MAN/DOLPHIN COMMUNICATION

Final Report

15 December 1966 - 13 December 1967

Prepared for

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I INTRODUCTION

This project, a program of research intended to determine the feasibility of establishing a language, approaching English, between man and dolphin was initiated in October of 1964.

Prior work, Bastian, (1) Bates, (2) Bateson, (3) Breland, (4) Busnel, (5) Kellogg, (6) Lilly (7) and Norris (8) indicated that the cetacea exhibit extensive cooperative behavior and that this behavior is dependant on a high rate of information exchange. The delphinidae in particular have been shown to produce and respond behaviorally to whistles, relatively pure sinusoidal tones, modulated in amplitude and in frequency between 1 and 25 kHz. Thus, they possess vocal and auditory apparatus capable of producing and processing acoustical information at a rate sufficiently high to permit the development of an extensive vocabulary of acoustical tokens or words which, when assigned meaning through consistent usage, may serve as a basis for the development of a language.

For this study, words were constructed by modulating pure tones in length and frequency. Electronic devices were built to translate human vocal sounds into whistle

Contours modulated in length and pitch and to translate dolphin whistles into humanoid vocal sounds. These devices provide a channel of communication between man and dolphin when coupled to the respective environment by microphone, loudspeaker and hydrophone. The program, from 5 October 1964 to October 1965 (9) was specifically designed to answer the following questions.

1. Will a dolphin respond to an electronically derived acoustic stimulus?

2. Can a dolphin separate or distinguish among frequency modulated whistles produced by electronically tracking modulation in articulated vowel sequences?

3. Can a dolphin imitate the modulated whistles?

During this portion of the study, conducted at the Pt. Mugu Cetacean Facility, Pt. Mugu, California, a dolphin, Tursiops truncatus (Montague) named "Dash" and subsequently renamed "Maui", was trained to differentiate among five words, BIP, BAIEP, BEIAP, BAEP and UWEIAP, and assign to them a behavioral response; hit a ball with his pectoral, go through a hoop, raise his flukes, produce a sonar sound (RAC) and roll over. This animal was also trained to imitate each of the above words.

Standard operant conditioning techniques were used to train the animal and the level of 85% correct responses achieved by Dash was thought sufficient to demonstrate differentiation. Having demonstrated the existence of a channel of communication and thus the possibility of developing an inter species language, the program from 4 October 1965 to 14 December 1966 (10) was designed to investigate the extent to which such an interaction might be developed.

This program was specifically designed to answer the following questions:

1. To what extent are secondary cues involved in behavior definitions and can they be systematically removed such that the stimulus word is the only available carrier of response evoking information.
2. Will the animal respond differentially to a time ordered sequence of response evoking stimuli.

The ability to answer these questions depended on the development of more stable translating devices and on the development of a device which would provide a clear visual presentation of the acoustic interaction.

A second animal, a female Tursiops named "Dopy" and subsequently renamed "Puka", was acquired and trained to respond differentially to two electronically generated and very stable whistle contours.

Both animals were moved for convenience to a large artificial lagoon located in Kaneohe Bay, Oahu, Hawaii, where development and training were continued. The data in Section IV below indicate the progress achieved at the end of that report period.

The program for the report period, 14 December 1966 to 13 December 1967 was designed to extend the interactions between trainer and dolphin and to include interaction between the two animals within the previously developed communication structure. Two devices developed in the previous report period were introduced for field testing.

Section II below is a description of the facilities used during this portion of the investigation, Section III describes the devices and equipment used and developed in this report period, and the course of the man-dolphin interaction is summarized in Section IV.

II FACILITIES

Training during the report period 14 December 1966 to 13 December 1967 was conducted at Coconut Island lagoon located in Kaneohe Bay, Oahu, Hawaii.

Figure 2-1 is a general view of the training facility showing most of the lagoon area, the houseboat which housed the apparatus and provided a working platform for the trainers, and the float circle which defined the work area in earlier training and which provided a place to position props associated with the animal's responses. This facility, personnel and animal transport to and from the island, food fish for the two dolphins, veterinary support, facility maintenance, idle care of the animals, and office space at Oceanic Institute, Makapuu Point, Hawaii was provided by the Oceanic Institute under USNOTS Contract N00123-67-0107.

On 1 November 1967, both animals were placed in a newly constructed training tank at Oceanic Institute.

Figure 2-1. Over view of training area at Coconut Island showing float circle, houseboat and training session in progress.

III DEVICES and APPARATUS

Two devices were constructed and field tested during the report period. A Man to Dolphin Translater Mark 5 (MDT-5)

was placed in service 5 May 1967. This instrument, an improved version of the Man to Porpoise Translator incorporated in the Man to Porpoise Intergrated communication system (MPI) previously in use to translate spoken words into frequency modulated whistles, is driven from an Electro-voice 647 A microphone and drives an Atlantic Research, Inc. LC 32 hydrophone. Subsequent testing and redesign produced MDT-5 serial 3, put in use 27 September 1967. A technical manual for this device is included as Appendix A.

A Multi Spectrum Analyzer, (MSA-1) was also placed in use 5 May 1967. This device accepted inputs from the lagoon via a second Atlantic Research Inc. LC 32 hydrophone, amplified by a Listening, Inc., FET preamplifier, and presented acoustic events plotted graphically, frequency in kHz v.s. time in inches per second, on electro statically sensitive chart paper, Time Fax NDK manufactured by Fitchburg C.P.I., Scranton, Pennsylvania. This instrument replaced the Porpoise to Man Translator (PMT) coupled to a Sanborne Co. 320 dual channel D.C. amplifier recorder previously in use for observation of underwater acoustic events.

Subsequent testing and redesign produced the MSA-2 which was put in use 27 September 1967. A technical manual for the MSA-2 is included as Appendix B.

In addition to the MDT-5-3, and MSA-2, a Crown 800 two channel tape recorder was used to record the trainer's voice and underwater sounds from the lagoon during sessions. The lagoon sounds could be monitored by the trainer via headphones driven by the Crown 800 tape recorder or via a Realistic Nova series loudspeaker driven by a Dyna Kit Stero 35 power amplifier.

The communication system used in this program at the Coconut Island facility is shown in block diagram in figure 3-1. The photograph in figure 3-2 shows the installation of the equipment aboard the houseboat.

IV TRAINING

Two dolphins, Tursiops truncatus, named Maui, a male, and Puka, a female, were trained using standard operant conditioning techniques (11) to respond with gross body motions and vocalizations to electronically translated English language phoneme sets. Tables 4-1-1 and 4-1-2 list the command - response sets for each animal in use as of 1 November 1967.

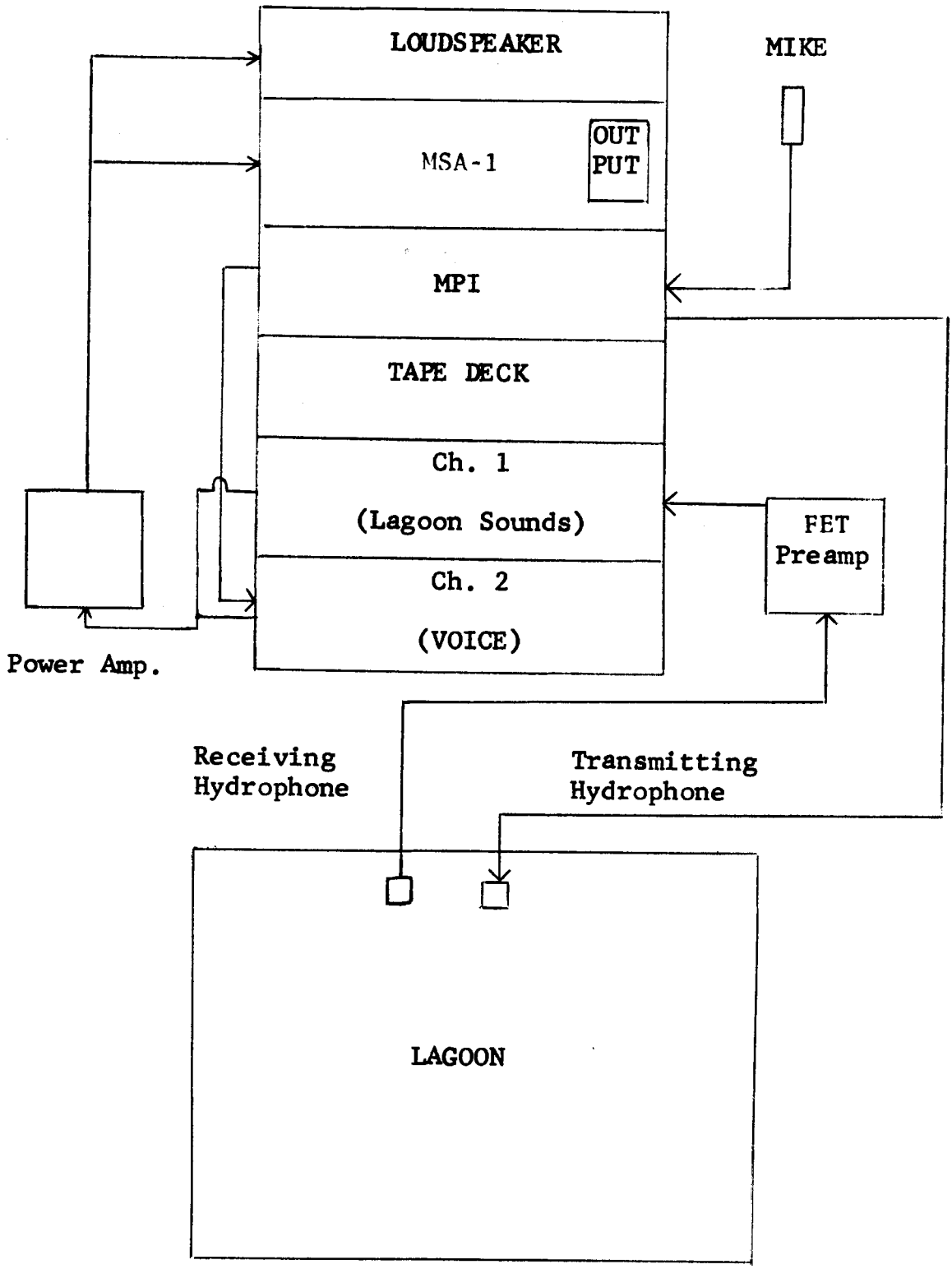


Figure 3-1. Block Diagram of Apparatus

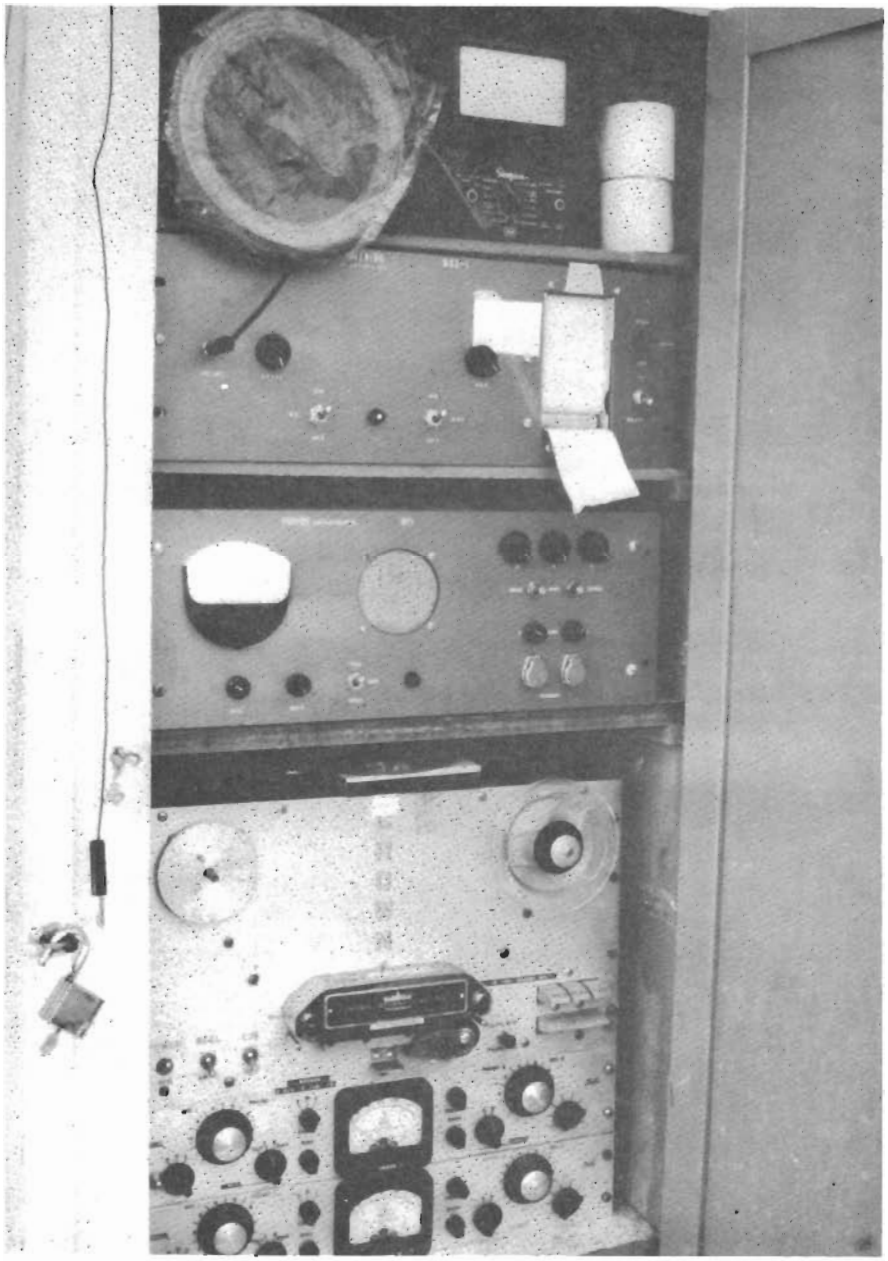


Figure 3-2. Equipment rack. Top to bottom, loudspeaker multimeter and spare tape, MSA-1, MPI and Crown 800 tape recorder.

ANIMAL NAME	COMMAND	RESPONSE	RESTRICTIONS
PUKA	IMUA BIP OK	Hit ball with pectoral	none
PUKA	IMUA BAIEP OK	Swim through hoop	none
PUKA	IMUA UWEIAP OK	Roll over	none
PUKA	IMUA WAVE OK	Wave pectoral	none
PUKA	IMUA MAUKA OK	Come to in-station	Must be outside float circle when receiving command.
PUKA	IMUA MAKAI OK	Go away from instation i.e. go seaward, outside float circle	Must be inside float circle when receiving command.
PUKA	IMUA PLOP OK	Slap flukes	none
PUKA	IMUA YUMP OK	Jump out of water	none
PUKA	REPEAT "above words" OK	Vocalizes word	Receives command and responds at instation (to date only BIP, BAIEP, UWEIAP and BAEP
MAUI	IMUA/REPEAT "word" OK	No response	none

Table 4-1-1. Command-response set for Puka as of 1 November 1967.

ANIMAL NAME	COMMAND	RESPONSE	RESTRICTIONS
MAUI	IMUA BIP OK	Hit ball with pectoral	none
MAUI	IMUA BAIEP OK	Swim through hoop	none
MAUI	IMUA UWEIAP OK	Roll over	none
MAUI	IMUA BAEP OK	Make sonar sound	none
MAUI	IMUA RETREIVE OK	Retreive bottle	Receives command inside float circle, takes bottle from anywhere on float circle, returns it to instation
MAUI	IMUA BURRAP	Swim farther away (seaward) than present location	none
MAUI	IMUA MAUKA OK	Came to instation	Must be at location other than instation when receiving command
MAUI	IMUA MAKAI OK	Go away from instation i.e. seaward, outside float circle	Must be inside float circle when receiving command
MAUI	IMUA PORT OK	Swim to his left	At instation
MAUI	IMUA STARBOARD OK	Swim to his right	At instation
MAUI	IMUA BEIAP OK	Raise flukes	none

MAUI	REPEAT "above words" OK	Vocalizes word	Receives command and responds at instation (to date, only "BIP", "BAIEP", "UWEIAP" and "BAEP."
PUKA	IMUA/REPEAT "word" OK	No response	none

Table 4-1-2. Command response set for Maui as of 1 November 1967.

Several of the above words, BIP, BAIEP, UWEIAP, BAEP, BIYIB, BEIAB, BIEAP and BAEIP were constructed from English language vowel sounds in an early part of this study to determine whether or not the dolphin could differentially respond to selected changes in translated vowel sounds. Table 4-1-3, at the end of this section compares the spoken words with frequency v.s. time plots of their electronic translations. Table 4-1-4 below is a key for the pronuncaition of the several specially constructed words.

VOWEL SYMBOL	PRONOUNCED
I	hit (Bip only)
I	heat
Y	yet
A	mama
U	Suit
E	bait

Table 4-1-4. Pronounciation key for artifical words.

Figures 4-2, 4-3 and 4-4 show the animals responding to the command sequences for jump, hit the ball and retrieve the bottle.

Figure 4-2. Puka executing the command"Puka IMUA YUMP OK"

Initial training during the report period, from 14 December 1966 to 20 March 1967, was conducted by Miss Randy Lewis with the assistance of Mr. Thomas Passin.

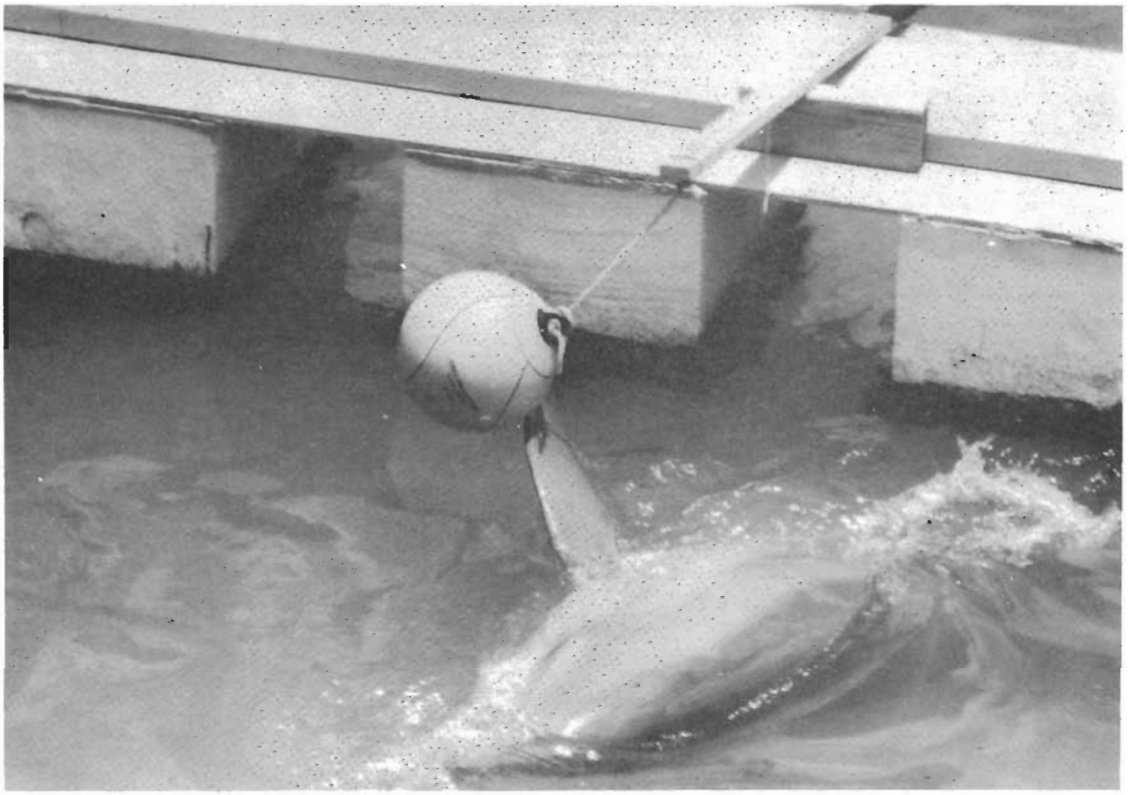


Figure 4-3. Puka hitting a tether ball with her pectoral.

