.23 0–1327.93	0.99 0.2–5.03	0.27 0.2–0.36	2.85 0.4–20.48	13.55[c]	14.06 0.93–212.6	0.31 0–21.76
209	0.05 0.03–0.08	0.0005 0.0004–0.0006	6.92 2.04–23.51	0.28 0.13–0.61	0.11 0.06–0.19	0.88 0.3–2.59	0.09 0.05–0.19	0.22 0–4035.87	0.44 0.06–3.03	0.12 0.06–0.24	2.57 0.06–106.58	1.73[c]	1.77 0.35–8.87	0.23 0.08–0.52
n[b]	79	41	8	4	6	10	13	2	7	7	4	2	7	3

[a] Geometric mean (lower 95% confidence interval–upper 95% confidence interval), dry wt
[b] Number of samples.
[c] Broad 95% confidence interval (<0.000001–>1000000) due to heterogeneity in these data.

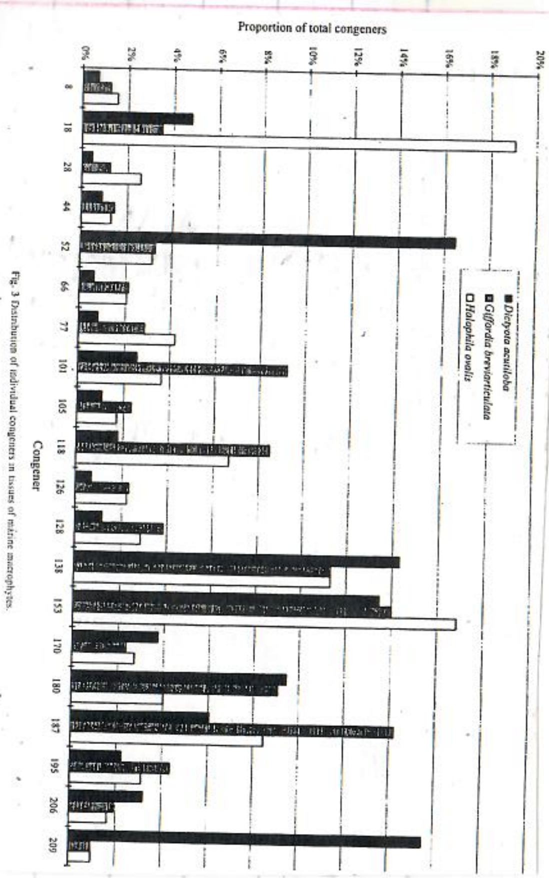

Fig. 3 Distribution of individual congeners in tissues of marine macrophytes.

chlorinated congeners, as evidenced by the elevated proportion (19%) of a trichlorobiphenyl (PCB 18) in sea grass (*H. ovalis*) and similarly (16%) for a tetrachlorobiphenyl (PCB 52) in the macroalgae, *D. acutiloba*. This effect is possibly attributable to the greater aqueous solubility of the lower chlorinated congeners (Bright *et al.*, 1995; Gobas *et al.*, 1991) and the mechanism (passive sorption) by which aquatic plants accumulate PCBs from water. Proportions of tri- and tetrachlorobiphenyls are generally low (< 10%) in animal species. In all biota, a reduction in the proportion of PCB 170 was a common pattern.

Oliver and Niimi (1988) and MacDonald *et al.* (1992) reported a relative constancy of congener proportions for biota in freshwater systems. In this marine system, however, collective proportions of five prominent congeners (PCBs 138, 153, 170, 180, 187) increased slightly with increasing trophic level-in sediments, and surface water collective proportions ranged from 36 to 52%, in plants from 43 to 50%, in invertebrates from 46 to 73% (excluding *Bohadschia*), and in fish from 67 to 80%. The nearly three-fold increase between abiotic media and fish suggests enrichment of these congeners. However, for all congeners with five or more chlorines (PCB 105 and above), any increases with trophic level were less apparent, with collective proportions ranging from 69 to 78% in sediments and surface water, from 66 to 84% in plants, from 81 to 91% in invertebrates (excluding *Bohadschia*), and from 89 to 96% in fish.

Changes in congener composition in some aquatic systems may be attributed to a decline in the proportion of less chlorinated PCBs that are more susceptible to losses through volatilization, sedimentation, and possibly microbial degradation (Brown *et al.*, 1987; MacDonald *et al.*, 1992; Quensen *et al.*, 1988). Moderately and higher chlorinated PCBs may remain at constant levels in the aquatic environment because they are less volatile, more soluble in lipids, adsorb readily to sediments, and are more resistant to metabolic and microbial degradation (Connell, 1988; Shiu and Mackay, 1986). Results of the preceding analysis of alterations in congener concentration and composition in various species and trophic levels for this large aquatic system suggest that: (a) proportions of some, but not all, higher chlorinated (≥5 Cl) congeners increase through the food web and (b) less chlorinated congeners constitute a relatively small proportion of congeners in biota that accumulate PCBs by absorption from the aqueous phase.

Pearson product–moment correlation assessed whether congener proportions among the different species moved together, i.e. did different species have similar values for proportions of each congener. As shown in Table 2, significant relationships ($p < 0.01$) in congener patterns were identified. Of note is the lack of significant correlation between congener patterns in seawater and any biota. Given the tendency for PCBs to sorb on macroalgal surfaces and partition into algal

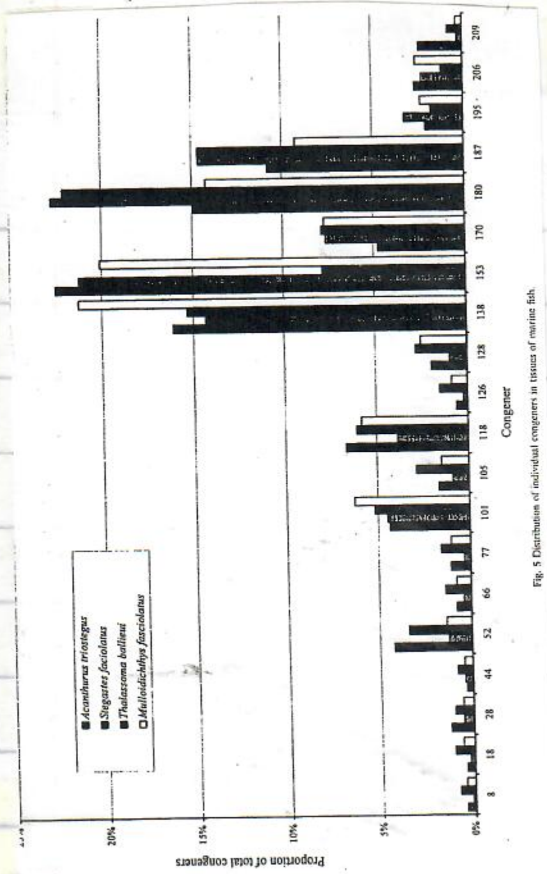

Fig. 5 Distribution of individual congeners in tissues of marine fish.

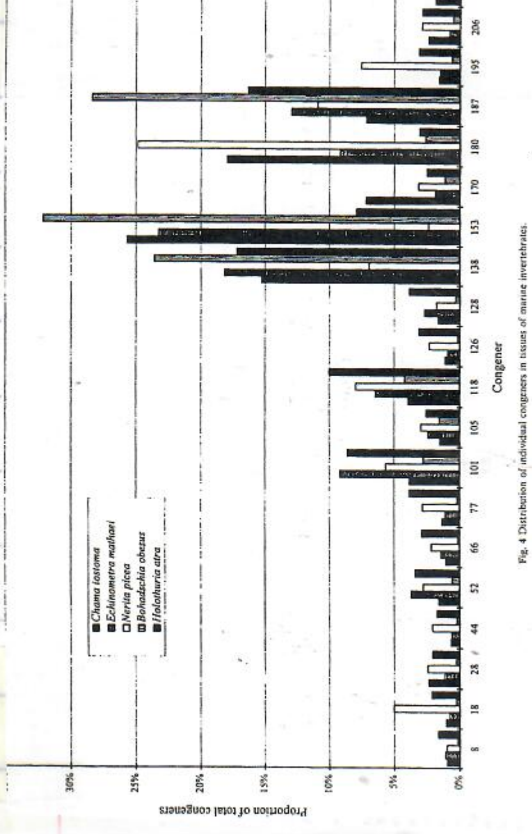

Fig. 4 Distribution of individual congeners in tissues of marine invertebrates.