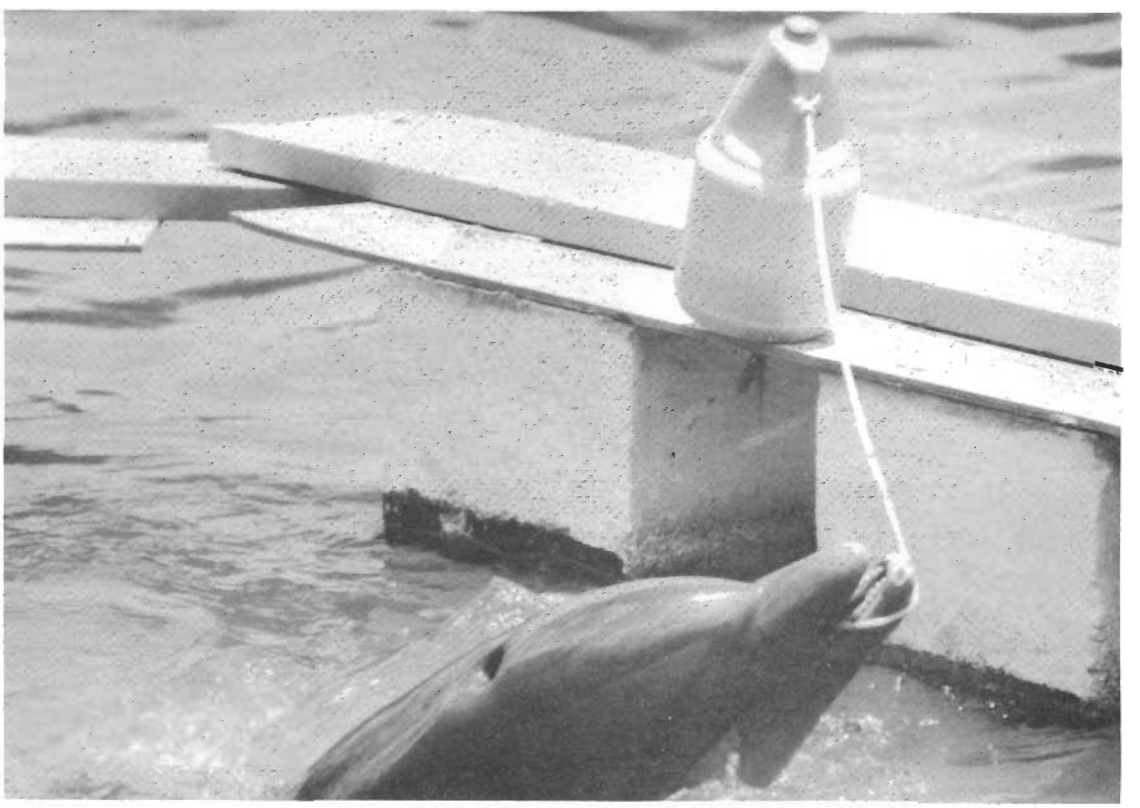


Figure 4-4. Maui, retrieveing a bottle by pulling a string.

Summaries of each training session, general observations and data on training progress were recorded in the project log book. Tape recordings were made of selected sessions.

During this period, Maui's training was directed towards maintaining the level of performance obtained in the prior report period, the addition of the word REPEAT to his vocabulary to separate gross body and vocal response, the addition of the words MAUI and PUKA to separate responding animals and improvement in response confidence level to the words MAKAI and MAUKA. As of 20 March 1967, Maui's commands and responses were as shown in Table 4-5 below.

ANIMAL NAME	COMMAND	RESPONSE	RESTRICTIONS
MAUI	IMUA BIP OK	Hit the ball	Must be at in-station.
MAUI	IMUA BAIEP OK	Go through hoop	Must be at in-station.
MAUI	IMUA BEIAP OK	Raise flukes	Must be at in-station.
MAUI	IMUA UWEIAP OK	Roll over	Must be at in-station.
MAUI	BAEP	Produce sonar sound	Must be at in-station.
MAUI	MAUKA	Come to in station	* Must be at outstation.
MAUI	MAKAI	Go to out-station	* Must be in-station.

MAUI	REPEAT BIP	Imitate the word	Must be at in-station. (See Figures 4-6 and 4-12.)
MAUI	REPEAT BAIEP	Imitate the word	" "
MAUI	REPEAT BEIAP	Imitate the word	" "
MAUI	REPEAT UWEIAP	Imitate the word	" "

For all above, Puka must be outside float circle.

* Must start session with Maui or Puka MAUKA/MAKAI, may not be preceded by any other command.

Table 4-5. Command - response set for Maui as of 20 March 1967.

Figure 4-6 below is a photographically reduced set of records produced on Sanborne Co. chart recording paper showing frequency v.s. time plots of Maui's vocal responses. This particular set was obtained from the animal during prior work on this project at Pt. Mugu, California but it is representative of the interaction. The obviously low signal to noise ratio limited the trainer's ability to use this method for recognition of correct vocal responses.

Puka, in this period, was trained to differentiate the words BIP, BAIEP and UWEIAP by producing the appropriate response. The animal had previously been trained to produce a behavior with the proximity of the prop or relative position in the

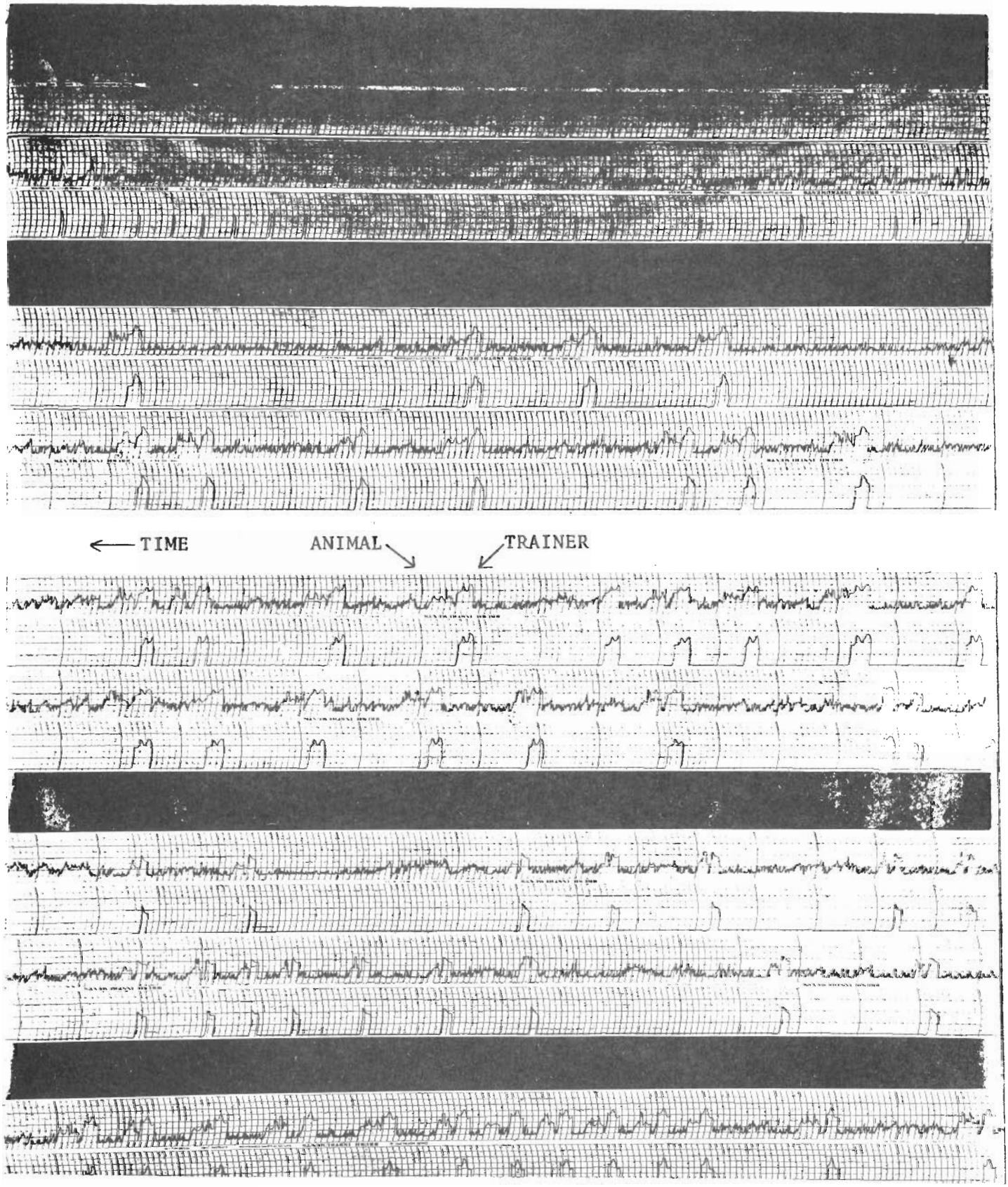


Figure 4-6. Photo reduced Sanborne strip chart of Maui's vocal responses.

lagoon as a cue and with a generalized hand signal to release the response. The graph in Figure 4-7 shows the response confidence level obtained for each of the three behaviors over the period of time in which two of the three behaviors were introduced as vocal commands.

These data were based on sessions of approximately 50 trials in which the a posteriori probability of each behavior occurring next was about one half for the two-behavior sessions and about one third for the three behavior sessions. The trial sequence was, however, determined by the trainer during the sessions.

Table 4-8 lists the session number corresponding to data points on the graph in figure 4-7, the date of the session and the numerical percentage correct choices for each response.

SESSION	DATE	CB	CH	CR	CT
1. Tues	12-27	.11	.65	-	.36
2. Wed.	12-28	.15	.70	-	.40
3. Wed.	12-28	.04	.96	-	.54
4. Tues.	1-3	.64	.74	-	.68
5. Tues.	1-3	1.0	.85	-	.92
6. Wed.	1-4	.61	.84	-	.70
7. Wed.	1-4	.83	.89	-	.86
8. Thur.	1-5	.61	.78	-	.70
9. Thur.	1-5	.88	.75	-	.80
10. Fri.	1-6	1.0	.09	-	.94
11. Tues.	1-10	1.0	.96	-	.98
12. Wed.	1-11	.92	.61	-	.70

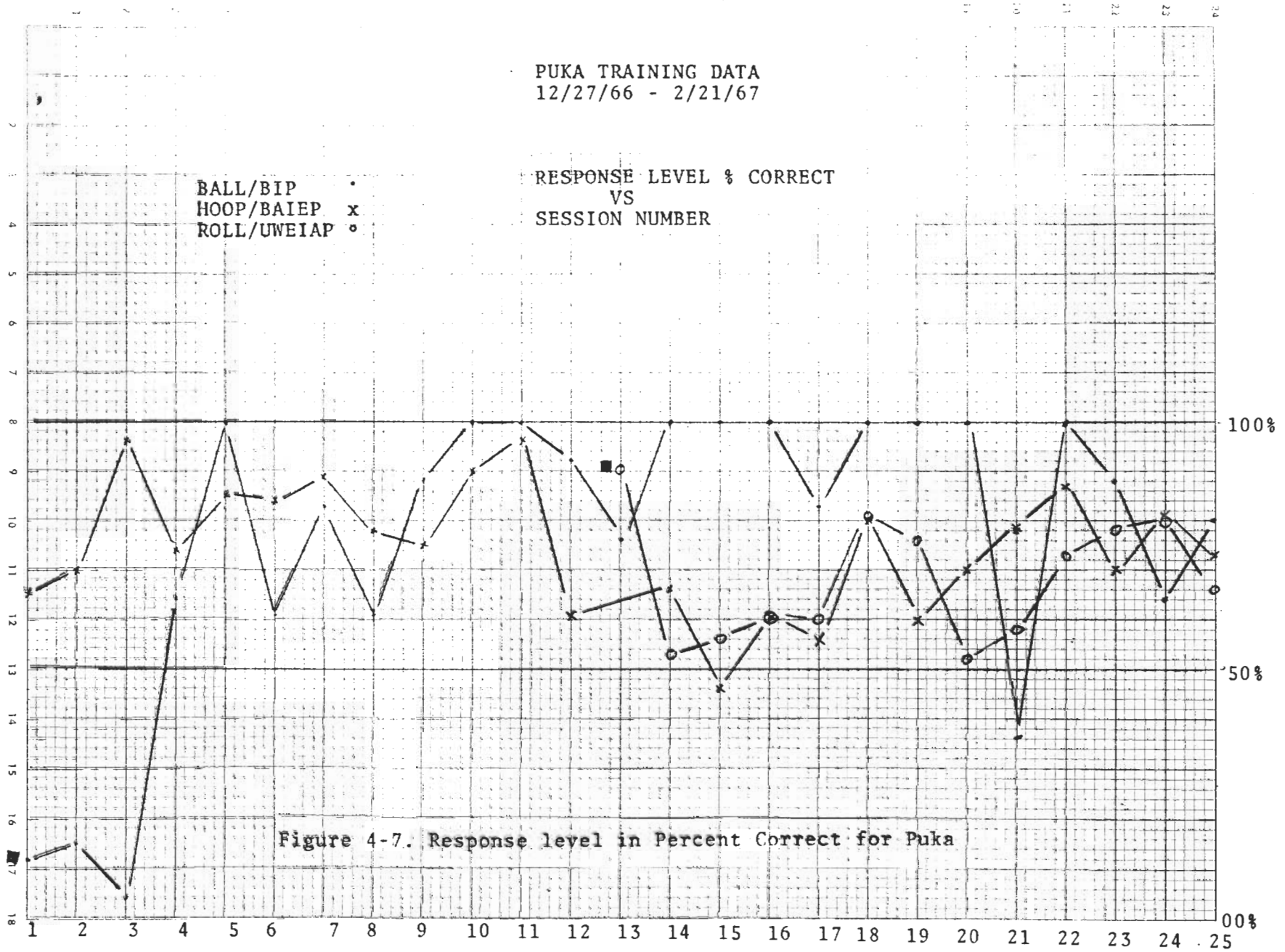


Figure 4-7. Response level in Percent Correct for Puka

13.	Wed.	1-18	.78	-	.90	.88
14.	Thur.	1-26	1.0	.68	.53	.65
15.	Fri.	1-27	1.0	.46	.56	.55
16.	Fri.	1-27	1.0	.60	.60	.63
17.	Mon.	1-30	.83	.56	.60	.60
18.	Wed.	2-1	1.0	.80	.81	.82
19.	Wed.	2-1	1.0	.60	.76	.71
20.	Thur.	2-2	1.0	.70	.52	.66
21.	Fri.	2-3	.38	.79	.58	.45
22.	Fri.	2-3	1.0	.87	.73	.81
23.	Mon.	2-6	.88	.70	.78	.76
24.	Tues.	2-7	.64	.81	.80	.26
25.	Wed.	2-8	.80	.73	.66	.70

B = Ball
H = Hoop
R = Roll over
T = Total
CB = No. correct ball responses/ no. ball commands, etc.

Data based on 50 trials/session.
Next command selected by trainer.

Table 4-8. Percentage correct responses.

Table 4-9 below lists the command sequence and responses from which the data points of session #24 were generated.

COMMAND/RESPONSE	COMMAND/RESPONSE
1. Ball/correct	9. Hoop/correct
2. Ball/hoop	10. Hoop/roll
3. Ball/roll	11. Hoop/roll
4. Ball/hoop	12. Hoop/correct
5. Roll/correct	13. Hoop/correct
6. Roll/correct	14. Roll/hoop
7. Roll/correct	15. Roll/correct
8. Hoop/correct	16. Roll/correct

17. Roll/correct
18. Ball/hoop
19. Ball/roll
20. Ball/correct
21. Ball/correct
22. Hoop/correct
23. Hoop/correct
24. Roll/correct
25. Roll/hoop
26. Roll/correct
27. Roll/correct
28. Hoop/correct
29. Hoop/correct
30. Hoop/correct
31. Ball/correct
32. Ball/correct
33. Hoop/correct
34. Hoop/correct
35. Roll/hoop
36. Roll/correct
37. Roll/hoop
38. Ball/correct
39. Roll/correct
40. Roll/correct
41. Roll/correct
42. Roll/correct
43. Hoop/roll
44. Hoop/correct
45. Hoop/correct
46. Roll/correct
47. Roll/correct
48. Roll/correct
49. Ball/correct
50. Ball/correct

Hoop 16/13, Ball 14/9, Roll 20/16

Table 4-9. Transcription of training session with Puka February 7, 1967.

This animal was also trained to respond to an electronically generated rising or falling whistle by turning her head to the right or left. This work was discontinued on 5 May 1967 when the contour generating device was returned for redesign. Table 4-10 displays the command response set in use for Puka as of 20 March 1967.

ANIMAL NAME	COMMAND	RESPONSE	RESTRICTIONS
PUKA	BIP OK	Hit ball	Must be at in-station.

PUKA	BAIEP OK	Go through hoop	Must be at in-station.
PUKA	UWEIAP OK	Raise flukes	Must be at in-station.
PUKA	MAKAI	Go to out-station *	Must be at in-station.
PUKA	MAUKA	Come to in-station *	Must be at out-station.
PUKA	BAEIP +	Turn head to right	Must be outside float circle.
PUKA	BIEAP +	Turn head to left	Must be outside float circle.

* Must start session with Maui/Puka - MAUKA/MAKAI, may not be preceded by any other command.

\+ Generated by ACB box. (10)

For all above, Maui must be outside float circle.

Table 4-10. Command response set for Puka as of 20 March 1967.

During the period 20 March 1967 to 1 November 1967, training was conducted by Mr. Peter Markey with the assistance of Miss Elizabeth Loeb. A systematic attempt was made to generalize the intended operational definitions of command words, to increase the number of command response points in each animal's set and to require the animal to initiate a trainer animal response sequence.

Table 4-11 below indicates the course of the man-dolphin interaction during this training period. This Table includes as section I, a graphical analysis of the response confidence level for each of the physical behaviors listed in Tables 4-1-1 and 4-1-2 above. Section II lists the total trials, number and percent correct responses for each of the command sequences involving gross body motion. Section III is a transcription and analysis of one of the included sessions, while section IV lists those events introduced in the course of training thought to be significant to the man-dolphin interaction.

In addition to the development of the non-vocal behavior, parallel work was done on vocal behavior. Maui was trained to imitate several of the command words with attention paid to absolute and relative pitch, duration and harmonic content. He was also required to hold his response until released by the word OK. Figure 4-12 shows a comparison of the word to be imitated and the animals response taken to be correct as of 5 May 1967.

The data presented as Table 4-13 at the end of this section were obtained from an inprogress training session, the 5th on 8 September 1967, and show a separation of non-vocal and vocal behaviors as well as the degree of imitation obtained at that date.

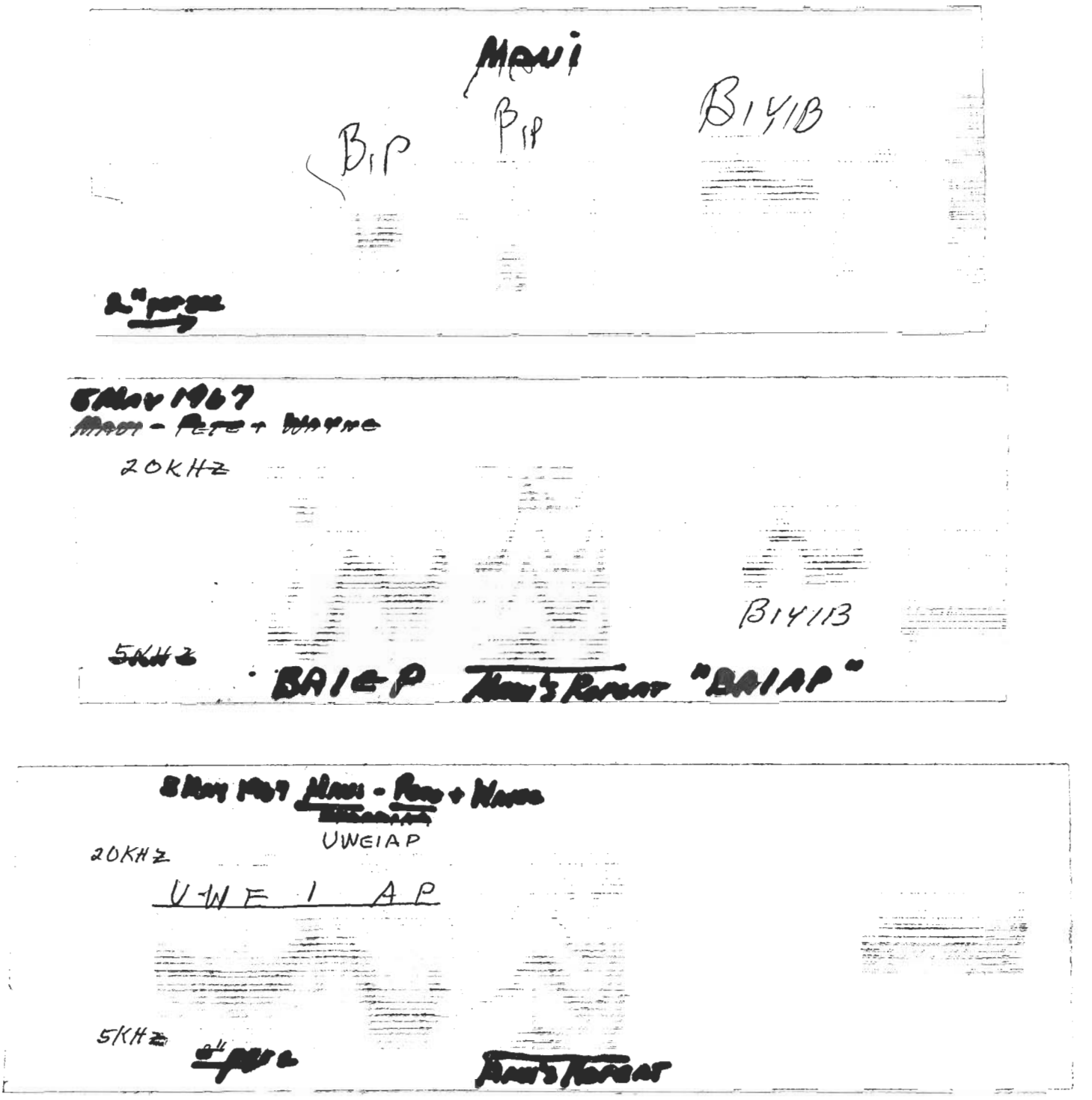


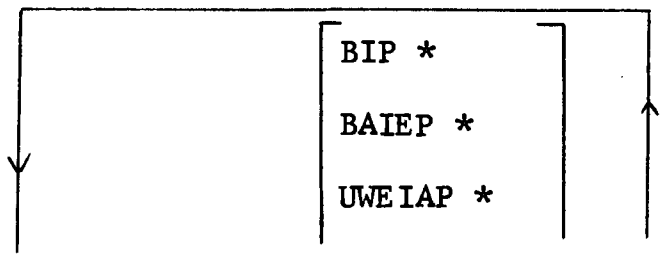
Figure 4-12. Maui's responses to the command, "MAUI REPEAT BIP/BAIEP/UWEIAP." "BIYIB" indicates response accepted by trainer.

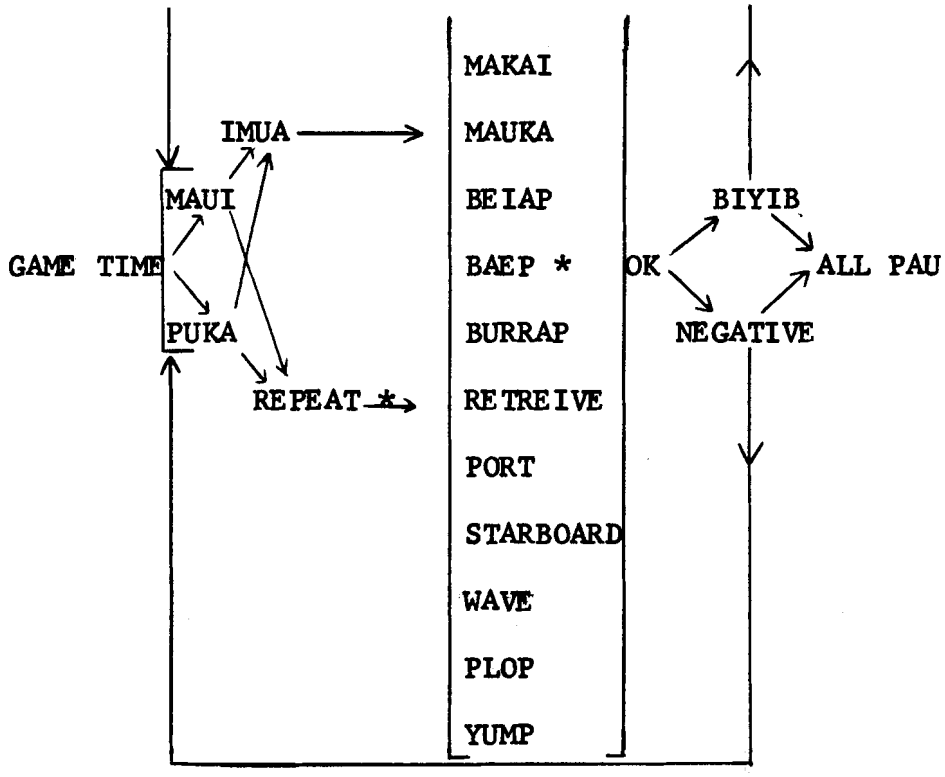
By September, Puka's physical and vocal responses to command situations were similar to those displayed in Table 4-13 for Maui.

In the attempt to remove unintentional enviromental secondary cues, an effort was made to randomize duration of training sessions, inter session interval and the order of command presentation sequence. Typical command response sequences for a one trainer two dolphin system during a session were as follows:

1. Trainer: "PUKA IMUA UWEIAP OK" "BIYIB" no fish.
   (Maui) no response fish.
2. Trainer: "MAUI IMUA BIP OK" "BIYIB" fish
   (Puka) no response no fish
3. Trainer: "MAUI REPEAT BAIEP OK" Negative no fish.
   (Puka) some response no fish

The Trainer - Dolphin decision paths for each stimulus - response event during a session are diagramed in Figure 4-14 below. An effort was also made to remove position cues by randomizing the animal's starting positions.





* Indicates words the animals have been asked to imitate.

Figure 4-14. Diagram of Trainer-Dolphin decision paths.

The initiation of each session was marked by the words "GAME TIME." The termination was marked by the words "ALL PAU." Time v.s. frequency plots at these two words appear in Figure 4-15 below.

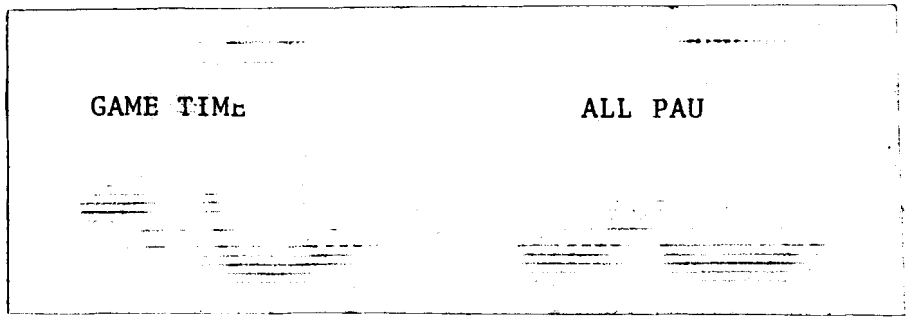
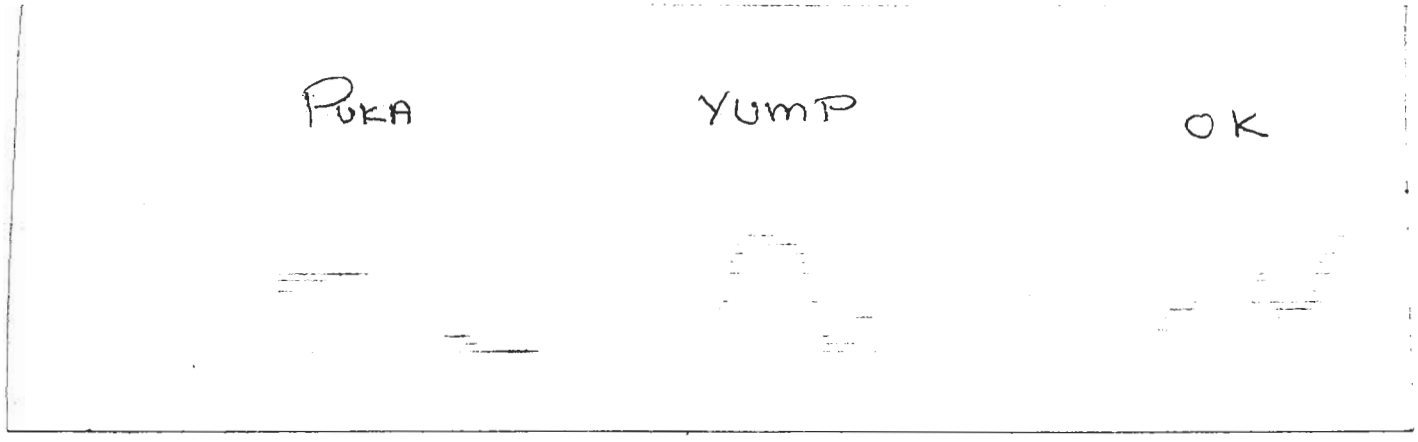
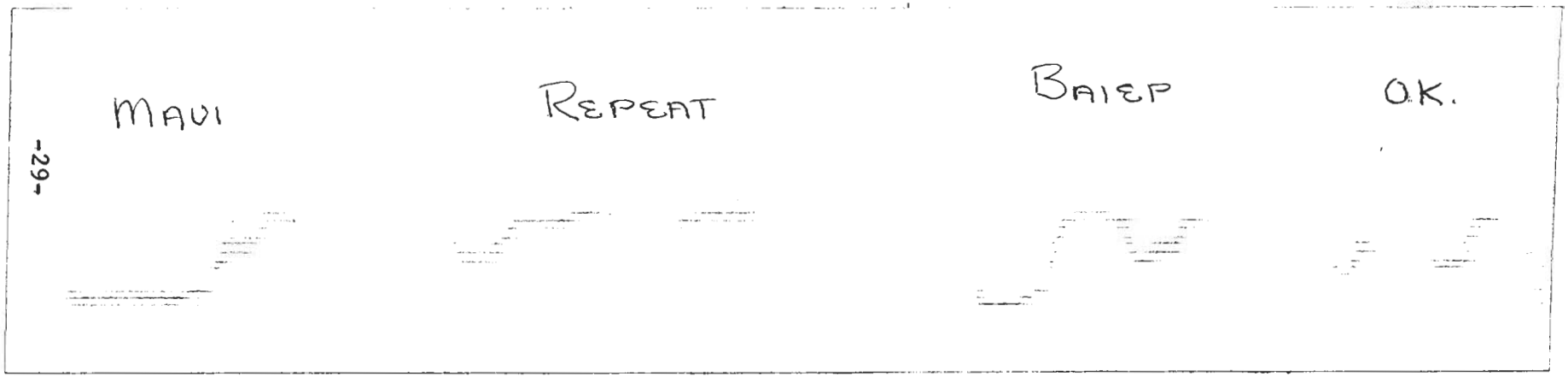


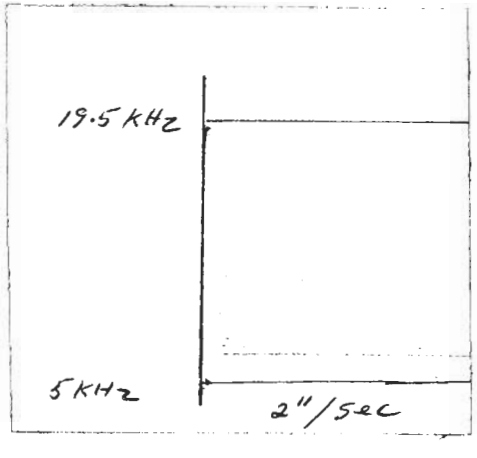
Figure 4-15. Time v.s. frequency plots of the words GAME TIME and ALL PAU.

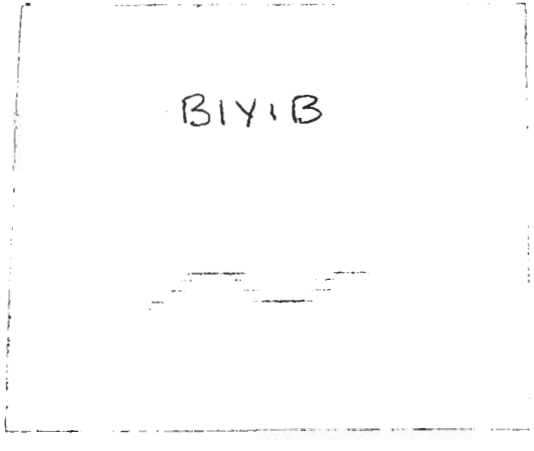
Table 4-1-3

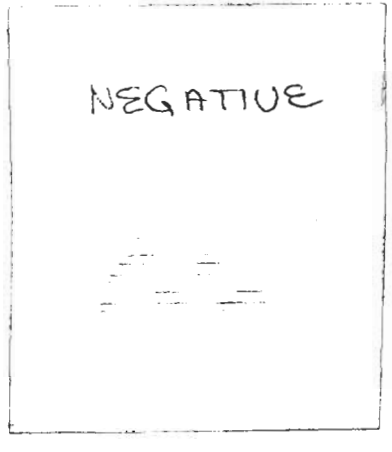
English language command words compared with frequency v.s. time plots of the whistle translation of the word generated by the Listening, Inc., Multi Spectrum Analyzer.

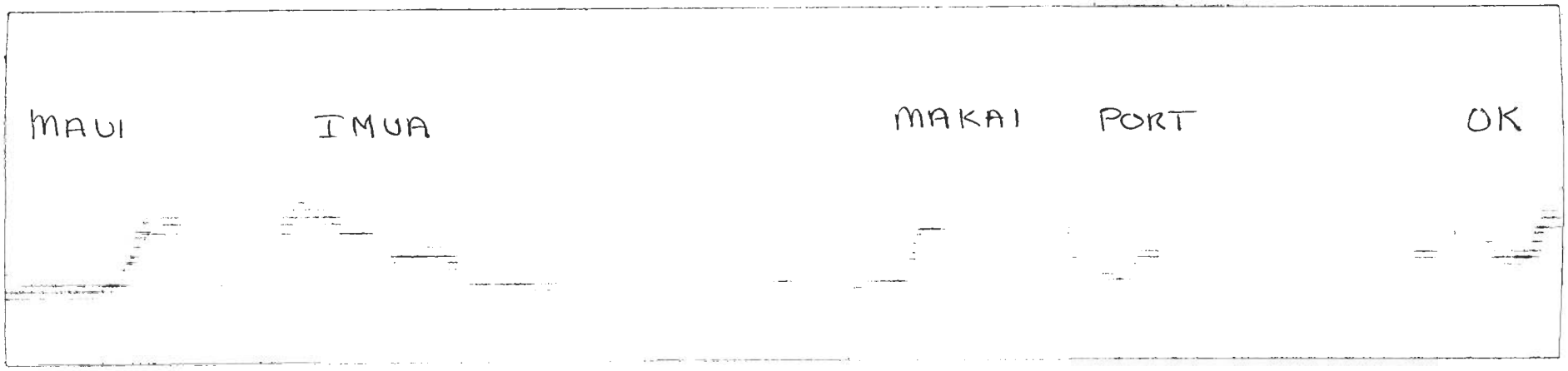

PUKA
YUMP
OK

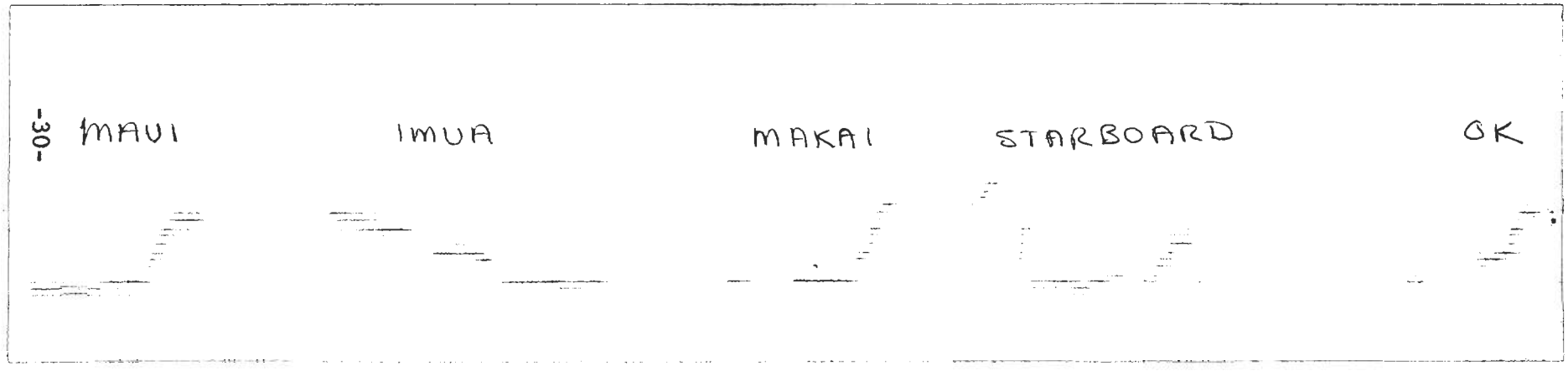

MAUI
REPEAT
BAIEP
O.K.