TABLE 2

Between species Pearson product–moment correlation coefficients based on mean congener proportions.

Media/species	Surface water	Sediment	*Dictyota acutiloba*	*Giffordia breviarticulata*	*Halophila ovalis*	*Bohadschia obesus*	*Holothuria atra*	*Chama iostoma*	*Echinometra mathaei*	*Nerita picea*	*Acanthurus triostegus*	*Stegastes fasciolatus*	*Mulloidichthys flavolineatus*	*Thalassoma ballieui*
Surface water														
Sediment	0.606													
Dictyota acutiloba	−0.025	0.377												
Giffordia breviarticulata	−0.096	0.662	0.402											
Halophila ovalis	−0.106	0.464	0.358	0.600										
Bohadschia obesus	−0.052	0.664	0.473	0.864	0.627									
Holothuria atra	−0.052	0.557	0.303	0.844	0.648	0.798								
Chama iostoma	0.122	0.734	0.556	0.759	0.542	0.751	0.462							
Echinometra mathaei	−0.088	0.648	0.548	0.924	0.612	0.916	0.767	0.882						
Nerita picea	0.148	0.475	0.214	0.510	0.133	0.180	0.279	0.469	0.329					
Acanthurus triostegus	0.040	0.735	0.620	0.865	0.563	0.841	0.633	0.969	0.947	0.487				
Stegastes fasciolatus	0.180	0.812	0.500	0.830	0.465	0.743	0.546	0.942	0.845	0.679	0.945			
Mulloidichthys flavolineatus	0.145	0.786	0.539	0.839	0.544	0.807	0.689	0.939	0.929	0.465	0.960	0.915		
Thalassoma ballieui	0.275	0.783	0.427	0.747	0.291	0.569	0.606	0.740	0.680	0.832	0.786	0.893	0.807	

For sample size = 20 (degrees of freedom = 18), critical value of R is 0.561 at the 1% level.
bold = Correlation between variables is significantly different than zero at the 1% level.

lipids (Rohrer *et al.*, 1982), some significant degree of correlation might be expected between the macroalgaes (*D. acutiloba* and *G. breviarticulata*) and seawater. Although congener concentrations in biota are undoubtedly influenced by ambient concentrations of PCBs in seawater, this lack of correlation suggests that seawater measurements alone may not be reliable predictors of congener concentrations in marine biota.

Congener profiles in biota result from the interaction of ecological factors, such as foraging range, food preferences, behaviour, etc., that influence exposure to PCBs. Profiles are also affected by species-specific and congener-specific metabolic activity rates that apparently influence the post-exposure form of PCBs (Barron, 1990; Boon *et al.*, 1984). Differences in species lipid content, depuration rates, and uptake of the different congeners in the diet as well as biotransformation also undoubtedly influence these profiles (Porte and Albaigés, 1993). Given the potential complexity of such interactions, this degree of significant correlation is remarkable.

Bioconcentration and bioaccumulation patterns

The degree of chlorination of the PCB molecule is known to have an effect on bioconcentration of PCBs, with the tetra-, penta- and hexachlorobiphenyls being accumulated to the greatest extent by fish (Fox *et al.*, 1994). Bioconcentration of PCBs by aquatic organisms is also correlated with lipophilicity (Fox *et al.*, 1994). Log bioconcentration factors (log BCF = $\log_{10}$(mean tissue concentration/mean surface water concentration)) and log bioaccumulation factors (log BAF = $\log_{10}$(mean tissue concentration/mean sediment concentration)) were calculated to indicate whether PCBs were accumulated in biota to concentrations greater than those in surrounding surface waters and whether any such accumulation displayed a characteristic pattern.

Lipophilicity is commonly measured as the partition coefficient (K_{ow}) between *n*-octanol and water. The log K_{ow} values of the PCB congeners, determined by Hawker and Connell (1988), are as follows (PCB #, log K_{ow}): 8, 5.07; 18, 5.24; 28, 5.67; 44, 5.75; 52, 5.84; 66, 6.20; 77, 6.36; 101, 6.38; 105, 6.65; 118, 6.74; 126, 6.89; 128, 6.74; 138, 6.83, 153; 6.92; 170, 7.27; 180, 7.36; 187, 7.17; 195, 7.56; 206, 8.09; 209, 8.18). Following the work of Fox *et al.* (1994) and Hansch and Clayton (1973), relationships between log K_{ow}, log BAF and log BCF values for marine biota at selected trophic levels were described by a parabolic relationship, where log BAF or log BCF first increases then decreases with increasing lipophilicity. This relationship takes the form: log BAF or log BCF = $a(\log K_{ow})^2 + b(\log K_{ow}) + c$. Such a relationship between log BAF, log BCF and log K_{ow} for a representative organism from each trophic level are shown graphically in Fig. 6a,b and as equations below:

- *G. breviarticulata* (GB) – primary producer

$$\log BAF = -0.19(\log K_{ow})^2 + 2.49(\log K_{ow}) - 6.85 \quad r^2 = 0.31, \; n = 20$$

$$\log BCF = -0.24(\log K_{ow})^2 + 3.21(\log K_{ow}) - 7.22 \quad r^2 = 0.23, \; n = 20$$

- *E. mathaei* (EM) – herbivorous invertebrate

$$\log BAF = -0.26(\log K_{ow})^2 + 3.55(\log K_{ow}) - 11.00 \quad r^2 = 0.31, \; n = 20$$

$$\log BCF = -0.32(\log K_{ow})^2 + 4.26(\log K_{ow}) - 11.31 \quad r^2 = 0.26, \; n = 20$$

- *T. ballieui* (TB) – carnivorous vertebrate

$$\log BAF = -0.26(\log K_{ow})^2 + 3.54(\log K_{ow}) - 10.72 \quad r^2 = 0.51, \; n = 20$$

$$\log BCF = -0.31(\log K_{ow})^2 + 4.25(\log K_{ow}) - 11.09 \quad r^2 = 0.39, \; n = 20$$

For all biota sampled, the strength (as indicated by the correlation coefficient, r^2) of the parabolic relationship, although never strong, does increase slightly with increasing trophic level. Relationships similar to these have also been reported by Fox *et al.* (1994) and may be based in part on the increased lipid content of higher trophic level species.

Boese *et al.* (1995) reported bulk sediment BAF values, for individual PCB congeners in the deposit-feeding marine clam (*Macoma nasuta*), from 0.9 (PCB 209) to 30.3 (PCB 118), with an average BAF value of 15.6 for 13 congeners. In the present study, BAF values for the sediment-dwelling bivalve *C. iostoma* ranged from 6.39 (PCB 18) to 80.85 (PCB 153), with an average BAF value of 23.7 for 20 congeners.

Influence of congener stereochemistry on distribution

Borlakoglu *et al.* (1990) and Bright *et al.* (1995) have suggested that the stereochemistry of PCBs can influence their differential metabolism by marine animals, including invertebrates, fish, mammals and birds. Not readily metabolized or persistent, congeners share the characteristics of chlorines at the *para*-positions on both phenyl rings and no adjacent unsubstituted *meta*- and *para*-sites (i.e. chlorine substituents at adjacent *meta-para* carbon atoms). Borlakoglu *et al.* (1990) have indicated that the absence of H atoms at adjacent C atoms is essential for accumulation of PCBs. In addition, there is no evidence for metabolism of *ortho*- and *meta*-unsubstituted congeners. Both Borlakoglu *et al.* (1990) and Bright *et al.* (1995)

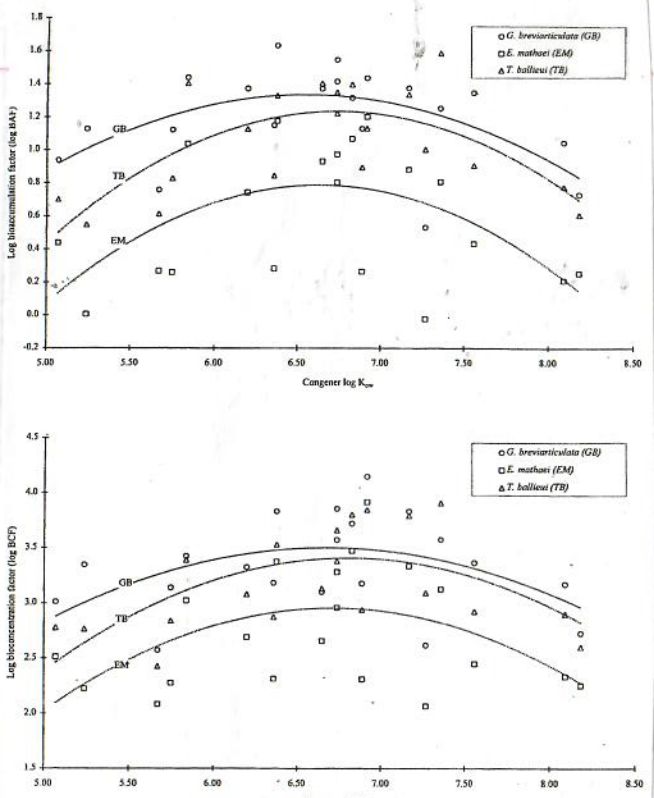

Fig. 6 (a) Bioaccumulation from marine sediment in relation to congener octanol–water partition coefficient (log K_{ow}). (b) Bioconcentration from marine surface water in relation to congener octanol-water partition coefficient (log K_{ow}).

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have suggested that metabolic modification is facilitated by adjacent unsubstituted *meta-* and *para*-carbons on one or both biphenyl rings. Thus more readily metabolized or non-persistent congeners have one pair of adjacent unsubstituted *meta-para* carbon atoms in their rings.

To explore whether similar relationships exist for the marine biota sampled at Midway, changes in congener composition for each species relative to both surface water and sediment were compared within groups defined by the stereochemical characteristics of each congener. To facilitate comparison to previous investigations, the stereochemical categories developed by Bright *et al.* (1995) were employed, so that there were: (A) no adjacent *ortho-*, *meta-* or *meta-*, *para*-unsubstituted sites (PCBs 153, 180, 187, 206, 209); (B) adjacent *ortho-*, *meta*-unsubstituted sites only (PCBs 28, 105, 118, 128, 138, 170, 195); (C) adjacent *meta-*, *para*-unsubstituted sites only (PCBs 52, 66, 77, 101, 126); and (D) both *ortho-*, *meta-* and *meta-*, *para*-unsubstituted sites (PCBs 8, 18, 44).

The results shown in Fig. 7a,b for the 12 Midway species are in good agreement with those presented by Bright *et al.* (1995) for four-horn sculpins alone. Persistent category (A) congeners are generally accumulated in these marine species (the exceptions being *H. ovalis* and *B. obesus*), while non-persistent category (C) and (D) congeners are generally (with several exceptions) not accumulated. The most striking difference between these results and those of Bright *et al.* (1995) is that here the category (B) congeners are apparently being metabolized by a majority of species (with the exception of *B. obesus* and *A. triostegus*).

*Distribution of non-*ortho- *and mono-*ortho*-substituted congeners*

Only 20 of the 209 possible PCB congeners have non-*ortho* chlorine substitutions in the biphenyl rings. These congeners can attain a planarity which makes their structure similar to the highly toxic dibenzo-*p*-dioxins and dibenzofurans (McKinney *et al.*, 1976, 1985). Particularly important within this group are the PCBs having four, five, or six chlorines in non-*ortho* positions, for example, PCBs 77, 126 and 169. These are very potent mimics of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) and 2,3,7,8-tetrachlorodibenzofuran (TCDF) both in P-450 induction and toxic effects (Safe, 1990). Certain mono-*ortho*-substituted PCBs (PCBs 105, 114, 118, 123, 156, 157, 167 and 189) induce aryl hydrocarbon hydroxylase (AHH) and resemble mixed-type inducers (De Voogt *et al.*, 1990). It has been suggested that some of these mono-*ortho* congeners (specifically, PCBs 105, 118 and 156) have a greater toxic impact on marine mammals, while non-ortho congeners are more prominent in terrestrial mammals (Kannan *et al.*, 1989; Tanabe *et al.*, 1994). The levels of the mono-*ortho* congener 105 and the planar congener 126, and possibly also the mono-ortho congeners 118 and 156 appear to contribute substantially to the total toxicity of PCB residues with respect to TCDD (De Voogt *et al.*, 1990). Thus, the presence of significantly elevated levels of these congeners into marine food chains at Midway could have possible long-term toxic potential on marine mammals or certain piscivorous birds (i.e. terns and noddies) that forage in the near-shore waters of the atoll.

In marine sediments, PCBs 77 and 126 respectively accounted for 3.7% and 3.1% of total congeners measured; in surface water 5.1% and 4.2%, respectively. In aquatic macrophytes, PCB 77 accounted for 0.8–4.2% and PCB 126 for 0.6%–2.3% of the total congeners, with the higher percentage for PCB 77, possibly due to its higher aqueous solubility. In invertebrates these congeners were present in the range of 0.1–3.8% for PCB 77 and 0.1–3.0% for PCB 126. In fish species, PCBs 77 and 126 accounted for 0.3–1.5% and 0.2–1.5% of the total congener concentration, respectively. These data suggest that both PCB 77 and 126 generally comprise a smaller percentage of total PCBs with increasing trophic level. Bright *et al.* (1995) also reported that congener 77 comprised a smaller percentage of total PCBs with increasing trophic level in Cambridge Bay (Canada); from 0.64% of total PCBs in sediment to 0.12–0.18% in sea urchins and 0.03–0.06% in four-horned sculpins.

In marine sediments, PCBs 105 and 118 accounted for 1.8% and 4.4% of the total congener in sediments; in surface water 5.1% and 3.2%, respectively. In aquatic macrophytes, these two congeners accounted for 1.0–2.3% and 1.8–8.4% of the total congener concentration, respectively. In invertebrate species, PCB 105 contributed 1.5–2.9% and PCB 118 contributed 3.9–10.0% of the total congener concentration. In fish, their respective contributions ranged from 0.8 to 2.8% and 3.8 to 6.6%. Both PCBs 105 and 118 displayed an approximately constant percentage of total PCBs with increasing trophic level.