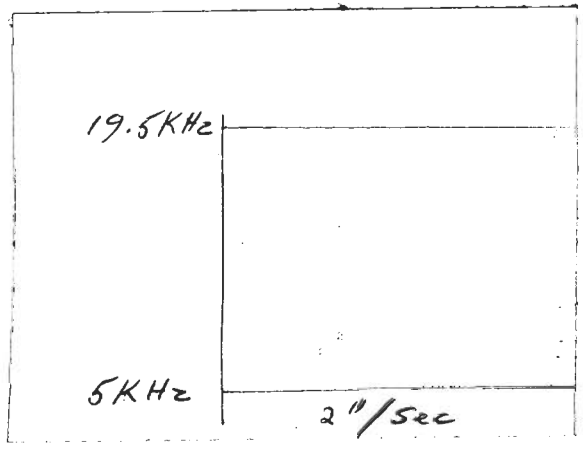

19.5 kHz
5 kHz
2"/sec

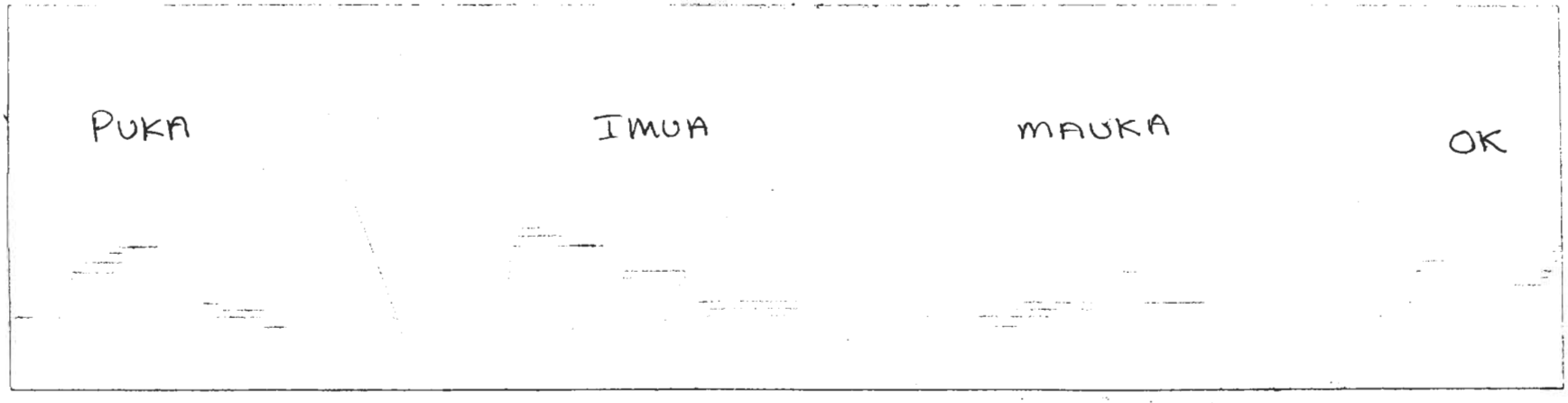

BIYIB

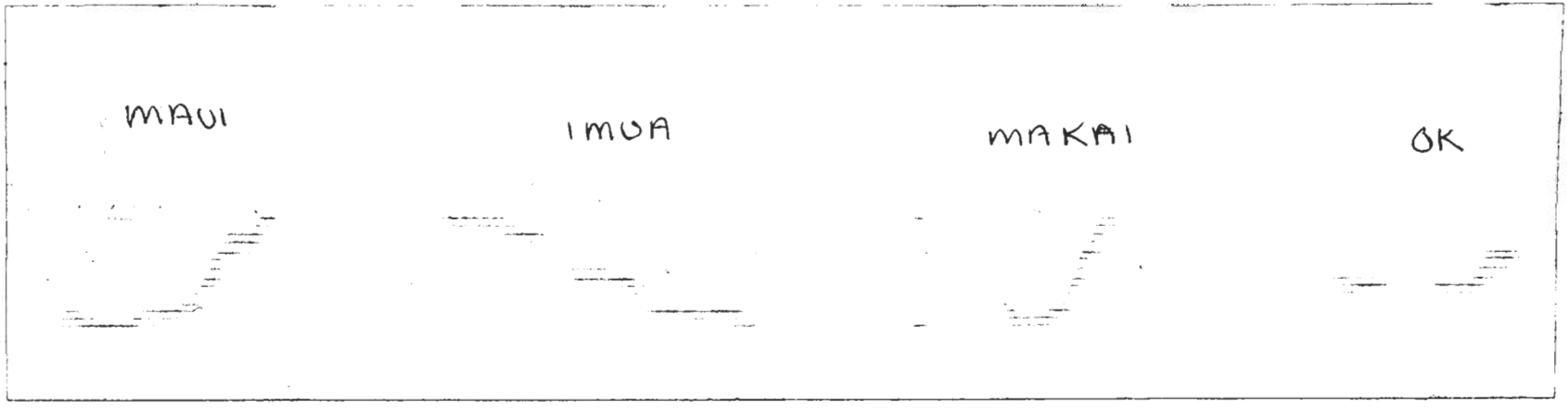

NEGATIVE

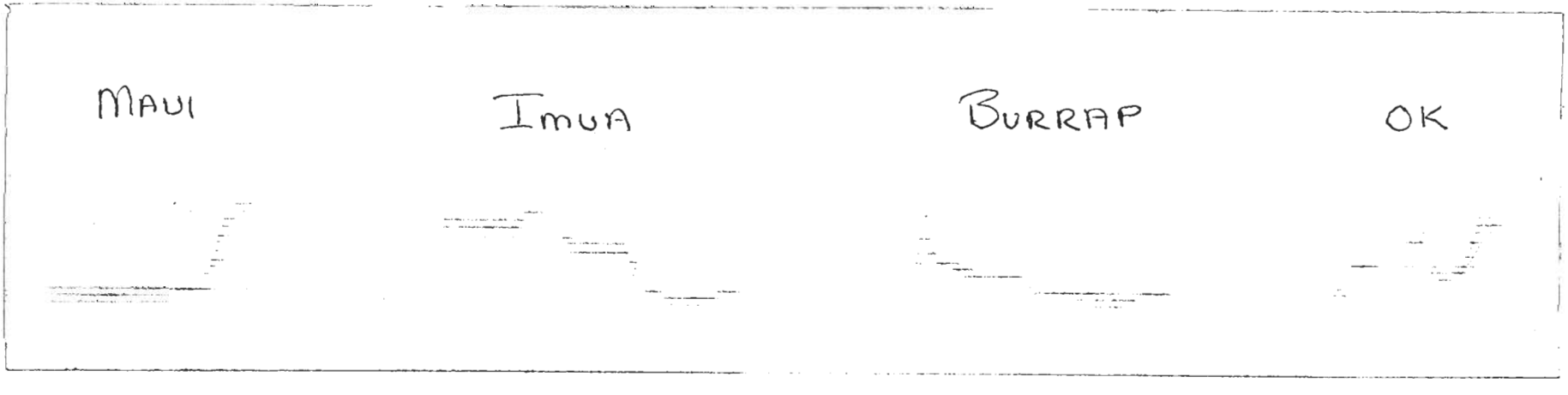

MAUI
IMUA
MAKAI
PORT
OK

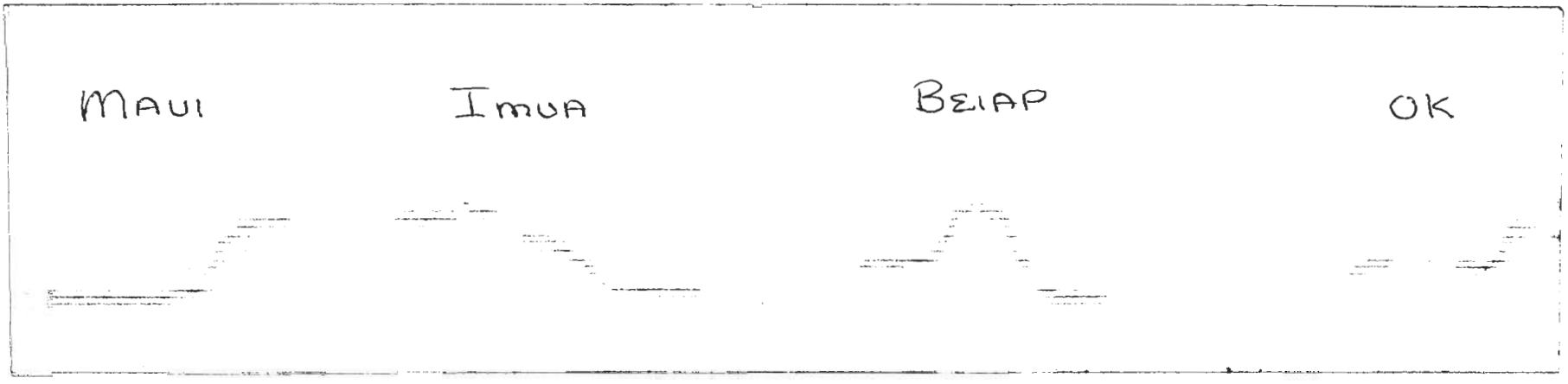

-30-
MAUI
IMUA
MAKAI
STARBOARD
OK

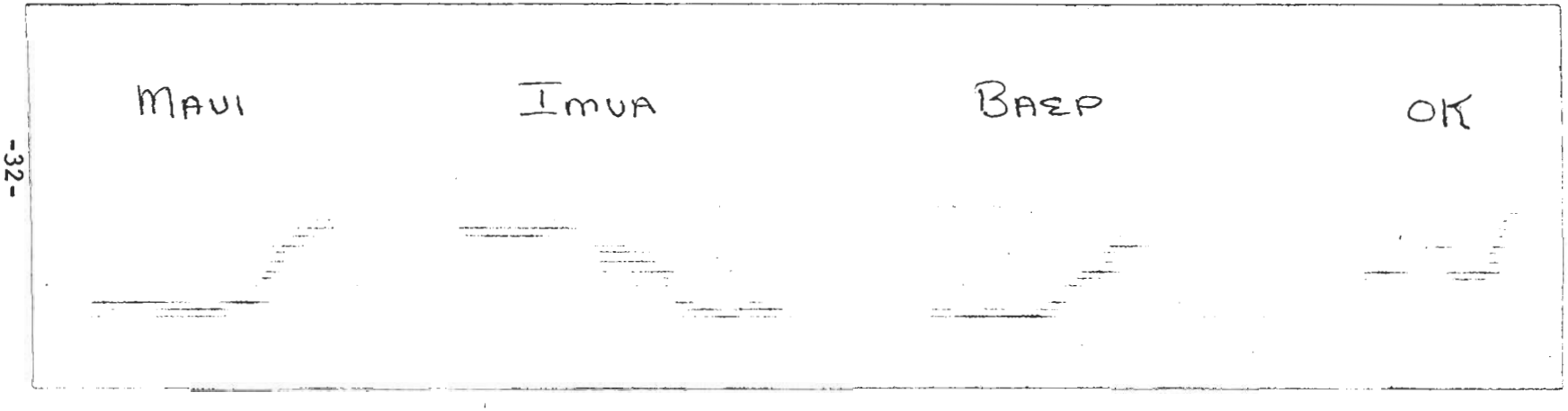

19.5KHz
5KHz
2"/Sec

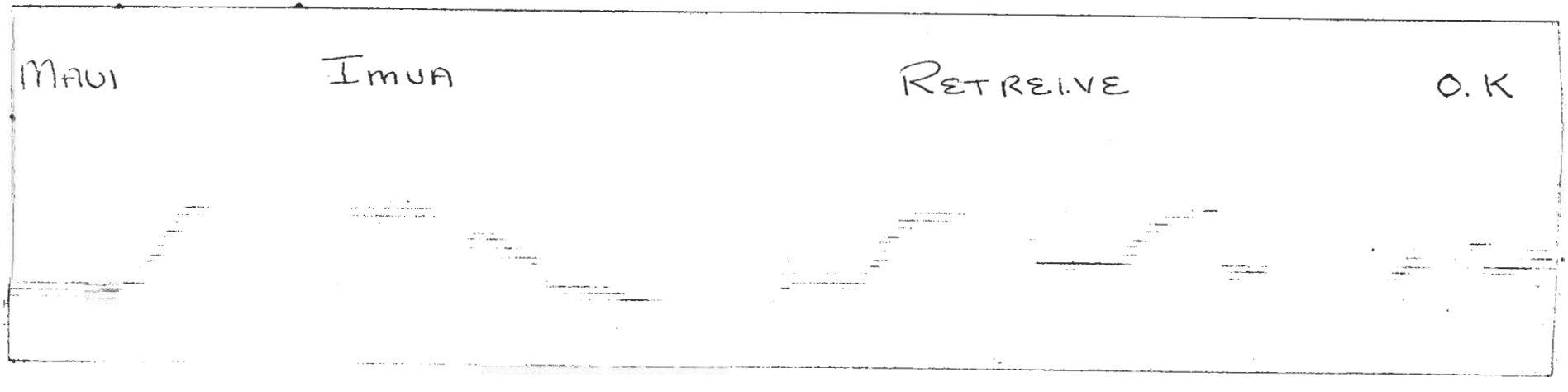

PUKA
IMUA
MAUKA
OK

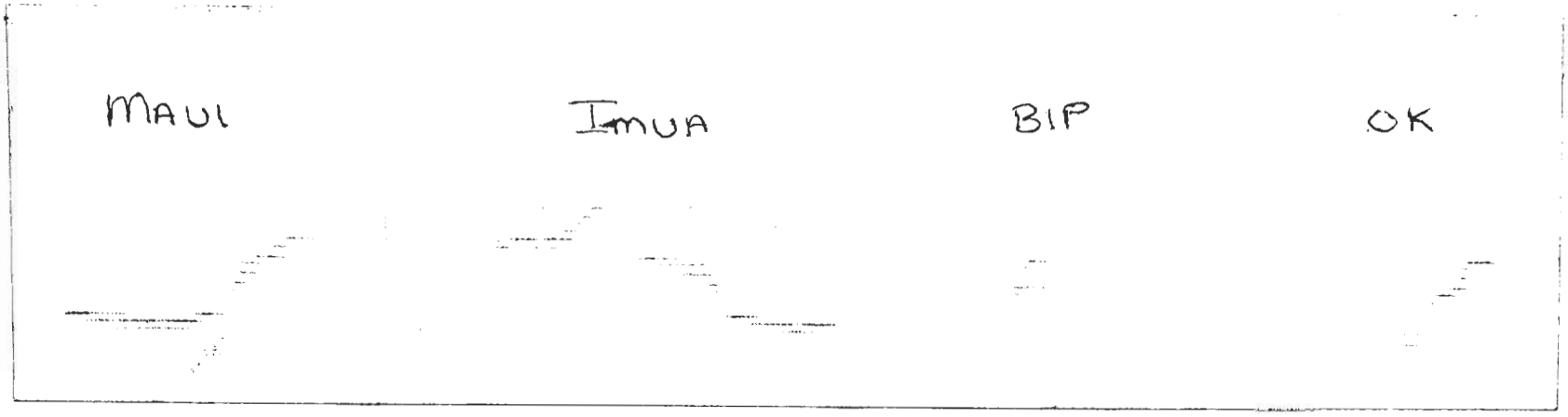

MAUI
IMUA
MAKAI
OK

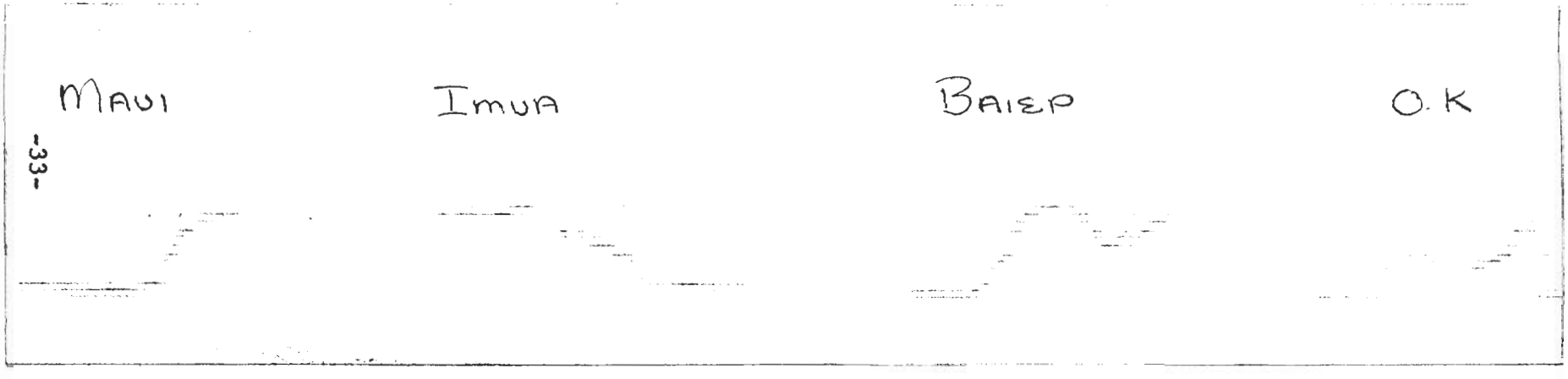

MAUI
IMUA
BURRAP
OK

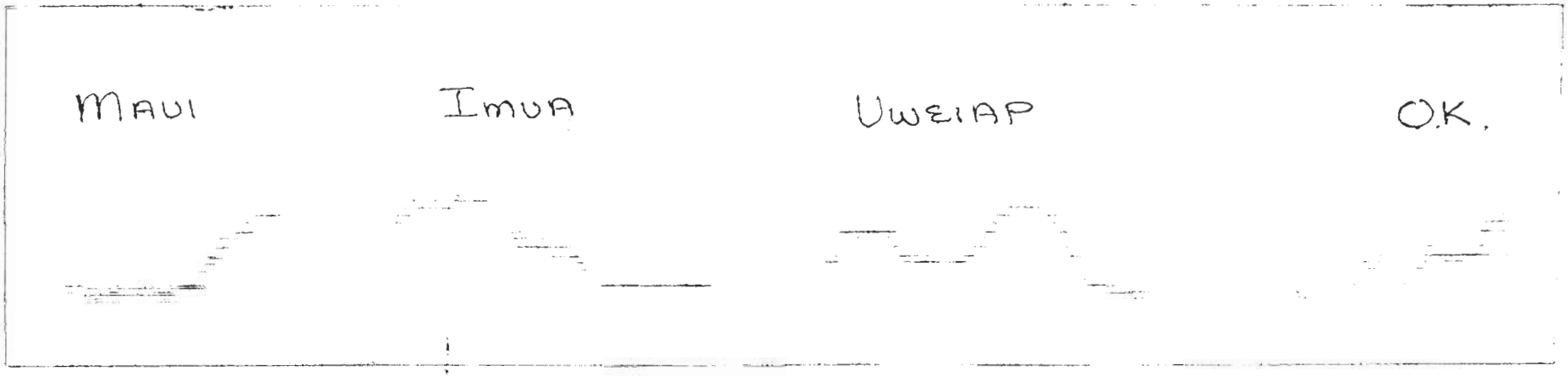

MAUI
IMUA
BEIAP
OK

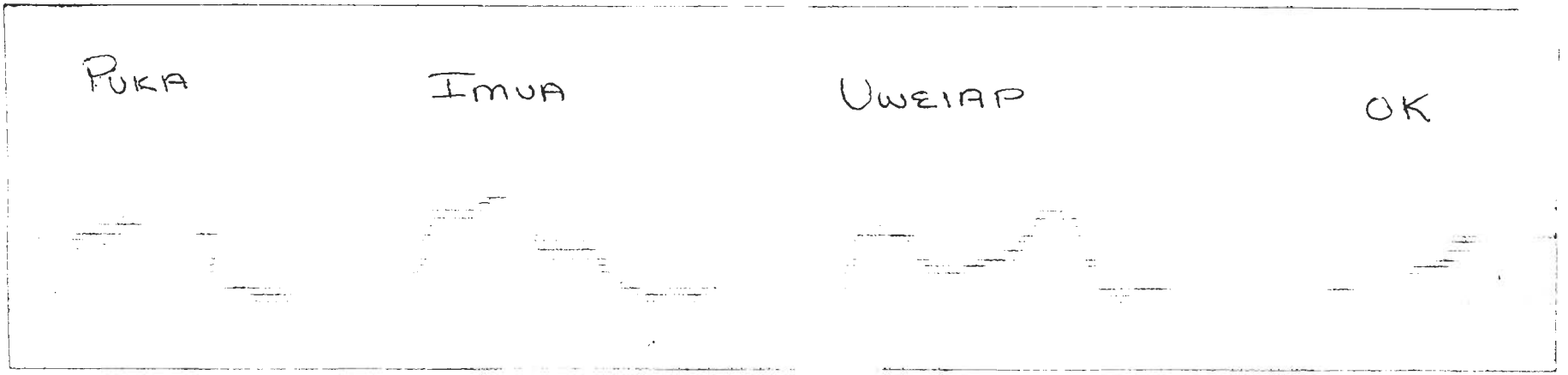

MAUI
IMUA
BAEP
OK

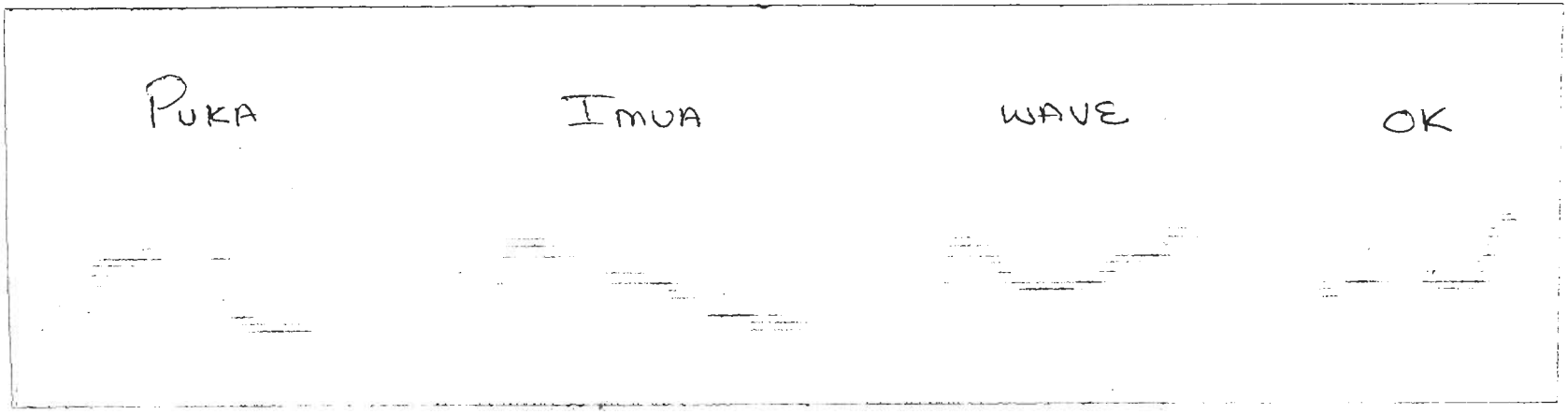

MAUI
IMUA
RETREIVE
O.K


MAUI
IMUA
BIP
OK


MAUI
IMUA
BAIEP
O.K


MAUI
IMUA
UWEIAP
O.K.


PUKA
IMUA
UWEIAP
OK


PUKA
IMUA
WAVE
OK

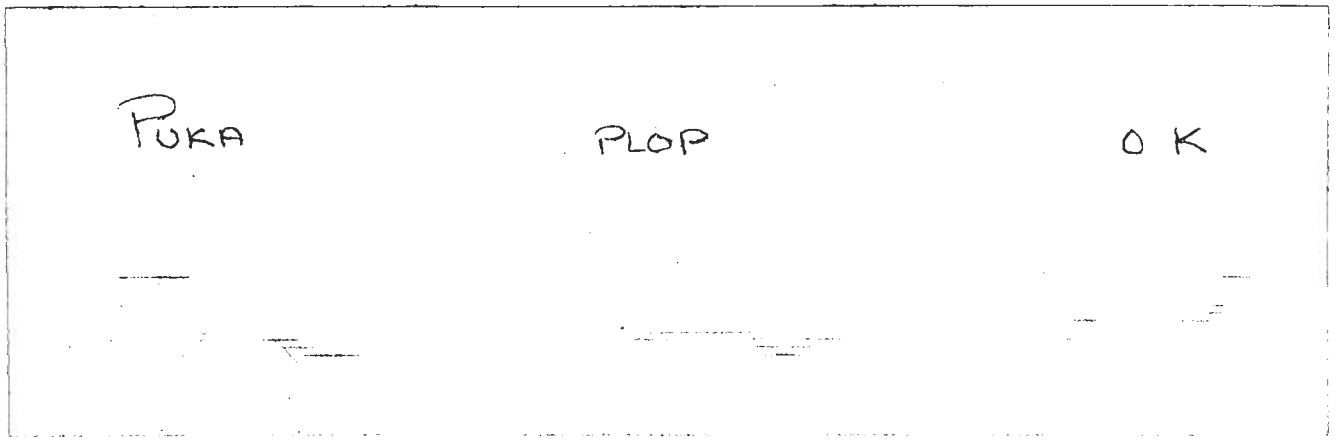

PUKA
PLOP
O K

Table 4-11

Section I

Response level in percent correct for selected sessions 29 May - 16 October 1967 v.s. animal's command.

Section II

Trial vs correct responses for each selected session.

Section III

Transcription and analysis of typical tape recorded session.

Section IV

Significant changes introduced to the man-dolphin system.