Toxic effects to wildlife appear to be correlated more with total TCDD toxicity equivalents than with absolute PCB concentrations. Toxic equivalency factor (TEF) values can be used to normalize PCB concentrations to their TCDD equivalents and Safe (1990) has proposed provisional TEF values of 0.01, 0.1, 0.001 and 0.001 for PCBs 77, 126, 105 and 118, respectively. Giesy *et al.* (1994) proposed the use of TCDD toxicity equivalents to determine levels of acceptable risk toward the protection of wildlife and human health. Total (sum of the four congeners) mean TCDD equivalent concentrations in marine biota collected at Midway ranged from 0.011 to 0.544 μg kg^{-1}, with a total (sum of 12 species) of 1.19 μg kg^{-1}. Although two higher trophic level species, *Stegastes* and *Mulloidichthys*, collectively contributed 0.74 μg kg^{-1} or approximately 62% of the total, there was no indication of TCDD equivalent concentrations increasing with trophic level. TCDD equivalent concentrations for

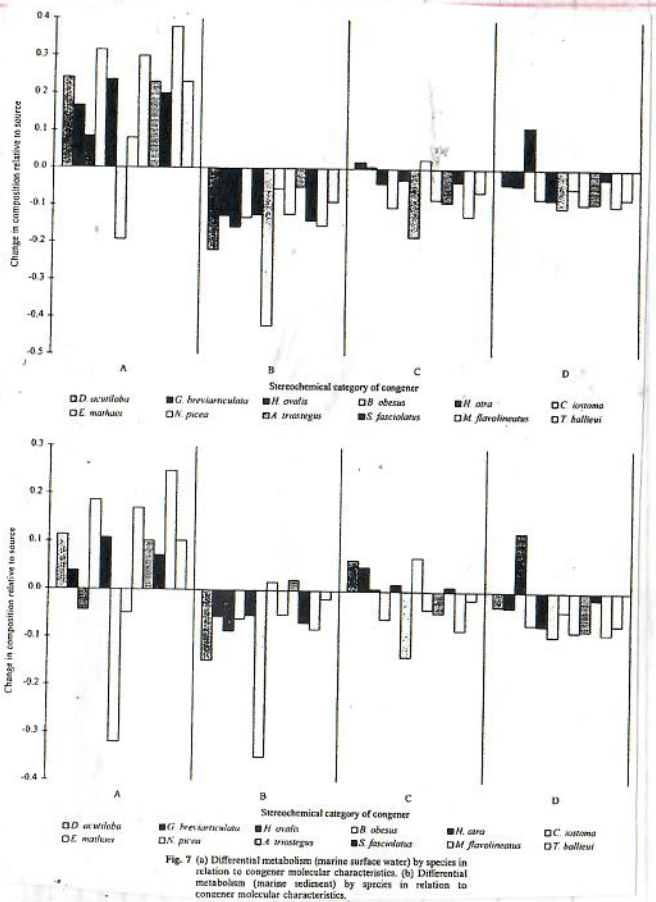

Fig. 7 (a) Differential metabolism (marine surface water) by species in relation to congener molecular characteristics. (b) Differential metabolism (marine sediment) by species in relation to congener molecular characteristics.

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BIOCONCENTRATION OF CHLORINATED BIPHENYLS IN BIOTA FROM THE NORTH PACIFIC OCEAN

BRUCE HOPE [†], SUSAN SCATOLINI, AND ERIC TITUS

Ogden Environmental and Energy Services Company, Inc.
680 Iwilei Road, Suite 660, Honolulu, Hawaii 96817 USA

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ABSTRACT

This study examined polychlorinated biphenyl (PCB) congener bioconcentration patterns in tissues of marine biota (macrophytes, urchins, mollusks, sea cucumbers, fishes) at Midway Atoll, North Pacific Ocean. Calculated mean lipid-normalized logarithmic bioconcentration factors (log BCF_L) for PCB congeners in various marine species ranged from 3.75 to 6.97. The relationship between log BCF_L and the logarithmic n-octanol-water partition coefficient (log K_{ow}) can be adequately described by species-specific parabolic models wherein log BCF_L generally increases then decreases with increases in log K_{ow}. With the exception of a bilinear model, a variety of hydrophobicity models were generally not successful in closely predicting measured tissue residue concentrations as a function of log K_{ow}. There is no evidence of a consistent pattern of progressive increase in bioconcentration of PCB congeners with increasing trophic level in this nearshore aquatic ecosystem. ©1998 Elsevier Science Ltd

INTRODUCTION

Midway Atoll is located in the North Pacific Ocean 1,100 miles northwest of Pearl Harbor, Hawaii, at approximately 177° 22' W longitude, 28° 11' N latitude. The atoll consists of two main islands, Sand and Eastern, surrounded by a fringing coral reef. Although heavily modified by human activity over the previous 90 years, the islands provide breeding and feeding habitat for more than one million migratory seabirds; a total of 45 migratory bird species have been recorded at the atoll. Midway also provides habitat for terrestrial and marine mammals, sea turtles and other reptiles, and a rich diversity of reef fishes and invertebrates. Pacific green sea turtles (*Chelonia mydas agassizi*) and the protected spinner dolphin (*Stenella longirostris*) both frequent the lagoon. Federally-listed endangered Hawaiian monk seals (*Monachus schauinslandi*) are present in small numbers and are known to pup on the atoll's beaches. The atoll is considered critical habitat for this species. In 1988, the atoll was designated as an overlay National Wildlife Refuge and came under the full control of the United States Fish and Wildlife Service in May 1996.

As a result of historical use in industrialized countries and current use in the rapidly industrializing countries

† Author to whom correspondence should be addressed. Current address: Oregon Department of Environmental Quality, Waste Management and Cleanup Division, 811 SW Sixth Avenue, Portland, OR 97204, USA

on seawater, sediment, and biotic material was Arthur D. Little, Inc., (ADL) Cambridge, Massachusetts. Low-level detection analysis for PCBs was performed in accordance with the National Oceanic and Atmospheric Administration's Status and Trends Program Methods. Sediment sample extracts were analyzed with a GC-ECD technique (ADL, 1994). Tissue sample extracts were analyzed using the GC-ECD technique employed for surface water and sediment samples (ADL, 1994). Method detection limits were determined in accordance with U.S. Environmental Protection Agency criteria (40 CFR 136, Appendix B). Congener-specific sample quantitation limits (SQLs) were 0.00022 to 0.003 ug/L for seawater, 0.011 to 0.21 ug/kg for sediments and tissues. All data were validated to Naval Energy and Environmental Support Activity (NEESA) Level D criteria. Additional information regarding the sampling and analysis program for this investigation is available elsewhere (ADL, 1994; Hope et al., in press).

RESULTS AND DISCUSSION

Tissue Concentrations

The geometric mean concentrations of individual congeners in each species (μg/kg, dry weight) are summarized in Table 1. Geometric mean concentrations (n = 49) of individual congeners in surface water were: (PCB #, concentration in μg/L): 8, 0.0002; 18, 0.0002; 28, 0.0005; 44, 0.0002; 52, 0.0002; 66, 0.0001; 77, 0.0003; 101, 0.0002; 105, 0.0003; 118, 0.0002; 126, 0.0002; 128, 0.0001; 138, 0.0003, 153; 0.0001; 170, 0.0007; 180, 0.0003; 187, 0.0003; 195, 0.0003; 206, 0.0002; 209, 0.0002). Means were calculated using log-transformed data to normalize residuals; non-detects ("U" qualified data) were included in these calculations with a value equal to one-half the SQL. Species-specific geometric mean lipid fraction values (f_L, mg[lipid]/mg[dry weight]) were as follows: *D. acutiloba*, 0.0179; *G. breviarticulata*, 0.0260; *H. ovalis*, 0.0107; *C. iostoma*, 0.0133; *E. mathaei*, 0.0026; *A. triostegus*, 0.1830; *S. fasciolatus*, 0.1838; *B. obesus*, 0.0725; *H. atra*, 0.0579; *N. picea*, 0.0049, *M. flavolineatus*, 0.1434; *T. ballieui*, 0.0547.

Because partitioning of hydrophobic organic chemicals into aquatic organisms is governed to first order by the lipid content of the organism (McKay, 1982; Thomann et al., 1992), a general increase in whole body total (sum of congeners) PCB tissue residues (v) with increasing lipid fraction (f_L) might be expected. Regression analysis of the concentration and lipid data presented in Table 1 and the above paragraph demonstrates such a relationship. If all species are considered, a moderately significant relationship ($v = 23.9 \times f_L - 18.2$, n = 12, r^2 = 0.59) between PCB tissue residues and lipid content is evident. If *Acanthurus triostegus*, a fish exhibiting unusually low tissue residues relative to its lipid level, is removed from consideration, the strength of the relationship improves considerably ($v = 35.3 \times f_L - 50.2$, n = 11, r^2 = 0.90).

Bioconcentration Factors

The bioconcentration factor is defined as the uptake of a chemical by an organism directly from water alone, i.e., the ratio of chemical concentration in an organism to chemical concentration in water at equilibrium. It is

PCBs 105 and 118, those of specific interest with respect to marine mammals, ranged from 0.001 to 0.038 μg kg^{-1}, with *Stegastes* and *Mulloidichthys* again collectively contributing 0.06 μg kg^{-1} or approximately 67% of the total.

The TCDD equivalent concentrations reported here are low in comparison to the lowest values (13 μg kg^{-1}) reported in oysters (*Crassostrea virginica*) taken from significantly contaminated regions of Galveston Bay, Texas (Sericano *et al.*, 1992). Murray *et al.* (1979) reported a NOAEL dose of 0.001 μg kg^{-1} day^{-1} for rats fed TCDD over three generations, including critical reproductive life stages, which extrapolates to a dietary NOAEL of ≈0.002 μg kg^{-1} for a 50-kg seal. Recognizing the significant uncertainties involved in such interspecies toxicological extrapolations, we nonetheless conclude that a large marine mammal which infrequently consumes PCB-contaminated food items from near-shore waters at Midway would not have a greater risk of experiencing adverse toxicological effects.

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6.74; 138, 6.83, 153; 6.92; 170, 7.27; 180, 7.36; 187, 7.17; 195, 7.56; 206, 8.09; 209, 8.18). Mean bioconcentration on a dry weight basis (BCF_D) was calculated as log BCF_D = $\log_{10}$(geometric mean dry weight tissue concentration / geometric mean surface water concentration) and on a lipid weight basis (BCF_L) as: log BCF_L = $\log_{10}((BCF_D \times 100) / f_L)$ (Fox et al., 1994). Normalizing measured BCFs to lipid content of the organism reduces the effects of intra- and inter-species variability (Barron, 1990). Calculated log BCF_L and log BCF_D values are presented in Tables 2a and 2b, respectively. These results are consistent with those from other investigations. Oliver & Niimi (1985) report congener-specific steady-state log BCF values in rainbow trout of 4.23 for PCB 18, 4.25 for PCB 52, and 4.14 for PCB 101. Log BCF values reported for Aroclor 1242 in freshwater fish and invertebrates are 5.43 and 4.55, respectively; for Aroclor 1254, reported values for fish and invertebrates are 4.69 and 3.60, respectively (Leblanc, 1995). Fox et al (1994) report log BCF_L values ranging from 5.38 to 7.50 for freshwater zebrafish under laboratory conditions.

Table 2a. Mean dry weight log bioconcentration factors (log BCF_D) for polychlorinated biphenyl congeners in various marine species.

PCB #	Species											
	DA	GB	HO	BO	HA	CI	EM	NP	AT	SF	MF	TB
8	3.19	3.26	2.95	3.11	2.88	3.35	2.74	2.60	3.38	3.56	4.08	3.02
18	4.03	3.71	4.04	3.36	3.00	3.39	2.60	3.24	3.34	3.84	4.19	3.13
28	2.60	2.86	2.76	2.95	2.58	3.35	2.38	2.62	3.42	3.82	3.77	2.72
44	3.30	3.33	2.88	3.21	2.90	3.19	2.48	2.95	3.26	4.12	4.06	3.04
52	4.57	3.69	3.26	3.72	3.20	3.59	3.28	3.08	4.36	4.58	4.55	3.65
66	3.45	3.80	3.38	3.41	3.43	3.68	3.18	3.28	3.93	4.39	4.62	3.56
77	3.10	3.45	3.20	3.05	3.08	3.33	2.56	2.92	3.58	3.86	4.26	3.15
101	3.76	4.14	3.32	4.41	3.61	2.96	3.68	3.40	4.37	5.15	5.22	3.83
105	3.19	3.36	2.82	3.98	2.90	3.38	2.92	2.94	3.77	4.26	4.42	3.40
118	3.60	4.10	3.59	4.59	3.67	3.97	3.33	3.54	4.56	5.08	5.19	3.90
126	3.19	3.54	3.11	3.13	3.16	3.42	2.65	3.00	3.51	3.86	4.35	3.30
128	3.72	4.06	3.52	3.76	3.56	3.89	3.45	3.20	4.32	4.77	5.12	3.87
138	4.33	4.05	3.64	4.60	3.73	4.38	3.80	3.31	4.76	5.47	5.57	4.13
153	4.78	4.62	4.29	5.16	3.87	5.09	4.38	3.32	5.39	6.12	6.02	4.31
170	3.38	3.99	2.65	3.47	2.52	3.69	2.43	2.60	3.86	4.83	4.76	2.47
180	4.15	3.95	3.19	4.20	2.99	4.45	3.51	3.86	4.72	5.68	5.40	4.29
187	3.95	4.15	3.51	4.56	3.70	4.05	3.65	3.51	4.59	5.48	5.21	4.11
195	3.52	3.63	3.08	3.57	2.99	3.40	2.72	3.34	3.87	4.83	4.61	3.19
206	3.85	3.45	2.98	3.69	3.13	3.75	2.60	3.10	4.15	4.85	4.83	3.19
209	4.54	3.13	2.74	3.34	2.78	3.64	2.65	3.04	4.11	3.95	3.94	3.02

Hydrophobicity Model

The most common model for estimating chemical-specific BCF values consists of establishing correlations between BCF values and hydrophobicity of the chemical. The majority of these are obtained from linear regression models between log transformations of BCF values and *n*-octanol-water partition coefficients (log K_{ow}) of the chemicals (Barron, 1990; Geyer et al., 1991). However, because the presumed linear relationship has been shown to fail for strongly hydrophobic chemicals (log K_{ow} > 6), several studies (Barron, 1990; Bintein

predicted by several linear, parabolic, and bilinear models approximated BCF_D or BCF_L values measured in this study. BCF values generated by both linear (Oliver & Niimi, 1988) and parabolic (Fox et al., 1994) models were significantly different ($\alpha = 0.05$) from the measured values. With another linear model (Mckay, 1982), however, estimated and measured values are not significantly different at $0.2 < P < 0.3$. A bilinear model (Bintein et al., 1993), produced estimated and measured values not significantly different at $0.05 < P < 0.10$. These comparisons suggest that simple linear models are adequate for estimating BCF values for log K_{ow} values ≤ 6, but that parabolic and possibly bilinear models are more appropriate if log K_{ow} values vary widely and include values > 6 (Bintein et al. 1993).

Table 3. Parameters of parabolic models showing relationships between congener lipophilicity (log K_{ow}) and lipid-normalized bioconcentration factors (BCF_L).