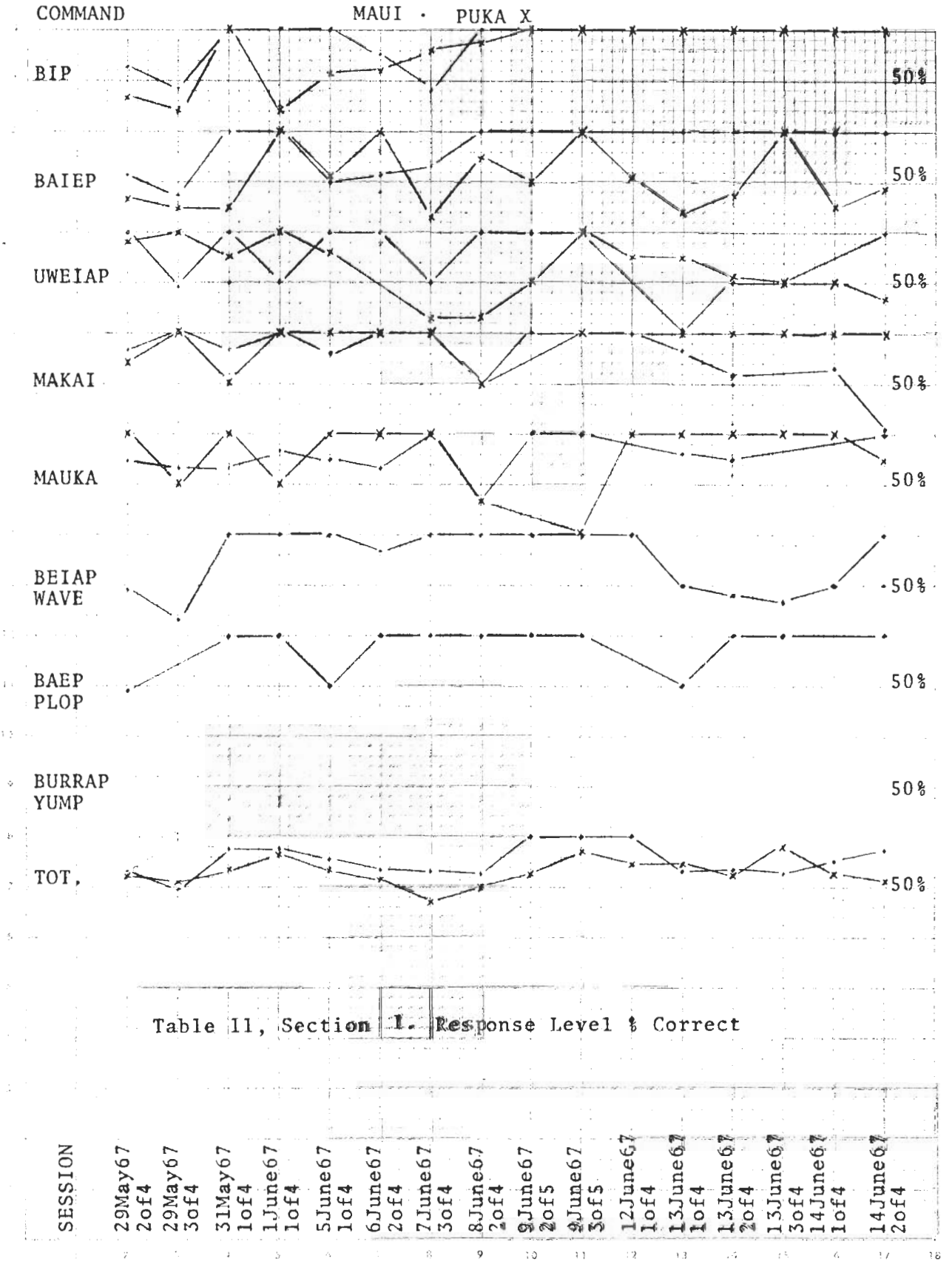


Table 11, Section 1. Response Level % Correct

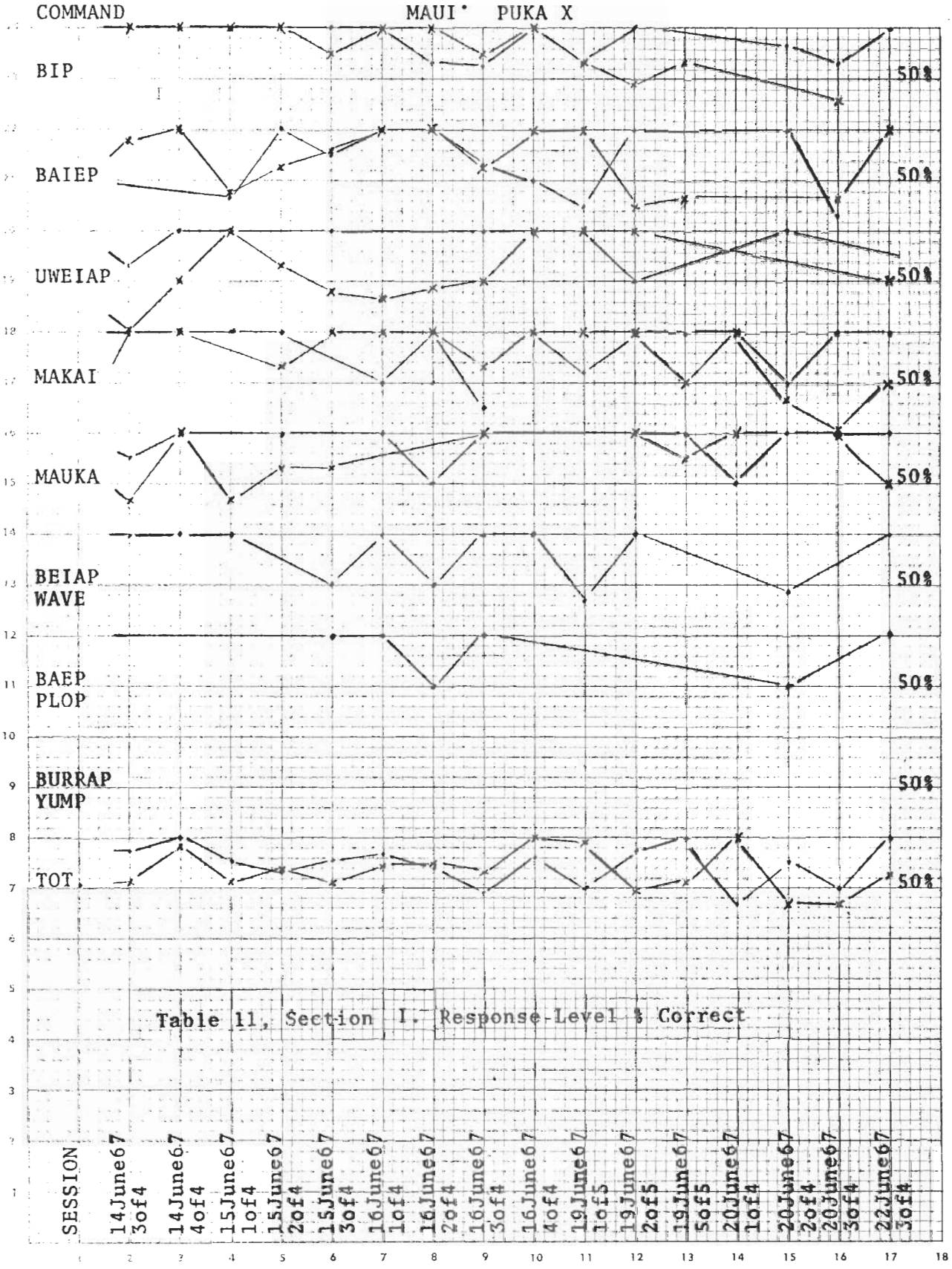


Table 11, Section I. Response-Level % Correct

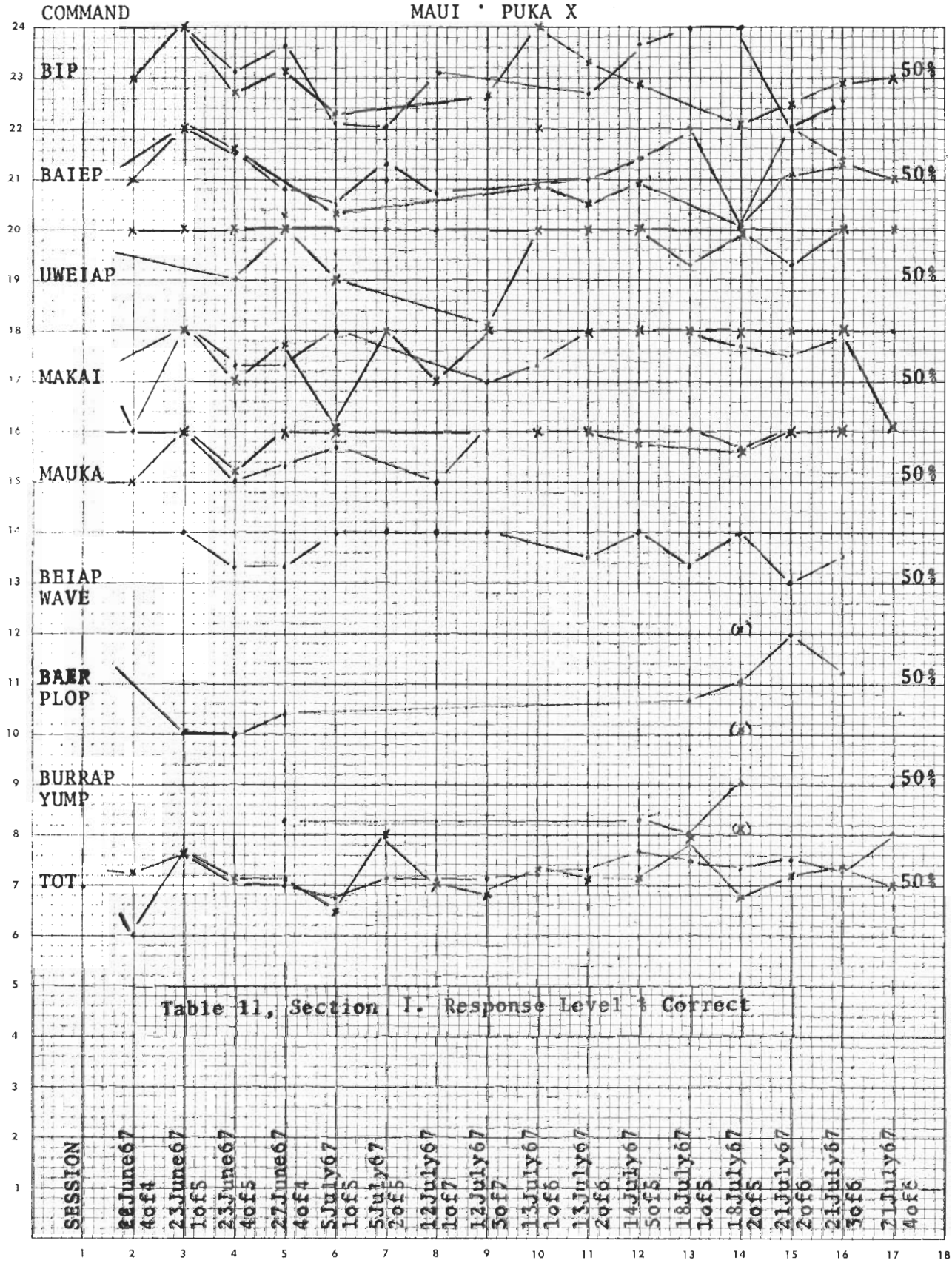


Table 11, Section I. Response Level % Correct

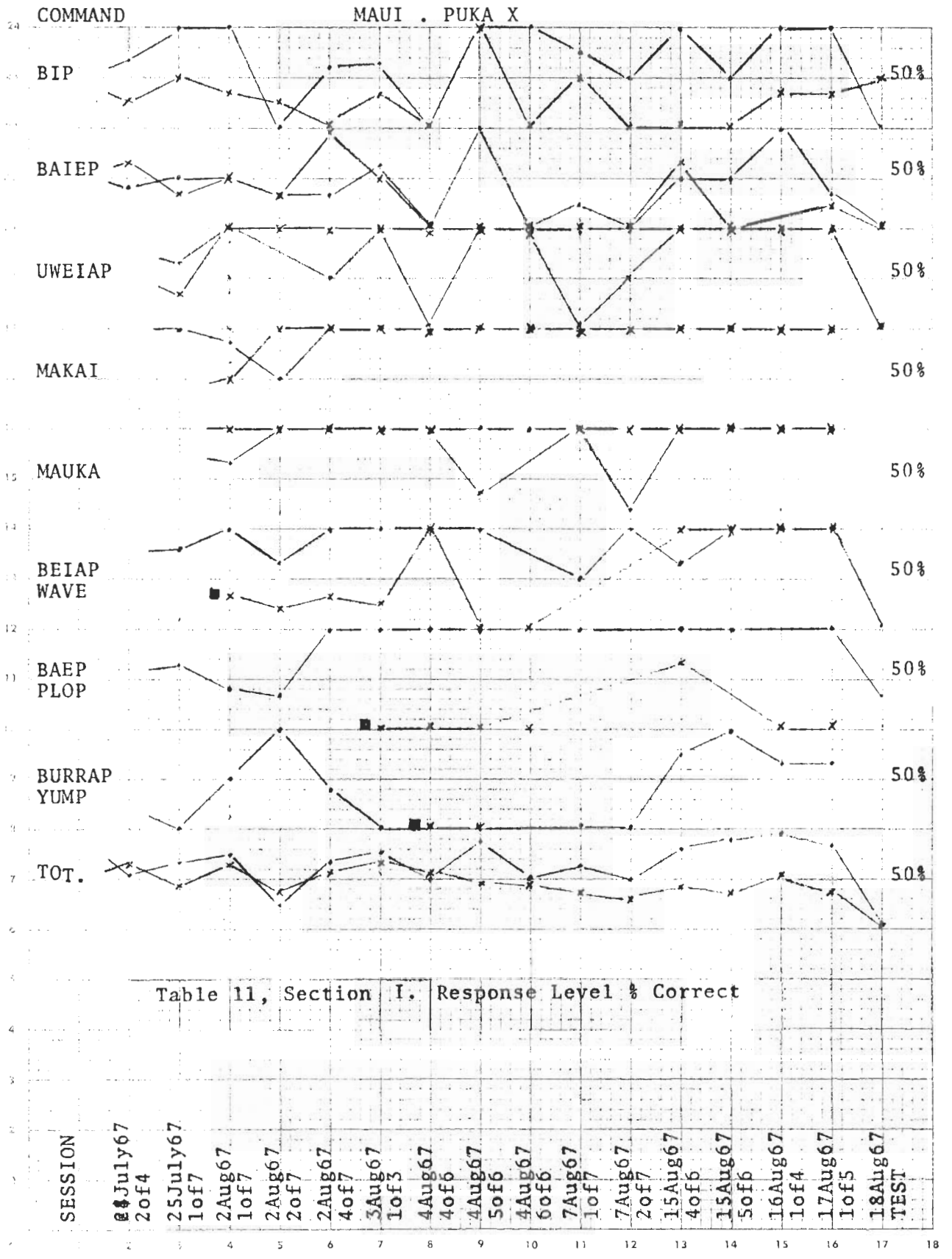


Table 11, Section I. Response Level % Correct

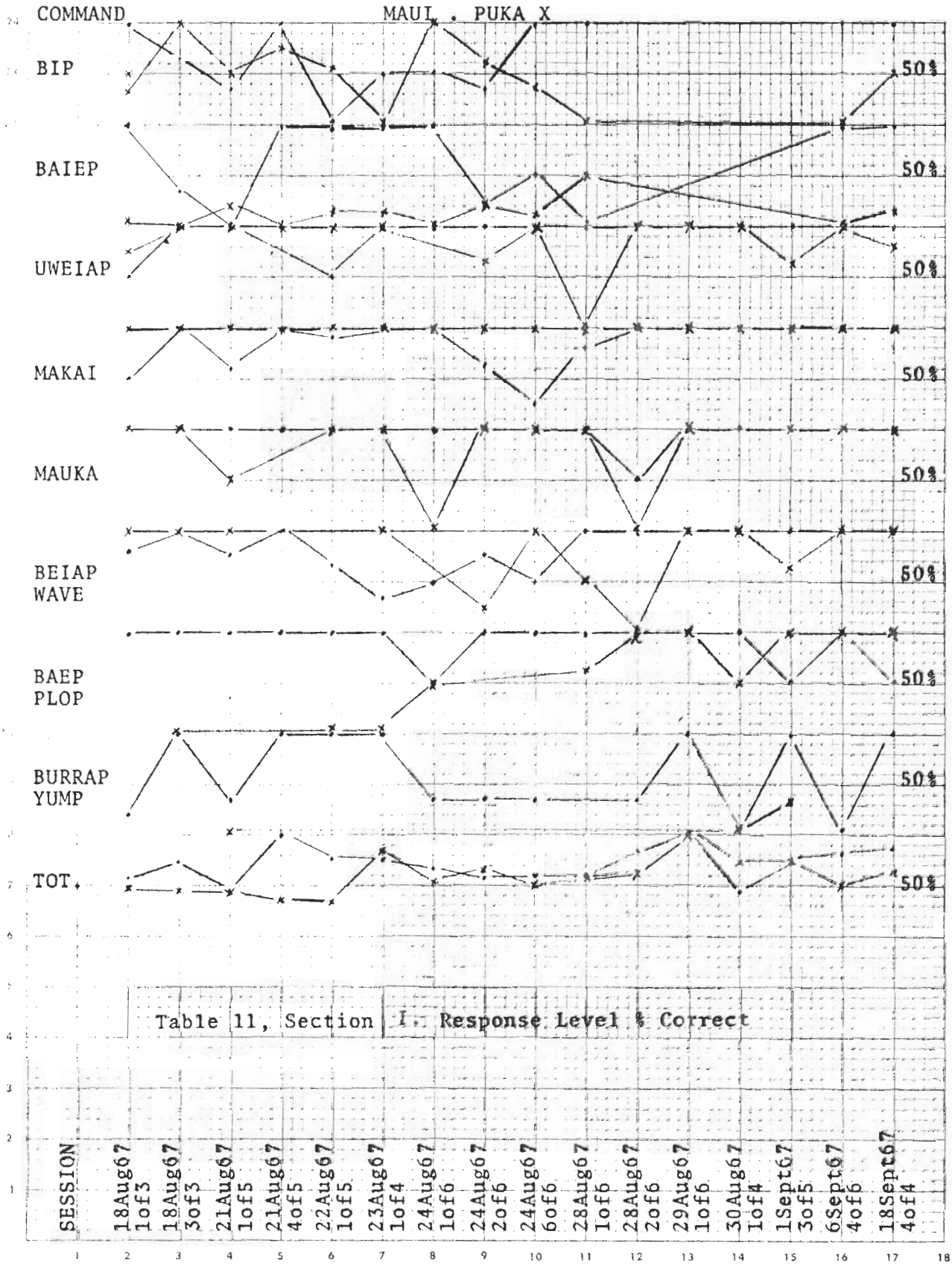


Table 11, Section I. Response Level % Correct

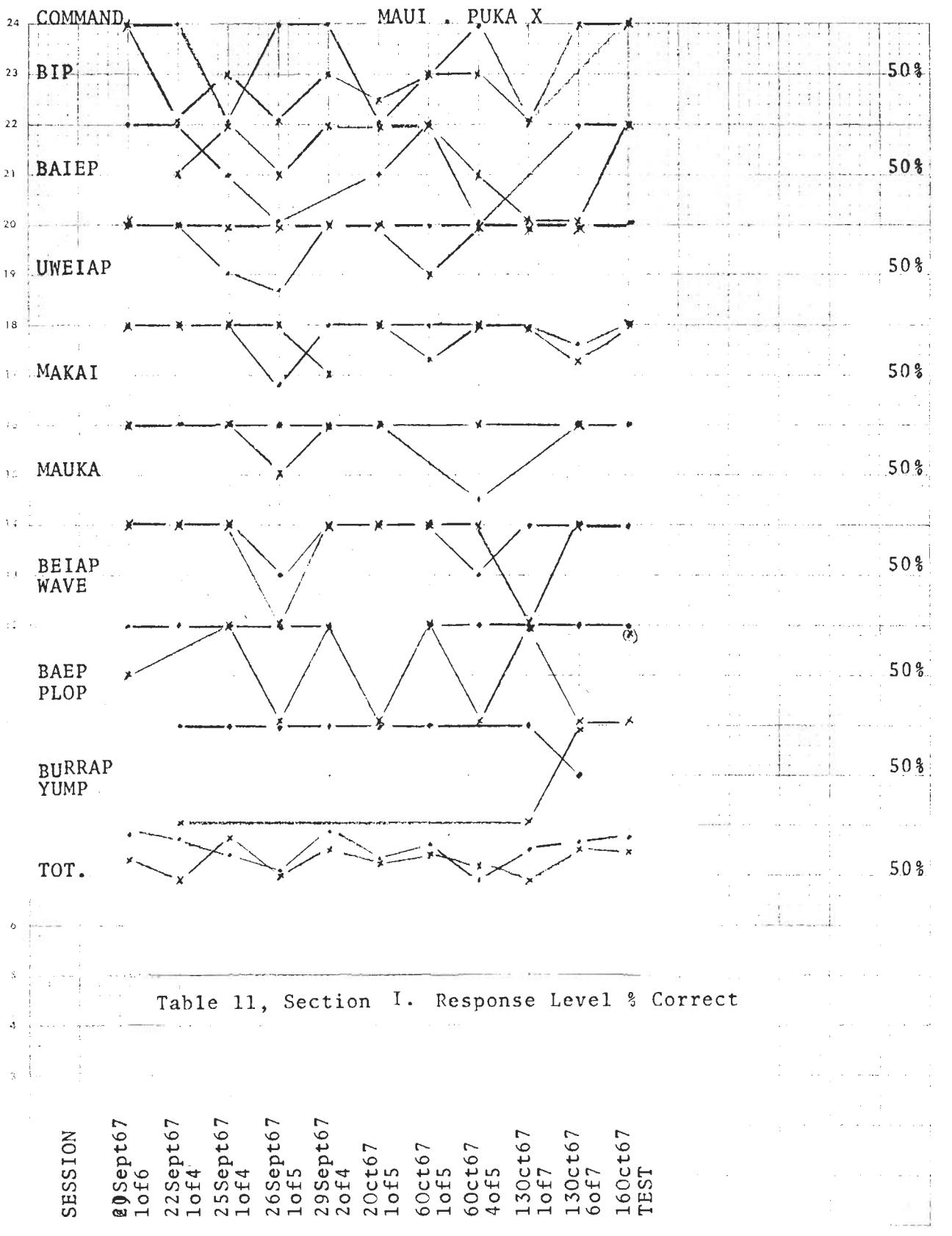


Table 11, Section I. Response Level % Correct

Table 4-11, Section II. Session summaries

SESSION		COMMAND												
		BIP	BAIEP	UWEIAP	MAKAI	MAUKA	BEIAP	BAEP	BURRAP	WAVE	RETRIEVE	YUMP	STD'B	TOT.
29May67 2of4 mauka-makai	MAT	8/5	7/4	4/4	11/9	11/8	13/6	9/4						63/41
	UI %	63	57	100	82	73	46	45						65
	PUT	12/4	13/4	10/9	17/12	9/9								61/38
	KA %	33	32	90	70	100								62
3of4	MAT	17/7	13/5	11/5	8/8	6/4	6/1							61/30
	UI %	41	38	45	100	66	16							49
	PUT	10/2	13/3	8/8	7/7	16/8								54/28
	KA %	20	23	100	100	50								52
31May67 1of4 review	MAT	4/4	3/3	1/1	6/5	6/4	3/3	1/1						24/21
	UI %	100	100	100	84	67	100	100						88
	PUT	3/3	4/1	4/3	12/6	8/8								31/21
	KA %	100	25	75	50	100								68
1June67 1of4 review	MAT	2/2	1/1	2/1	2/2	6/5	2/2	1/1						16/14
	UI %	100	100	50	100	83	100	100						88
	PUT	5/1	1/1	1/1	5/5	4/2								12/10
	KA %	20	100	100	100	50								83
5June67 1of4	MAT	2/2	2/1	3/3	5/4	4/3	2/2	4/2						22/17
	UI	100	50	100	80	75	100	50						77
	PU	7/4	9/5	5/4	1/1	3/3								25/17
	KA	57	56	80	100	100								68

Table 4-11, Section II. Session summaries

SESSION		COMMAND												
		BIP	BAIEP	UWEIAP	MAKAI	MAUKA	BEIAP	BAEP	BURRAP	WAVE	RETRIEVE	YUMP	STD'B	TOT.
6June67 2of4 Maui Imua bip-baiep ok test-neg	MAT	9/6	9/5	2/2	3/3	6/4	7/6	2/2						38/26
	MAU%	77	56	100	100	66	81	100						69
	PUT	5/3	3/3	0/0	3/3	4/4								23/13
	PUK%	60	100	00	100	100								57
7June67 3of4 check	MAT	5/2	3/2	6/3	3/3	1/1	2/2	1/1						21/14
	MAU%	40	66	50	100	100	100	100						67
	PUT	5/4	13/2	6/1	1/1	2/2	1/0							28/10
	PUK%	80	15	16	100	100	00							36
8June67 1of4 review	MAT	1/1	2/2	1/1	4/2	6/2	1/1	1/1						16/10
	MAU%	100	100	100	50	33	100	100						63
	PUT	8/7	7/5	11/2	2/1	6/2								34/17
	PUK%	88	72	18	50	33								50
8June67 2of4 review	MAT	3/3	1/1	2/2	1/1	1/1	2/2	1/1						11/11
	MAU%	100	100	100	100	100	100	100						100
	PUT	4/4	6/3	6/3										16/10
	PUK%	100	50	50										63
9June67 2of5 check	MAT	2/2	1/1	2/2		2/2	2/2	2/2						11/11
	MAU	100	100	100		100	100	100						100
	PU	1/1	1/1	1/1	2/2	1/0								7/6
	PUK	100	100	100	100	00								87

Table 4-11, Section II. Session summaries

SESSION		COMMAND												
		BIP	BAIEP	UWEIAP	MAKAI	MAUKA	BEIAP	BAEP	BURRAP	WAVE	RETRIEVE	YUMP	STD'B	TOT.
9June67 3of5 Puka switch baiep-uweiap	MAUI T				2/2		1/1							3/3
	MAUI %				100		100							100
	PUKA T	7/7	17/9	9/7		4/4								37/27
	PUKA %	100	53	78		100								74
12June67 1of4 check ignore repeats	MAUI T	5/5	3/3	5/0	6/5	5/4	4/2	2/1						30/20
	MAUI %	100	100	00	84	80	50	50						66
	PUKA T	2/2	5/1	4/3	1/1	3/3								15/11
	PUKA %	100	20	75	100	100								73
13June67 1of4 both inside circle	MAUI T	4/4	3/3	6/3	5/3	4/3	5/2	1/1						28/19
	MAUI %	100	100	50	60	75	40	100						68
	PUKA T	4/4	13/5	7/4	2/2	4/4								30/19
	PUKA %	100	38	57	100	100								63
13June67 2of4 both inside ignore repeats	MAUI T	1/1	2/2	4/2			3/1	1/1						11/7
	MAUI %	100	100	50			33	100						64
	PUKA T	3/3	2/2	2/1	1/1	2/2								10/9
	PUKA %	100	100	50	100	100								90
13June67 3of4 both inside tape out	MAUI T	1/1	2/2		3/2		2/1							8/6
	MAUI	100	100		66		50							75
	PUKA	2/2	7/2	2/1	1/1	4/4								16/10
	PUKA	100	29	50	100	100								63

Table 4-11, Section II. Session summaries

SESSION		COMMAND												
		BIP	BAIEP	UWEIAP	MAKAI	MAUKA	BEIAP	BAEP	BURRAP	WAVE	RETRIEVE	YUMP	STD'B	TOT.
14June67 1of4 check both inside	MAT	3/2	2/2	3/2	1/1	1/1	3/3	1/1						14/12
	UI %	66	100	66	100	100	100	100						86
	PUT	2/2	6/4	4/4	1/1	3/2								16/13
	KA %	100	66	100	100	66								81
14June67 2of4 check both inside ignore repeats	MAT	1/1	1/1	2/2	1/0	1/1	1/1	1/1						8/7
	UI %	100	100	100	00	100	100	100						88
	PUT	2/2	7/3	3/1	1/1	4/3								17/10
	KA %	100	44	33	100	75								59
14June67 3of4 Puka baiep-uweiap ignore repeats	MAT	1/1		3/2	4/4	4/3	2/2							14/12
	UI %	100		66	100	75	100							86
	PUT	3/3	10/9	2/0		3/1								18/10
	KA %	100	90	00		33								56
14June67 4of4 both inside tape out	MAT	2/2	1/1	2/2	1/1	1/1	1/1							8/8
	UI %	100	100	100	100	100	100							100
	PUT	2/2	4/4	2/1	1/1	1/1								10/9
	KA %	100	100	50	100	100								90
15June67 1of4 check	MAT	2/2	3/1	2/2	1/1		1/1							9/7
	UI	100	33	100	100		100							78
	PU	2/2	8/3	2/2		3/1								15/8
	KA	100	37	100		33								53

Table 4-11, Section II. Session summaries

SESSION		COMMAND												
		BIP	BAIEP	UWEIAP	MAKAI	MAUKA	BEIAP	BAEP	BURRAP	WAVE	RETRIEVE	YUMP	STD'B	TOT.
15June67 2of4 Puka check Maui out	MAUI T	1/0			1/1	1/1								3/2
	MAUI %	00			100	100								66
	PUKA T	2/2	8/5	6/4	3/2	3/2								22/15
	PUKA %	100	63	66	66	66								68
16June67 3of4 both inside	MAUI T	3/3	4/3	2/2			4/2	1/1						14/11
	MAUI %	100	75	100			50	100						78
	PUKA T	4/3	10/8	10/4	2/2	6/1								32/18
	PUKA %	75	80	40	100	68								56
16June67 1of4 check both inside	MAUI T	1/1	1/1		4/2	2/2	4/4	1/1						13/11
	MAUI %	100	100		50	100	100	100						84
	PUKA T	1/1	1/1	3/1	2/2									7/5
	PUKA %	100	100	33	100									72
16June67 2of4 Puka baiep-uweiap	MAUI T	3/2	2/2		1/1	2/1	2/1							10/7
	MAUI %	66	100		100	50	50							70
	PUKA T	1/1	6/6	7/3	3/3									17/13
	PUKA %	100	100	43	100									76
16June67 3of4 check both inside	MAUI T	8/5	3/2	3/3	4/1	2/2	1/1	2/2						23/15
	MAUI	63	66	100	25	100	100	100						45
	PUKA	8/6	8/5	6/3	3/2	2/2								27/18
	PUKA %	75	63	50	66	100								67

Table 4-11, Section II. Session summaries

SESSION		COMMAND												
		BIP	BAIEP	UWEIAP	MAKAI	MAUKA	BEIAP	BAEP	BURRAP	WAVE	RETRIEVE	YUMP	STD'B	TOT.
16June67 4of4 sequence of commands without reward tape out	MAT	1/1	2/1	1/1			1/1							5/4
	UI %	100	50	100			100							80
	PUT	1/1	1/1	1/1	1/1									4/4
	KA %	100	100	100	100									100
	MAT													
	UI %													
	PUT													
	KA %													
	MAT													
	UI %													
	PUT													
	KA %													
	MAT													
	UI %													
	PUT													
	KA %													
	MAT													
	UI													
	PU													
	K													

Table 4-11, Section II. Session summaries

SESSION		COMMAND												
		BIP	BAIEP	UWEIAP	MAKAI	MAUKA	BEIAP	BAEP	BURRAP	WAVE	RETRIEVE	YUMP	STD'B	TOT.
19June67 1of5 check both inside	MAUI T	3/2	4/1	3/3	5/3		3/1							22/11
	MAUI %	66	25	100	60		33							50
	PUKA T	3/2	2/2	4/4	3/3									12/11
	PUKA %	66	100	100	100									97
19June67 2of5 sequence	MAUI T	2/2	1/1	2/1	2/2		2/2							9/8
	MAUI %	100	100	50	100		100							89
	PUKA T	9/4	8/2	1/1	2/2	1/1								21/10
	PUKA %	45	25	100	100	100								48
19June67 5of5 Liz Puka inside Peter Maui outside	MAUI T				1/1	2/2								3/3
	MAUI %				100	100								100
	PUKA T	6/4	6/2		4/2	4/3								22/13
	PUKA %	66	33		50	75								59
20June67 1of4 wait for ok	MAUI T	3/0			1/1	2/1								6/2
	MAUI %	oo			100	50								33
	PUKA T				1/1	1/1								2/2
	PUKA %				100	100								100
20June67 2of4 wait for ok	MAUI T	17/14	10/10	6/6	2/1	2/2	7/3	4/2						48/38
	MAUI	82	100	100	50	100	44	50						79
	PUKA				3/1									3/1
	PUKA				33									33