Species	Model Parameters *			
	a	*b*	*c*	r^2
Dictyota acutiloba	0.06	-0.67	+6.86	0.13
Giffordia breviarticulata	-0.23	+3.40	-6.04	0.24
Halophila ovalis	-0.14	+1.79	-0.35	0.10
Chama iostoma	-0.11	+1.57	-0.06	0.17
Echinometra mathaei	-0.33	+4.56	-10.69	0.29
Nerita picea	-0.23	+3.15	-5.98	0.25
Bohadschia obesus	-0.18	+2.64	-3.67	0.24
Holothuria atra	-0.33	+4.49	-9.29	0.26
Acanthurus triostegus	-0.25	+3.57	-7.92	0.35
Mulloidichthys flavolineatus	-0.36	+5.07	-11.84	0.40
Stegastes fasciolatus	-0.38	+5.44	-13.69	0.42
Tholassoma ballieui	-0.32	+4.44	-10.21	0.41

* Model: $\log(BCF_L) = a(\log K_{ow})^2 + b(\log K_{ow}) + c$

Laboratory-derived BCF values would be expected to deviate from field-derived BCF values depending on the contributions made through food consumption. Field-derived BCF values reported herein are generally less than those achieved in the laboratory and are also less than field-derived BAF values reported by Oliver & Niimi (1988). This suggests either that: (a) consumption of contaminated food may not be a significant exposure pathway in this ecosystem or (b) unspecified environmental factors are possibly limiting exposure or (c) food items actually being consumed by the various species were not those sampled in this investigation.

Trophic Relationships

The trophic relationships among organisms examined in this study have not been well-defined in the Midway Atoll near-shore marine ecosystem. However, based on some life history information and field observations, the 12 species in this study can be nominally grouped into four trophic levels: primary producers (*D. acutiloba*; *G. breviarticulata*, *H. ovalis*), herbivorous primary consumers (*C. iostoma*, *E. mathaei*, *A. triostegus*, *S. fasciolatus*), omnivorous secondary consumers (*B. obesus*, *H. atra*), and carnivorous tertiary

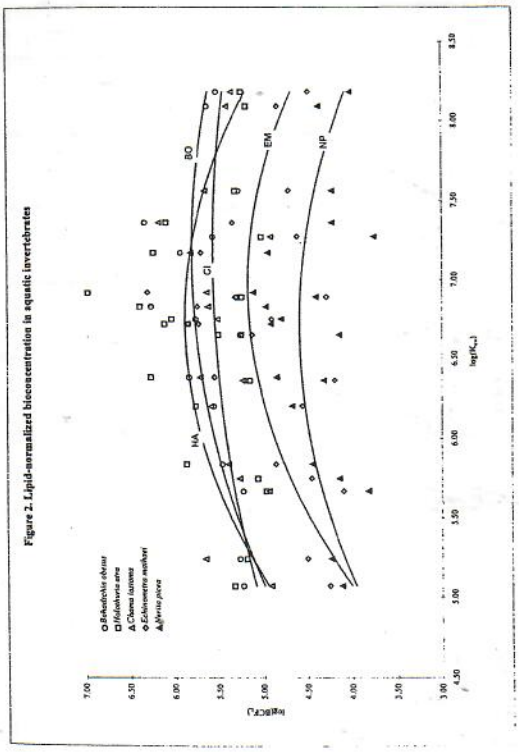


Figure 2. Lipid-normalized bioconcentration in aquatic invertebrates

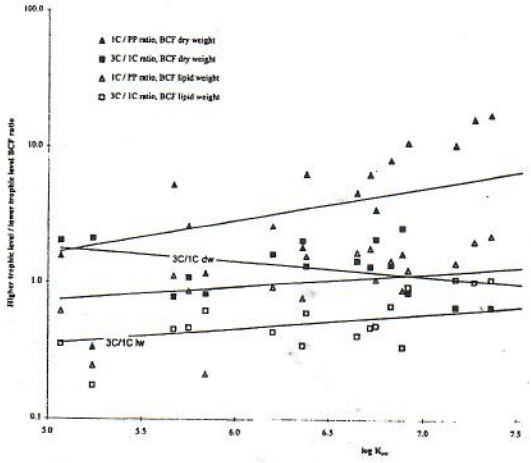
consumers (*N. picea*, *M. flavolineatus*, *T. ballieui*). Given that species were assigned to trophic levels on the basis of field observations and inferences concerning potential ecological relationships, without regard to the lipid content of individual species, it is not surprising that the mean lipid fraction of species in each trophic level does not necessarily increase with increasing trophic level: 0.0182 for primary producers, 0.0956 for primary consumers, 0.0652 for secondary consumers, and 0.0677 for tertiary consumers.

While it is unlikely that all of these species are simultaneously involved in the same food web, some feeding relationships are suggested by field observations. The herbivores (*E. mathaei*, *A. triostegus*, *S. fasciolatus*) and omnivores (*B. obesus*, *H. atra*) may graze to some extent on algae species (*D. acutiloba*; *G. breviarticulata*) or sea grass (*H. ovalis*). *Dictyota* contains alkaloids that discourage grazing on its own tissues but may support epiphytic algae that are consumed by fish. The carnivorous fish *M. flavolineatus* preys primarily on benthic invertebrates which could include *C. iostoma*, *E. mathaei*, or *N. picea*. *T. ballieui* may prey on other fish species possibly including *A. triostegus*, *S. fasciolatus*, or *M. flavolineatus*. The bivalve mollusc (*C. iostoma*) is potentially a prey item for the carnivorous snail (*N. picea*). Indiscriminate grazing of sediments by *B. obesus* or *H. atra* may lead to the ingestion of particles or fragments of primary producers that have settled on the sediment; however, it is unlikely that these holothurians serve as a food source for any other species in this study.

A trophic level mean BCF_L was calculated by averaging individual species BCF_L values within each trophic group. In contrast with the findings of others (Leblanc, 1995; Oliver & Niimi, 1988), these trophic level means show (Figure 4) no consistent pattern of progressive increase in bioconcentration of PCB congeners with increasing trophic level. Twelve of the twenty congeners have primary consumer BCF_L values higher than primary producer values, but sixteen of the twenty congeners analyzed have tertiary consumer BCF_L values not significantly different than those for other trophic levels. Only four congeners (153, 170, 180, 187) display a slight upward trend in bioconcentration from primary producers to tertiary consumers. Bioconcentration by secondary consumers is frequently much greater than that of other trophic levels. However, as this trophic level is represented here only by holothurians, generalization to other secondary consumer species should be approached with caution.

Leblanc (1995) has suggested that the ratio of fish to invertebrate wet weight bioconcentration factors increases linearly with increasing log K_{ow}, for log K_{ow} > 5 and that, in general, trophic level differences in bioconcentration could be estimated as: $BCF_{\text{higher trophic level}} = BCF_{\text{lower trophic level}} \times [(8.2 \times \log K_{ow}) - 40]$. To examine this hypothesis, primary consumers / primary producers (1C/PP) and tertiary consumers / primary consumers (3C/1C) mean BCF_D and BCF_L ratios were calculated with data from this study for. The results, as shown in Figure 5, indicate only a weak linear relationship between trophic level ratio and log K_{ow}; specifically: $1C/PP = 2.49 \times \log K_{ow} - 10.96$; $n = 20$, $r^2 = 0.19$ and $3C/1C = -0.30 \times \log K_{ow} + 3.32$, $n = 20$, $r^2 = 0.20$. If the

Figure 5. Relationship between log K_{ow} and the ratio of higher and lower trophic leve



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Green Turtles — MIDWAY — BARNACLES Collected — ACC IN ALCOHOL

MTR label here

MT	Number BARNS	Date	SCL	
MT 43	1	11/12/00	49.4	
44	1	11/12/00	45.5	
~~47~~	1	11/13/00	44.9	No Found
16	4	11/13	43.4	
15	1	11/14	53.2	+ Skin barns not deeply embedded
52	4	11/15	61.9	ID 4135Ø87C4A
53	4	11/15	77.3	LFF embedded MT 53 in cryovial Alcohol
54	1	11/15	48.2	
55	8	11/16	86.2	/ Print photo plastrons /
29	8	11/17	38.0	+ Skin barns not deeply embedded.