Table 4-11, Section II. Session summaries

SESSION		COMMAND												
		BIP	BAIEP	UWEIAP	MAKAI	MAUKA	BEIAP	BAEP	BURRAP	WAVE	RETRIEVE	YUMP	STD'B	TOT.
20June67 3of4 Peter-Maui wait for ok Liz-Puka outside tape out	MAUI T	3/2	7/1		1/1	3/3								14/7
	MAUI %	66	14		100	100								50
	PUKA T	10/3	3/1		1/0	1/1								15/5
	PUKA %	30	33		00	100								33
22June67 3of4 Liz check& repeat ignore repeats	MAUI T	2/2			2/2	2/2	1/1	1/1						8/8
	MAUI %	100			100	100	100	100						100
	PUKA T		2/2	2/1	2/1	2/1								8/5
	PUKA %		100	50	50	50								64
22June67 4of4 Peter-Puka repeat Liz-Maui outside ignore repeats	MAUI T				4/0									4/0
	MAUI %				00									00
	PUKA T	4/2	4/2	2/2		4/2								14/8
	PUKA %	50	50	100		50								64
23June67 1of5 check both inside ignore repeats	MAUI T	2/2	1/1		1/1	1/1	1/1	1/0						7/6
	MAUI %	100	100		100	100	100	00						80
	PUKA T	1/1	2/2	2/1	1/1	1/1								7/6
	PUKA %	100	100	50	100	100								80
23June67 4of5 2 trainers 2 translators ignore repeats tape out	MAUI T	7/4	4/3	2/1	3/2	4/2	3/2	4/0						27/14
	MAUI	57	75	50	66	50	66	00						52
	PUKA	6/2	5/4	2/2	6/3	5/3								24/14
	PUKA	33	80	100	50	60								57

Table 4-11, Section II. Session summaries

SESSION		COMMAND												
		BIP	BAIEP	UWEIAP	MAKAI	MAUKA	BEIAP	BAEP	BURRAP	WAVE	RETRIEVE	YUMP	STD'B	TOT.
27June67 4of4 Maui burrap-baep	MAT	5/4	10/4	4/4	6/4	3/2	9/6	10/2	7/1					54/27
	UI %	80	40	100	66	66	66	20	14					50
	PUT	7/4	6/1	2/2	6/5	1/1								23/13
	KA %	57	16	100	84	100								57
5July67 1of5 moved hoop & ball	MAT	16/1	22/6	2/2	3/3	6/5	2/2							51/19
	UI %	6	27	100	100	84	100							37
	PUT	6/1	6/1	2/1	7/0	2/2								22/5
	KA %	16	16	50	00	100								23
5July67 2of5 moved hoop & ball tape out	MAT	3/0	6/4	1/1			1/1							11/6
	UI %	00	66	100			100							55
	PUT				4/4									4/4
	KA %				100									100
12July67 1of7 Maui review	MAT	11/6	8/3	1/1		2/1	2/2	2/2						24/13
	UI %	55	37	100		50	100							54
	PUT				4/3									4/2
	KA %				50									50
12July67 3of7 Puka bip-baiep	MAT				4/2	1/1	1/1							7/4
	UI				50	100	100							57
	PU	16/5		7/4	1/1		1/0							25/10
	K A	31		57	100		00							40

Table 4-11, Section II. Session summaries

SESSION		COMMAND											
		BIP	BAIEP	UWEIAP	MAKAI	MAUKA	BEIAP	BAEP	BURRAP	WAVE	RETRIEVE	YUMP	STD'B	TOT.
13July67 1of6 Liz-Puka tape stoped	MAUI T				3/2									3/2
	MAUI %				66									66
	PUKA T	1/1	7/3	1/1		1/1								10/6
	PUKA %	100	43	100		100								60
13July67 2of6 Peter-Maui's off cue behavior distracting Puka	MAUI T	3/1	4/2	1/1	2/2	2/2	4/3							16/11
	MAUI %	33	50	100	100	100	75							69
	PUKA T	3/2	7/2	1/1	1/1	2/2								14/8
	PUKA %	66	29	100	100	100								57
14July67 5of5 wire cage around hyd. tape out	MAUI T	6/5	10/7	5/5	9/9	7/7	6/6		6/1					49/40
	MAUI %	84	70	100	100	100	100		16					82
	PUKA T	50/2	321/10	2/2	1/1	7/6								71/42
	PUKA %	46	48	100	100	86								59
18July67 1of5 fixed seq. of commands Liz-Maui	MAUI T	3/3	3/3	3/2	4/4/	3/3	3/2	3/1	3/0					25/18
	MAUI %	100	100	66	100	100	66	33	00					72
	PUKA T				1/1									1/1
	PUKA %				100									100
18July67 2of5 fixed seq. of commands Peter-both	MAUI T	3/3	3/0	3/3	6/5	6/5	3/3	2/1	4/2					32/22
	MAUI	100	00	100	84	84	100	50	50					69
	PUKA	3/0	3/0	3/3	4/4	5/4	3/0	3/0	3/0					29/11
	PUKA	00	00	100	100	80	00	00	00					38

Table 4-11, Section II. Session summaries

SESSION		COMMAND												
		BIP	BAIEP	UWEIAP	MAKAI	MAUKA	BEIAP	BAEP	BURRAP	WAVE	RETRIEVE	YUMP	STD'B	TOT.
21July67 2of6 hoop&ball moved in S.1 Liz Maui-baep Puka-baiep-bip	MAUI T	2/0	1/1	3/2	4/3	1/1	2/1	7/7						20/15
	MAUI %	00	100	66	75	100	50	100						75
	PUKA T	4/1	8/5		2/2	1/1								15/9
	PUKA %	25	63		100	100								60
21July67 3of6 review	MAUI T	7/2	10/7	4/4	1/1	1/1	4/3	5/3						32/21
	MAUI %	29	70	100	100	100	75	60						66
	PUKA T	9/4	11/7	5/5	2/2	1/1								28/19
	PUKA %	45	64	100	100	100								68
21July67 4of6 Liz fixed seq. of commands tape out	MAUI T				1/1									1/1
	MAUI %				100									100
	PUKA T	2/1	4/2	2/2	2/0									10/5
	PUKA %	50	50	100	00									50
	MAUI T													
	MAUI %													
	PUKA T													
	PUKA %													
	MAUI T													
	MAUI													
	PUKA													
	PUKA													

Table 4-11, Section II. Session summaries

SESSION		COMMAND												
		BIP	BAIEP	UWEIAP	MAKAI	MAUKA	BEIAP	BAEP	BURRAP	WAVE	RETRIEVE	YUMP	STD'B	TOT.
24July67 2of4 both-bip-baiep	MAT	24/16	25/10											49/26
	MAU I %	67	40											53
	PUT	24/7	27/18											52/35
	PUKA %	28	67											67
25July67 1of7 review	MAT	3/3	10/4	3/2	7/7		5/4	3/2	2/0					33/22
	MAU I %	100	50	66	100		80	66	00					67/3
	PUT	10/5	6/2	3/1										19/8
	PUKA %	50	33	33										42
2Aug67 1of7 Peter review ignore repeats	MAT	2/2	2/1	1/1	8/7	3/2	3/3	5/2	2/1					26/19
	MAU I %	100	50	100	88	66	100	40	50					73
	PUT	6/2	2/1	1/1	2/1	3/3				3/1				14/9
	PUKA %	33	50	100	50	100				33				64
2Aug67 2of7 Liz hoop& ball moved	MAT	7/0	3/1		4/2	2/2	3/2	3/1	1/1					23/9
	MAU I %	00	33		50	100	66	33	100					27
	PUT	7/2	9/3	1/1	2/2	1/1				5/1				26/10
	PUKA %	29	33	100	100	100				20				39
2Aug67 4of7 both bip-baiep	MAT	10/6	6/2	2/1	6/6	2/2	3/3	2/2	5/2					36/24
	MAU I	60	33	50	100	100	100	100	40					67
	PUT	7/0	4/4	1/1	3/3	3/3				3/1				21/12
	PUKA	00	100	100	100	100				33				57

Table 4-11, Section II. Session summaries

SESSION		COMMAND												
		BIP	BAIEP	UWEIAP	MAKAI	MAUKA	BEIAP	BAEP	BURRAP	WAVE	PLOP/ RETRIEVE	YUMP	STD'B	TOT.
3Aug67 1of3 Peter review	MAUI T	3/2	3/2	2/2	6/6	3/3	3/3	1/1	3/0					24/19
	MAUI %	66	66	100	100	100	100	100	00					79
	PUKA T	3/1	2/1	3/3	6/6	3/3				4/1	4/0 /			22/15
	PUKA %	33	50	100	100	100				25	00			68
4Aug67 4of6 Peter-both check ignore repeats	MAUI T	1/0	1/0	1/0	1/1	1/1	1/1	1/1	1/0					8/4
	MAUI %	00	00	00	100	100	100	100	00					50
	PUKA T	1/0	1/0	1/1	2/2	1/1				1/1	1/0 /	1/0		9/5
	PUKA %	00	00	100	100	100				100	00 /	00		56
4Aug67 5of6 Liz check ignore repeats	MAUI T	1/1	1/1	1/1	2/2	1/1	1/1	1/1	1/0					9/8
	MAUI %	100	100	100	100	100	100	100	00					89
	PUKA T	1/1	1/0	1/1	2/2	3/1				1/0	1/0 /	1/0		11/5
	PUKA %	100	00	100	100	33				00	00 /	00		46
4Aug67 6of6 Peter Maui retrieve tape out	MAUI T	1/1	1/0	1/1	2/2	2/2					/5/0			14/4
	MAUI %	100	00	100	100	100					/00			50
	PUKA T	3/0	1/0	2/2	2/2					1/0				9/4
	PUKA %	00	00	100	100					00				45
7Aug67 1of7 Liz ball & hoop moved	MAUI T	4/3	4/1	1/1	2/2	1/1	2/1	1/1	1/0					16/10
	MAUI	75	25	100	100	100	50	100	00					63
	PUKA	4/2	5/0	2/0	2/2	2/2								16/6
	PUKA	50	00	00	100	100								37

Table 4-11, Section II. Session summaries

SESSION		COMMAND									PLOP/			
		BIP	BAIEP	UWEIAP	MAKAI	MAUKA	BEIAP	BAEP	BURRAP	WAVE	RETRIEVE	YUMP	STD'B	TOT.
7Aug67 2of7 Peter	MAT	2/1	2/0	1/1	3/3	5/1	2/2		2/0					18/9
	UI %	50	00	100	100	20	100		00					50
	PUT	9/0	5/0	2/1	2/2	4/4								22/6
	KA %	00	00	50	100	100								30
15Aug67 4of6 Liz review	MAT	1/1	4/2	2/2	4/4	4/4	3/2	1/1	4/3					25/20
	UI %	100	50	100	100	100	66	100	75					80
	PUT	12/1	3/2	1/1	1/1	1/1				1/1	3/2 /			22/9
	KA %	8	66	100	100	100				100	66 /			41
15Aug67 5of6 Peter review	MAT	2/1	4/2	2/2	3/3	3/3	3/3	3/3	1/1					20/18
	UI %	50	50	100	100	100	100	100	100					90
	PUT	6/0	6/0	2/2	2/2	2/2				1/1				19/7
	KA %	00	00	100	100	100				100				37
16Aug67 1of4 Liz review	MAT	1/1	1/1	1/1	6/6	4/4	2/2		3/2					18/17
	UI %	100	100	100	100	100	100		66					95
	PUT	8/3		1/1	2/2	2/2				1/1	2/0 /			19/10
	KA %	38		100	100	100				100	00			53
17Aug67 1of5 Peter review	MAT	2/2	3/1	2/2	3/3	1/1	3/3	1/1	3/2					18/15
	UI	100	33	100	100	100	100	100	66					83
	PUK	15/5	18/4	5/5	2/2	1/1				1/1	4/0 /			46/18
	A	33	22	100	100	100				100	00			38

Table 4-11, Section II. Session summaries

SESSION		COMMAND BIP	BAIEP	UWEIAP	MAKAI	MAUKA	BEIAP	BAEP	BURRAP	WAVE	PLOP/ RETRIEVE	YUMP	STD'B	TOT.
18Aug67 1of3 partI test TT-2 trial 1-3	MAT	3/0	3/0	3/0			3/0	3/1						15/1
	UI %	00	00	00			00	33						6
	PUT	2/0	2/0	3/0			2/0	2/0						11/1
	KA %	50	00	00			00	00						9
18Aug67 1of3 part II Peter review	MAT	1/1	1/1	2/1	8/4		3/4	2/2	5/1					24/14
	UI %	100	100	50	50		80	100	20					58
	PUT	13/4	6/1	4/3	2/2	3/3				1/1				29/14
	KA %	31	6	75	100	100				100				48
18Aug67 3of3 Maui retrieve Puka plop	MAT	3/2	3/1	2/2	5/5	3/3	7/7	2/2	1/1		8/3			34/26
	UI %	66	33	100	100	100	100	100	100		37			74
	PUT	2/2	4/0	2/2	6/6	2/2				1/1	12/0			29/13
	KA %	100	00	100	100	100				100	00			45
21Aug67 1of5 Liz hoop & ball moved	MAT	3/1	1/0		5/3	2/2	4/3	1/1	3/1					18/8
	UI %	33	00		60	100	75	100	33					45
	PUT	2/1	5/1	1/1	1/1	2/1				1/1		1/0		13/6
	KA %	50	20	100	100	50				100		00		46
21Aug67 4of5 Liz Puka repeat	MAT	1/1	1/1		3/3	1/1	1/1	2/2	1/1					10/10
	UI	100	100		100	100	100	100	100					100
	PUK	4/3	9/1	1/1										14/5
	A	75	1	100										36

Table 4-11, Section II. Session summaries

SESSION		COMMAND											
		BIP	BAIEP	UWEIAP	MAKAI	MAUKA	BEIAP	BAEP	BURRAP	WAVE	PLOP/ RETRIEVE	YUMP	STD'B	TOT.
22Aug67 1of5 Peter hoop & ball moved	MAT	1/0	2/2	2/1	10/9	1/1	6/4	1/1	3/3					26/20
	UI %	00	100	50	90	100	66	100	100					77
	PUT	9/5	12/2	4/4	1/1	1/1					16/1/ /			43/14
	KA %	56	16	100	100	100					6 /			33
23Aug67 1of4 Liz hoop & ball moved	MAT	2/1	1/1	1/1	3/3		3/1	1/1	1/1					12/9
	UI %	50	100	100	100		33	100	100					75
	PUT	5/0	8/1	1/1	1/1	1/1				1/1	1/0 /			18/15
	KA %	00	12	100	100	100				100	00			83
24Aug67 1of6 Liz hoop & ball moved	MAT	2/1	1/1	1/1	4/4	1/1	2/1	2/12	3/1					16/11
	UI %	50	100	100	100	100	50	50	33					69
	PUT	1/1	5/0		5/5	2/0					2/1 /			15/7
	KA %	100	00		100	00					50 /			51
24Aug67 2of6 Peter	MAT	6/2	5/1	3/3	13/8	2/2	4/3	2/2	3/1					38/22
	UI %	33	20	100	61	100	75	100	33					58
	PUT	5/3	5/1	3/2	4/4	3/3				4/1				21/14
	KA %	60	20	66	100	100				25				67
24Aug67 6of6 Liz Maui rammed float circle	MAT	2/2	2/1	1/1	8/2	2/2	2/1	2/2						20/12
	UI	100	50	100	25	100	50	100						60
	PU	8/3	9/1	2/2	2/2	3/3				2/2				26/13
	K *	37	11	100	100	100				100				50

Table 4-11, Section II. Session summaries

SESSION		COMMAND												
		BIP	BAIEP	UWEIAP	MAKAI	MAUKA	BEIAP	BAEP	BURRAP	WAVE	PLOP/ RETRIEVE	YUMP	PORT/ STD'B	TOT.
28Aug67 1of6 Liz Maui rammed float circle	MAUI T	2/2	9/0	2/2	5/4	2/2	2/2	1/1	2/2					25/15
	MAUI %	100	00	100	80	100	100	100	100					60
	PUKA T	5/0	2/1	1/0	2/2	7/7				2/1	3/2 /			22/13
	PUKA %	00	50	00	100	100				50	66 /			59
28Aug67 2of6 Peter check float circle removed	MAUI T			1/1	4/4	2/1	1/1	1/1	3/1					12/9
	MAUI %			100	100	50	100	100	33					82
	PUKA T			1/1	1/1	1/0				1/0	1/1 /			5/3
	PUKA %			100	100	00				00	100 /			60
29Aug67 1of6 Liz check float circle removed	MAUI T			1/1	1/1	1/1	2/2	1/1	1/1					7/7
	MAUI %			100	100	100	100	100	100					100
	PUKA T			1/1	1/1	1/1				1/1	1/1			5/5
	PUKA %			100	100	100				100	100			100
30Aug67 1of4 Liz check Maui port-starboard ignore repeats	MAUI T			1/1		1/1	2/2	1/1	1/0				2/0 6/1	14/6
	MAUI %			100		100	100	100	00				00 16	43
	PUKA T			1/1	2/2					1/1	2/1	1/0		7/5
	PUKA %			100	100					100	50	00		72
1Sept67 3of5 Peter check	MAUI T			1/1	2/2		4/4	2/1	1/1				3/0 1/1	15/11
	MAUI			100	100		100	50	100				00 100	74
	PUKA			3/2	1/1	1/1				3/2	2/2	3/1		12/9
	PUKA %			66	100	100				66	100	33		75

Table 4-11, Section II. Session summaries

SESSION		COMMAND									PLOP/		PORT/	
		BIP	BAIEP	UWEIAP	MAKAI	MAUKA	BEIAP	BAEP	BURRAP	WAVE	RETRIEVE	YUMP	STD'B	TOT.
6Sept67	MAUI T	2/2	2/2	2/2	1/1	2/2	1/1	1/1	2/0				1/1 2/1	1613
4of6	MAUI %	100	100	100	100	100	100	100	00				100 50	81
both bip-baiep	PUKA T	3/0	2/0		2/2	1/1				1/1	1/1 /			10/5
ignore repeats	PUKA %	00	00		100	100				100	100 /			50
18Sept67	MAUI T	2/2	3/3	1/1	1/1	1/1	1/1	4/2	1/1					14/12
4of4	MAUI %	100	100	100	100	100	100	50	100					86
review	PUKA T	4/2	6/1	5/4	1/1	3/3				1/1	1/1 /			22/14
ignore repeats	PUKA %	50	16	80	100	100				100	100 /			64
20Sept67	MAUI T	1/1	1/1	2/2	1/1	1/1	1/1	1/1	1/1				1/0	10/9
1of6	MAUI %	100	100	100	100	100	100	100	100				00	90
review	PUKA T	1/1	2/0	1/1	1/1	1/1				1/1	2/1 /			9/6
ignore repeats	PUKA %	100	00	100	100	100				100	50 /			67
22Sept67	MAUI T	1/1	1/1	1/1	2/2	2/2	1/1	1/1	2/2				1/1 2/0	14/12
1of4	MAUI %	100	100	100	100	100	100	100	100				100 00	86
review	PUKA T	3/0	2/1	2/2	1/1						1/1 /	2/0		11/5
ignore repeats	PUKA %	00	50	100	100						100 /	00		46
25Sept67	MAUI T	2/0	2/1	2/1	1/1	3/3	1/1	1/1	2/2				1/1 2/1	17/12
1of4	MAUI %	00	50	50	100	100	100	100	100				100 50	70
review	PUKA T	2/1	1/1	1/1	2/2	1/1				1/1	1/1 /			9/8
ignore repeats	PUKA %	50	100	100	100	100				100	100 /			89