Camp Possession Ventral

INCONEL TAG

+ K898 w/ Barnacle on it recovered from green turtle BAY 11-21-ØØ

Fedex tracking # 8215 1157 9811

TO Bill Neuman

Scripps

brown, varied with drab; a patch of orange-brown scales behind the tip of the pectoral; teeth white; iris yellow; upper and lower lip dark red; an irregular dark red patch on the side of the head, which is followed behind and below by a number of scale marks of the same color; dorsal and anal about equal in height; dorsal light brown, passing into blackish-brown posteriorly, everywhere mottled with drab and brown of different shades; a blackish spot on the first and second membrane; pectoral uniform brown: ventrals drab-brown, the outer rays bluish-drab; anal drab-brown, brownish at the margin; caudal uniform umber-brown.

The type (B. P. B. Museum No. 3366) here described was secured in the Honolulu market February 12, 1903, and is 9.5 inches in length. (Fig. 8.)

Report of a Visit to Midway Island.

WM. ALANSON BRYAN.

Introduction.

DURING the months of July and August, 1902, the writer made a voyage in the schooner Julia E. Whalen to the small and isolated Marcus Island, in the interest of the Bishop Museum, to investigate its fauna and flora.[1] On the return voyage we called at Midway, and I was thus afforded an opportunity to see this small and then seldom visited island. Since our call was the last one to be made prior to the taking over of the island as a cable station, it seems that a brief account of the observations made during the day and a half on shore will not be out of place, especially since the island had been visited but once before by an ornithologist. It is hoped that the notes here given may in the future prove of value in noting the change in the plant and bird life which will doubtless be effected through the influence of the colony that has since been permanently established there.

As a matter of convenience the Hawaiian group has been divided into the windward or inhabited islands and the leeward or uninhabited chain. It is to this latter division that Midway belongs. Beginning at Niihau, the most western of the heretofore

[1] Bryan. Monograph of Marcus Island. Occ. Pa. B. P. B. Mus., vol. ii, no. 1, pp. 77-140 (1903).

inhabited islands, and omitting a few barren rocks near it, the chain is composed, in the order mentioned, of Nihoa, Necker, French Frigates Shoal, Gardner, Laysan, Lisianski, Midway and Ocean Islands, together with various sunken rocks and reefs. Midway lies something over 1000 miles west by north from Honolulu (28° 12′ 22″ N., 177° 22′ 20″ W.), and is, as its name implies, near the geographical centre of the North Pacific.

For the ornithologist, interest centres about the pelagic birds which make these low coral islands their home, no less than about the migratory species which have established themselves as regular visitors. But such stragglers as may from time to time come ashore as ocean waifs on such out of the way places should always be recorded as a fact having an important bearing on the range and distribution of the species in question.

Narrative.

The return voyage from Marcus (24° 14′ N., 154° E.) was begun August 7. August 19 we crossed the 180° meridian and decided to stand down for Midway, since we were then less than 400 miles to the northwest of it. At 10 A. M., August 21, we sighted Sand, the larger of the two islets of the Midway group. When approaching the island from the north, as we did, or indeed from any direction, Sand is always the first island sighted. It is visible at a distance of not more than fifteen miles as a shimmering white strip along the horizon. On a nearer approach breakers can be seen on the reef surrounding it. By passing out well around the western end of the breakers our little vessel came safely to anchor in blue water off the wide, shallow opening in the northwest part of the reef. A boat was lowered and we began a row of more than four miles to shore. Landing on Sand Island we pulled our boat up on the beach in a little cove fronting on Wells Harbor, and went at once to the sailors' cabin close by. This cabin was built years ago from beach wood and wreckage, and has been rebuilt several times since to form shelter for shipwrecked crews that have gone ashore there. We found no signs of recent occupants, other than the cast-off garments of the colony of Japanese bird-poachers, to whose work of destruction I shall later refer. From the cabin we went to the high sand pile marked on the accompanying plan by a flag, in order to gather from that point of vantage the relation existing between the two islets and the surrounding reef.

Stretching from a point west by north from the spot where we stood, and extending from there about the southeast and north of us, could be seen the line of encircling breakers. Coral rocks awash were visible on the reef almost the whole way around. Thus, on the sides mentioned is formed an irregular coral barrier which is about six miles in its greatest diameter. To the northwest of our point of observation the reef is broken up or wanting. The entrance to the lagoon and into Wells Harbor is at the extreme south side of the open portion of the reef, and is about three-quarters of a mile in width. The remaining northern portion is very shallow, with narrow tortuous channels through the masses of submerged coral rock.

Well to the south and east of this lagoon enclosure are located the two bits of land which are designated as Sand and Eastern Island respectively. The one which served as a point of general observation is little more than a barren, blinding heap of sand, of irregular and constantly varying form, forty-three feet high; one mile and a quarter long by three-quarters broad more or less. Here and there the sand has been heaped up in piles a few feet high by the wind. On the top of most of these dunes a few hardy shrubs and grasses manage to subsist, and form the only relief for the eye in what is little else than a waste of shifting sand. Not far from the sailors' cabin referred to were a few graves, marked by three rude wooden crosses, which added the last touch to a picture of desolation such as I had never before witnessed.

To the east a mile or more, but connected with Sand Island by a narrow submerged sand spit lies Eastern Island. Its roughly formed triangular outline can be seen from so slight an elevation as that on which we stand, for it is nowhere more than twenty-five feet above sea level. Compared with the island just described it presents an interesting contrast, for it is clothed in green down to the beach, and differing thus in its flora, it differs still more in the number of birds which inhabit it. What freak of old ocean has placed these two specks of land side by side, under apparently the same conditions, and has covered the one with low shrubs, creeping plants and grasses, and has left the other an uninviting heap of sand? Eastern Island is smaller than its neighbor, being approximately one mile and one-quarter in length by half a mile wide in the broadest part. The centre is a trifle lower than the

edges, which gives it the general form of a broad, flat platter. Although composed of coral and coral sand it differs from Sand Island in having the interior portion mixed to some extent with vegetable mould and guano. Almost the whole surface of the island is honeycombed with the burrows of the Wedge-tailed Shearwater. Near the middle, on the northwest shore, were three crude shanties, two made of wood and one of grass. These had been standing a considerable time, and had doubtless been built by the Japanese poachers during some of their early visits.

1859 Capt. Brooks

Midway was discovered by Captain Brooks, of the Gambia, in 1859, who took possession of it for the United States. At one time the Pacific Mail Steamship Company intended using it as a depot for its transpacific steamers in preference to Honolulu, which was then under foreign influence. With this plan in view it was surveyed in 1867, but it was never utilized for the purpose intended. It was again carefully surveyed by the officers and men of the U. S. Iroquois in 1900, and an elaborate map, showing several thousand soundings, has been published. The second survey was made preparatory to the establishment of a cable and naval station there, which now gives the island an importance far out of proportion to its area.

The island has been repeatedly visited by small tramp vessels, and has more than once been the haven for shipwrecked sailors. However, it was not until Mr. Henry Palmer visited it in July, 1891, that the nature of its bird life was definitely made known, although all those who visited it made frequent reference to the swarms of sea birds that inhabited it.

Limited as our stay was to but a few hours, the following can be regarded as little more than a running list of the plants and birds which we were able to secure in a short time. Doubtless both the number of plants and birds could be increased without difficulty, while a protracted stay on the island would no doubt bring to light many interesting records of rare visitors, as well as record forms of bird life which would be common enough at other seasons of the year.

On the two islets I collected, in all, eleven species of plants, securing six on Sand and ten on Eastern. With the exception of a single species, *Eragrostis cynosuroides* (Retz), all the plants secured on Sand Island were found growing on Eastern. The

more important plants determined for Midway are: *Cenchrus calyculatus* Cav., *Boerhaavia tetrandra* Forst., a variety near *Lepidium oahuensis* Chan. I. Schl., *Capparis sandwichiana* DC., *Ipomæa insularis* Stend., *Scævola kœnigii* Vahl., *Tribulus cistoides* Linn., and *Eragrostis cynosuroides* (Retz). In addition to the above are three widely distributed beach plants, two of which are grasses that are as yet undetermined.

List of Birds.

LARIDÆ.

Sterna fuliginosa Gmel.—**Sooty Tern.**

Under the low *Scævola* bushes on the eastern end of Sand Island was an extensive colony of Sooty Terns that were rearing their young. They were in about the same stage of development as I had found them on Marcus Island. On Eastern the colony was much larger than on Sand Island. This was doubtless due to the more abundant growth of shrubs and grass, which was thick enough to furnish some protection from the sun. Although I made diligent search, only one egg, an infertile one, was found. From what I have seen on the outlying islands I conclude that all the colonies of Sooty Terns in the North Pacific nest at or near the same time. A good series of skins was secured.

Mr. Palmer spent a week on the island (July 11 to 19) without seeing the Gray-backed Tern, *Sterna lunata* (Peale). It is a peculiar freak in distribution that this species should be met with on all the low islands except Midway, but during my sojourn I did not see a single example, although here, as at Marcus, I was especially on the lookout for it.

Anous stolidus (Linn.).—**Noddy.**

There were but few examples of this species on either island. The few nests found were built on the ground, usually under the shrubs which grew on top of the sand mounds. The young were still in the down.

Micranous hawaiiensis Roths.—**Hawaiian Tern.**

Only a little colony of a dozen or twenty individuals were seen on Sand Island. These were huddled together sitting on the low bushes on a sand mound. I have observed that birds of this species seldom leave the place where they have been reared, so that when

disturbed they rise and circle gracefully about for a time, but always return to the same spot. When they alight they all sit facing the wind.

On Eastern Island I found a number of colonies of different sizes distributed here and there over the island. All of the twenty birds shot had the feet black in life. A nest located in the bushes toward the centre of Eastern Island may be taken as typical of all seen; it is a rather bulky structure composed for the most part of sea moss, to which were added twigs, leaves, bits of sponge, etc. All of the material is cemented together with the droppings of the bird. The nests were always placed in colonies of a dozen or more, and the fully fledged young were usually sitting on the bushes. But a single egg, which proved to be infertile, was found close by, and as the nests contained no young it would seem that this species nests earlier than the other Terns on the island.

The Hawaiian Tern seldom goes far out to sea. It is always to be seen in small flocks sailing about over the reefs in search of surface-swimming fish, which constitute its chief food.

Gygis alba kittlitzi Hartert.—**White Tern.**

This fearless and inquisitive bird was by no means abundant on Sand Island. The few found were sitting with their young in the bushes on the sand piles. Specimens secured were taken without difficulty by the hands. On Eastern Island the birds were more abundant. No eggs were collected, but one newly hatched young was secured. Young which were assuming the first plumage were quite common.

DIOMEDEIDÆ.

Diomedea immutabilis Roths.—**Gooney.**

There were the carcasses of a very few birds on Sand Island which had evidently been killed several months before our visit. On Eastern Island skeletons of this species were more common, but they were by no means as plentiful as those of the following species. I should say that the Gooney was less than a third as abundant as the Black-footed Albatross, judging by the number of dead bodies of each to be seen. None of our party saw a living bird of either species.

Diomedea nigripes Aud.—**Black-footed Albatross.**

Everywhere on Eastern Island great heaps, waist high, of dead albatrosses were found. Thousands upon thousands of both species had been killed with clubs, the wing and breast feathers stripped off to be sold as hat trimmings, or for other purposes, and the carcasses thrown in heaps to rot. After my acquaintance with the colony of bird pirates on Marcus Island it was but too apparent that a similar gang had been in full operation at Midway not many months prior to our visit, and that they had worked sad havoc among the birds there, in spite of the severe warning which had been given by Captain Niblack, of the Iroquois, to a party similarly engaged the season before. The work of exterminating the Midway colony was surely well under way, and I was convinced that unless something definite was done, and that at once, to prevent such wanton destruction, before long this colony of albatrosses, as doubtless all those on the low outlying islands, would be wiped out precisely as the one on Marcus Island had been.

On my return to Honolulu I took the matter up with the proper officials in Washington, among others addressing a letter to the Chief Executive, with the result that the subject was brought to the attention of the various cabinet officers concerned. With the cooperation of Dr. Henry Palmer, of the U. S. Biological Survey, together with the energetic services of Mr. Wm. Dutcher, President of the Audubon Societies, to whom the whole matter of bird protection for the Pacific had been presented in person by the writer, most satisfactory results have been obtained. A naval vessel will in the future make at least two patrol trips each year to the outlying islands of the Hawaiian group to break up or prevent further depredations. The officers and men stationed on Midway have strict orders to protect the bird colonies there. The fishing rights to certain of the outlying islands will only be let by the Territory, with special clauses protecting the bird colonies thereon; while the Japanese Government will in future refuse to allow predatory hunting and fishing vessels to leave Japanese ports.

PROCELLARIIDÆ.

Priofinus cuneatus (Salvin).—**Wedge-tailed Shearwater.**

This species was only occasionally met with under the bushes on the mounds on Sand Island, while on Eastern the whole interior

of the island was honeycombed by their burrows. They were so numerous indeed that crossing the island in any direction was a difficult task by reason of one dropping, unexpectedly, hip deep in them, only to climb out of the sand to repeat the experience again and again. They were abundant birds, everywhere dodging beside their holes, or stowed away in them. Several downy young but no eggs were secured.

The absence of the Christmas Island Shearwater, *Puffinus nativitatis* Streets, was another mystery in distribution. Having found it fairly common on Marcus Island, sitting beside its half grown young under the trees, and knowing that it had been met with at French Frigates Shoal and Laysan I fully expected to find it at Midway, especially on Eastern Island where the conditions are fully as favorable for its nidification as they are on Laysan. I am at a loss to account for such a freak in distribution, except it may be that the bird has a great attachment for the locality where the young is reared, and even though it knows of and possibly visits other islands equally suited to its habits, always returns to its own island to in turn rear its young. If such is the case it would indicate the difficulty of establishing new colonies or restocking old ones by artificial means.

PHAETHONTIDÆ.

Phaethon rubricauda Bodd.—**Red-tailed Tropic Bird.**

A few birds of this species were met with on both islets. All had young in the down, for which they would fight most savagely when molested.

SULIDÆ.

Sula piscator (Linn.).—**Red-footed Booby.**

A single individual, which had evidently been left behind when its neighbors took their leave of the island, was seen asleep on the bushes on Sand Island. I captured it in my hands. It was the only example seen by any of us.

Sula cyanops (Sund.).—**Blue-faced Booby.**

A number of this species was seen and a specimen was collected.

FREGATIDÆ.

Fregata aquila Linn.—**Man-o'-war Bird.**

There was quite a large colony of Man-o'-war Birds nesting on the top of the bushes on Eastern. Twenty-eight nests were counted all within a space a few rods square. The clatter of the bills of the downy young birds as one entered the colony was most interesting and curious.

SCOLOPACIDÆ.

Numenius tahitiensis (Gmel.).—**Bristle-thighed Curlew.**

The Curlew was quite common on the shore of Eastern Island, where I had little difficulty in securing a series of twelve specimens.

Arenaria interpres (Linn.).—**Turnstone.**

The Turnstone was met with on both islands at Midway.

RALLIDÆ.

Porzanula palmeri Frowh.—**Laysan Island Rail.**

A number of years ago Captain Walker, of Honolulu, carried a cage of the Laysan Rails down to Midway and liberated them on Eastern Island. They have multiplied until, at the time of our visit, they were almost as abundant there as they are on Laysan. A single immature specimen was taken, which, when compared with a large series in the Museum from Laysan, exhibits differences in coloration which would lead one unfamiliar with the circumstances of its introduction to separate it by a specific name.

August 26, 1905.