Table 4-11, Section II. Session summaries

SESSION		COMMAND												
		BIP	BAIEP	UWEIAP	MAKAI	MAUKA	BEIAP	BAEP	BURRAP	WAVE	PLOP/ RETRIEVE	YUMP	PORT? STD'B	TOT.
26Sept67 1of5 review	MAUI T	1/1	3/0	3/1	5/2	1/1	2/1	1/1	2/2				1/1	19/10
	MAUI %	100	00	33	40	100	50	100	100				100	53
	PUKA T	1/0	2/1	2/2	1/1	2/1				1/0	1/0 /			10/5
	PUKA %	00	50	100	100	50				00	00 /			50
29Sept67 2of4review ignore repeats	MAUI T	2/2		2/2	2/2	3/3	1/1	1/1	1/1				1/0 1/1	14/13
	MAUI %	100		100	100	100	100	100	100				00 100	93
	PUKA T	2/1	2/2	1/1	4/2	2/2				1/1	1/1 /			13/10
	PUKA %	50	100	100	50	100				100	100 /			77
20Oct67 1of5 review ignore repeats	MAUI T	2/o	2/1	1/1	2/2	3/3	1/1	2/0	1/1				1/1	15/10
	MAUI %	00	50	100	100	100	100	00	100				100	67
	PUKA T	4/1	2/2	1/1	2/2	1/1				1/1	2/0			13/8
	PUKA %	25	100	100	100	100				100	00			62
60Oct67 1of5 review ignore repeats	MAUI T	2/1	1/1	1/1	1/1		1/1	1/1	1/1				2/1	10/8
	MAUI %	50	100	100	100	1	100	100	100				50	80
	PUKA T	2/1	1/1	2/1	3/2					1/1	1/1 /			10/7
	PUKA %	50	100	50	66					100	100 /			70
60Oct67 4of5 review ignore repeats tape out	MAUI T	1/1	3/0	1/1	1/1	4/1	2/1	1/1						13/6
	MAUI	100	00	100	100	25	50	100						46
	PUKA	2/1	4/2	2/2	3/3	1/1				1/1	2/0 /			15/9
	PUKA %	50	50	100	100	100				100	00 /			60

Table 4-11, Section II. Session summaries

SESSION		COMMAND												
		BIP	BAIEP	UWEIAP	MAKAI	MAUKA	BEIAP	BAEP	BURRAP	WAVE	PLOP/ RETRIEVE	YUMP	STD'B	TOT.
130ct67 1of7 review	MAT	1/0	1/0	1/1	1/1		1/1	1/1	1/1					7/5
	UI %	00	00	100	100		100	100	100					72
	PUT	1/0	2/0	1/1	1/1					1/0	1/1 /			7/3
	KA %	00	00	100	100					00	100			43
130ct67 6of7 review ignore repeats	MAT		2/2	2/2	5/4	2/2	2/2	1/1	2/1			1/0		17/14
	UI %		100	100	80	100	100	100	50			00		82
	PUT	1/1	1/0	2/2	3/2	3/3				1/1	1/0 /	2/2		14/11
	KA %	100	00	100	66	100				100	00 /	100		78
160ct67 3of4 test Puka on baep for cross learning	MAT	1/1	1/1	1/1	2/2	1/1	1/1	1/1					1/0	9/8
	UI %	100	100	100	100	100	100	100					00	89
	PUT	1/1	1/1		2/2			1/1			2/0			7/5
	KA %	100	100		100			100			00			72
	MAT													
	UI %													
	PUT													
	KA %													
	MAT													
	UI													
	PUK													
	A													

Table 4-11 - Section III

August 16, 1967
Session I
(Liz-Maui-Puka)

COMMAND	MAUI	PUKA
GAME TIME		
P i makai ok		+
M i makai ok	+	
P i uweiap ok		+
M i mauka ok	+	* in
M i makai ok	&	
M i burrap ok	no response	
M i burrap ok (+ fish)	+	
M i beiap ok	+	* out
M i mauka ok	+	* in
P i bip ok		neg-fluke slap
P i bip ok		neg-hoop
M i bip ok	+	
M i baiep ok	+	
P i wave ok		+
P i baiep ok		+
P i bip ok		neg-fluke slap
M i makai ok	&	
M i burrap ok (+ fish)	+	
M i uweiap ok	+	
M i mauka ok	+	
P plop ok		neg-wave
P plop ok		neg-wave
P i baiep ok		neg-fluke slap
P i makai ok		+
MAUI REPEAT BAIEP OK - See MSA readouts.		
M i beiap ok	+	
P i mauka ok		+
P i baiep ok		neg-fluke slap
P i baiep ok (+ fish)		neg-out
P i bip ok		no response
P i bip ok (+ fish)		+
P i bip ok		+
M i makai ok	+	
M i makai ok	+	
	* in	
M i makai ok	+	
P i mauka ok		+
P REPEAT BAIEP OK - See MSA readouts.		
M i mauka ok	+	

P i bip ok — no response
P i bip ok (+ fish)

ALL PAU

+ = Animal did correct behavior got "biyib" and a fish.

& = Animal did correct behavior got no "biyib" and no fish.

* - Animal moved off cue.

August 16, 1967

1st. Session (Liz)

	MAKAI	MAUKA	BIP	BAIEP	BEIAP	BURRAP	WAVE	PLOP	UWEIAP
MAUI	6/6	4/4	1/1	1/1	2/2	3/2			1/1
PUKA	2/2	2/2	8/3				1/1	2/0	1/1

NO. OF COMMANDS/CORRECT RESPONSES

MAUI:
Commands 18
Correct Responses 17
Incorrect Responses 1

1 no response on burrap
1 Off cue - (came in)

PUKA:
Commands 19
Correct Responses 10
Incorrect Responses 9

2 fluke slap on "P i bip ok"
1 hoop on "P i bip ok"
2 no response on "P i bip ok"
1 fluke slap on "P i baiep ok"
1 out on "P i baiep ok"
2 wave in "P plop ok"

Off cue - 3
1 went out)
2 came in) on Maui's commands.

Table 4-11

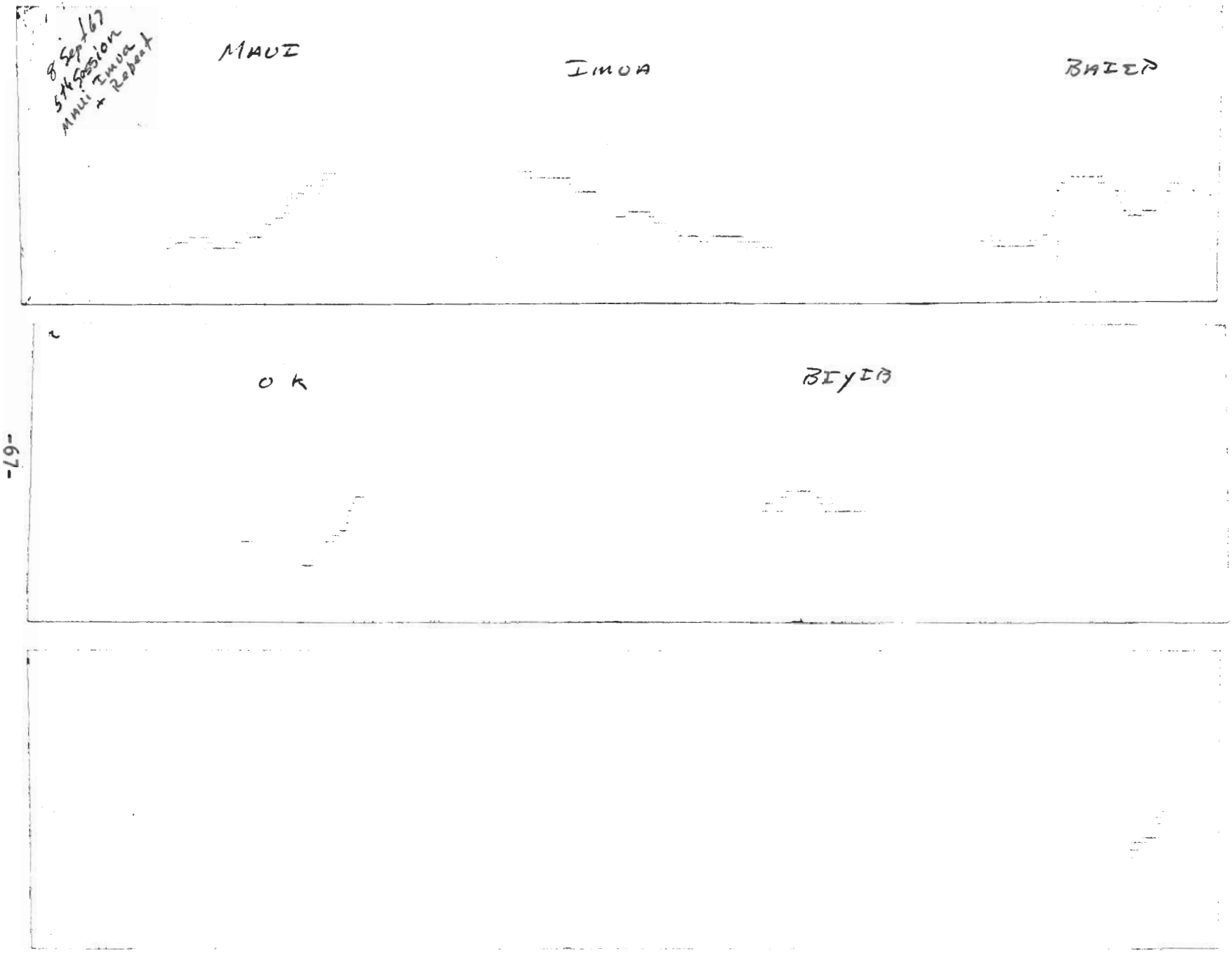
Section IV

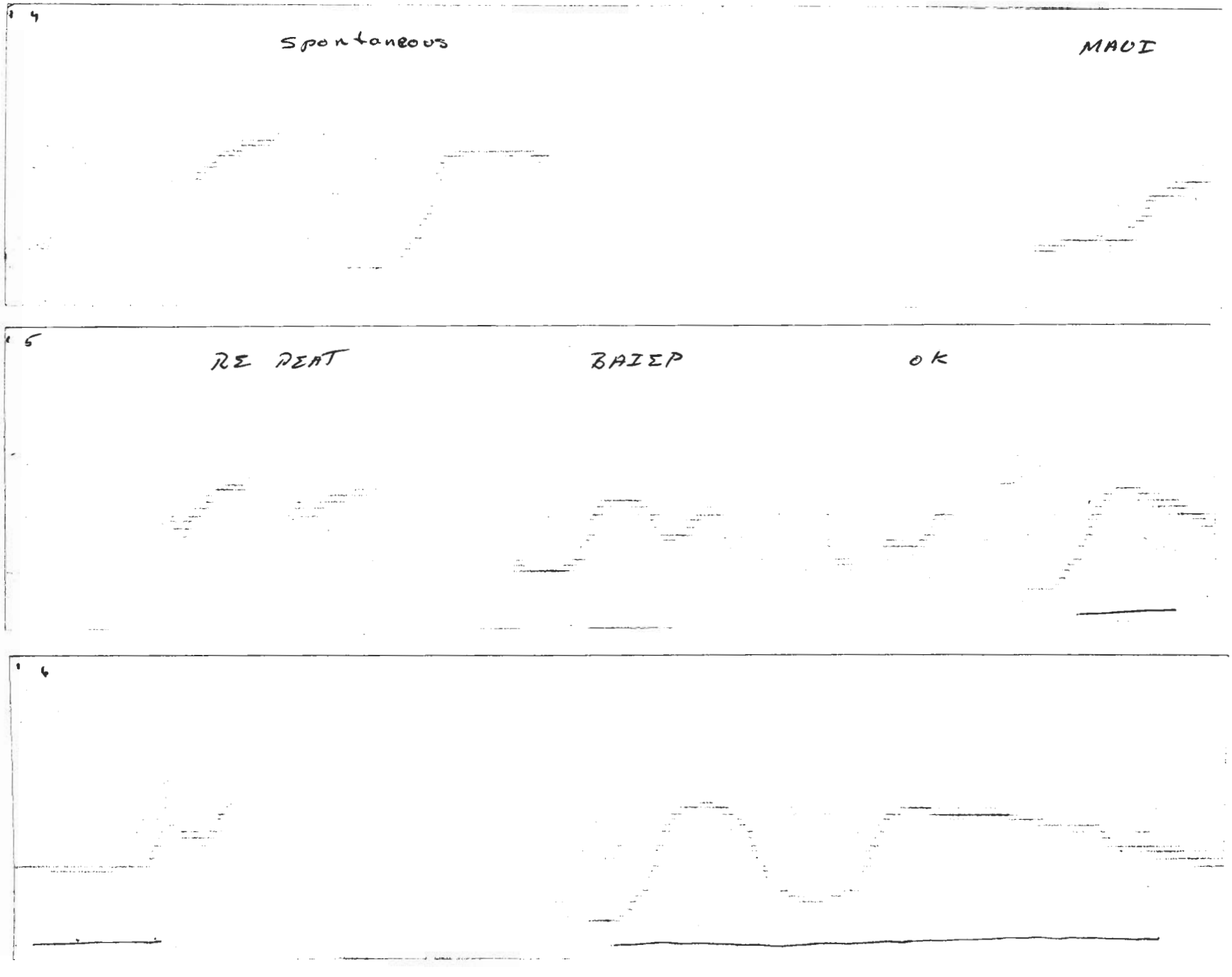
30 May 1967	Puka responded to the vocal commands BIP, BAIEP and UWEIAP without hand signals.
	Dual control test. Two trainers, two translators.
1 June	Maui's Repeat behavior extinguished in an attempt to raise the response frequency.
5 June	Puka offered behavior. Start of play session. Put her Jump on a hand signal.
6 June	Started Maui on retrieve work. Asked Maui to do two behaviors with the command MAUI IMUA BIP BAIEP OK.
8 June	Asked Maui to respond to sequence of three commands without reward.
9 June	Worked both animals inside the float circle together.
14 June	Puka did UWEIAP outside the float circle.
19 June	Started Puka retrieving a ball.
26 June	Maui responded to vocal command for BURRAP.
27 June	Maui responded to vocal command for RETRIEVE.
28 June	Maui responded correctly to the minimally different words, BAI of BAIEP, BEI of BEIAP and UWE of UWEIAP.
5 July	Positions of the hoop and ball were reversed.
14 July	Placed wire cages around the hydrophones to protect them.
18 July	Tested responses with a predetermined random sequence of commands.
19 July	Added IMUA to MAUKA and MAKAI-OK.
	Asked Maui to do BIP and BAIEP from outside the float circle.

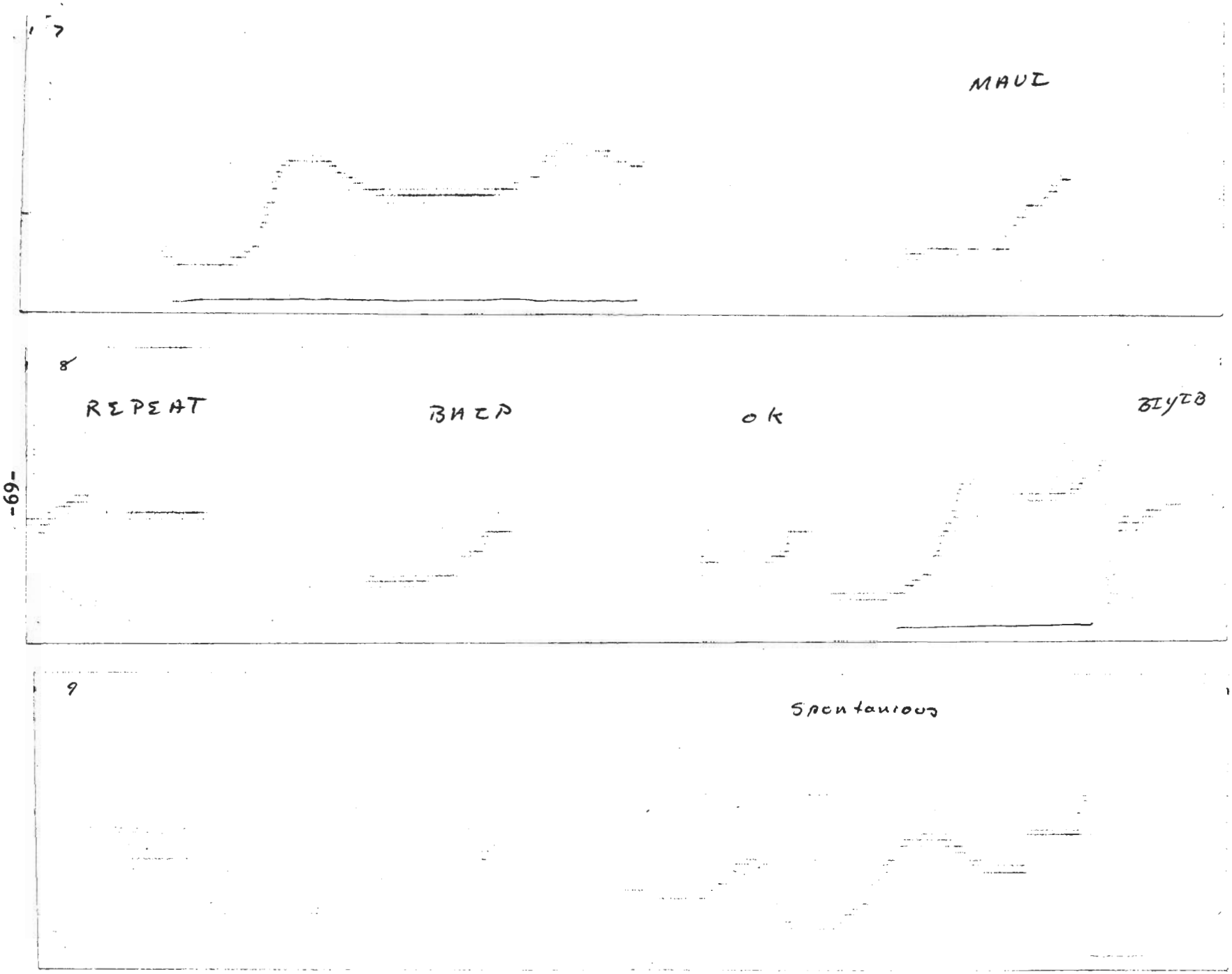
25 July	Started Puka on WAVE.
31 July	Maui attacked the float circle. Added OK to the REPEAT command.
2 August	Started Puka on PLOP
4 August	Started to work on separating the sonar and whistle in vocal responses.
10 August	Started Puka on the vocal command YUMP-OK.
18 August	Attempted to use a prerecorded command test sequence.
22 August	Started Maui on the vocal commands PORT and STARBOARD.
28 August	Removed the float circle.
4 September	Replaced then removed the float circle. Suspended the hoop and ball from poles attached to the houseboat.
18 September	Started Maui on Play Time.
19 September	Asked Maui to respond to BIEAP, UWEIAP and MAUKA while stationed on the far side of the lagoon, about 75 yards away.
22 September	Maui offers behavior.
26 September	Puka initiates a game of retrieve without reward. Started cage training in preparation for moving to Oceanic Institute.
16 October	Tested Puka for cross learning on the word BAEP.
25 October	Tested Puka for cross learning on the word BEIAP.
1 November	Moved both animals to new facility at Oceanic Foundation.

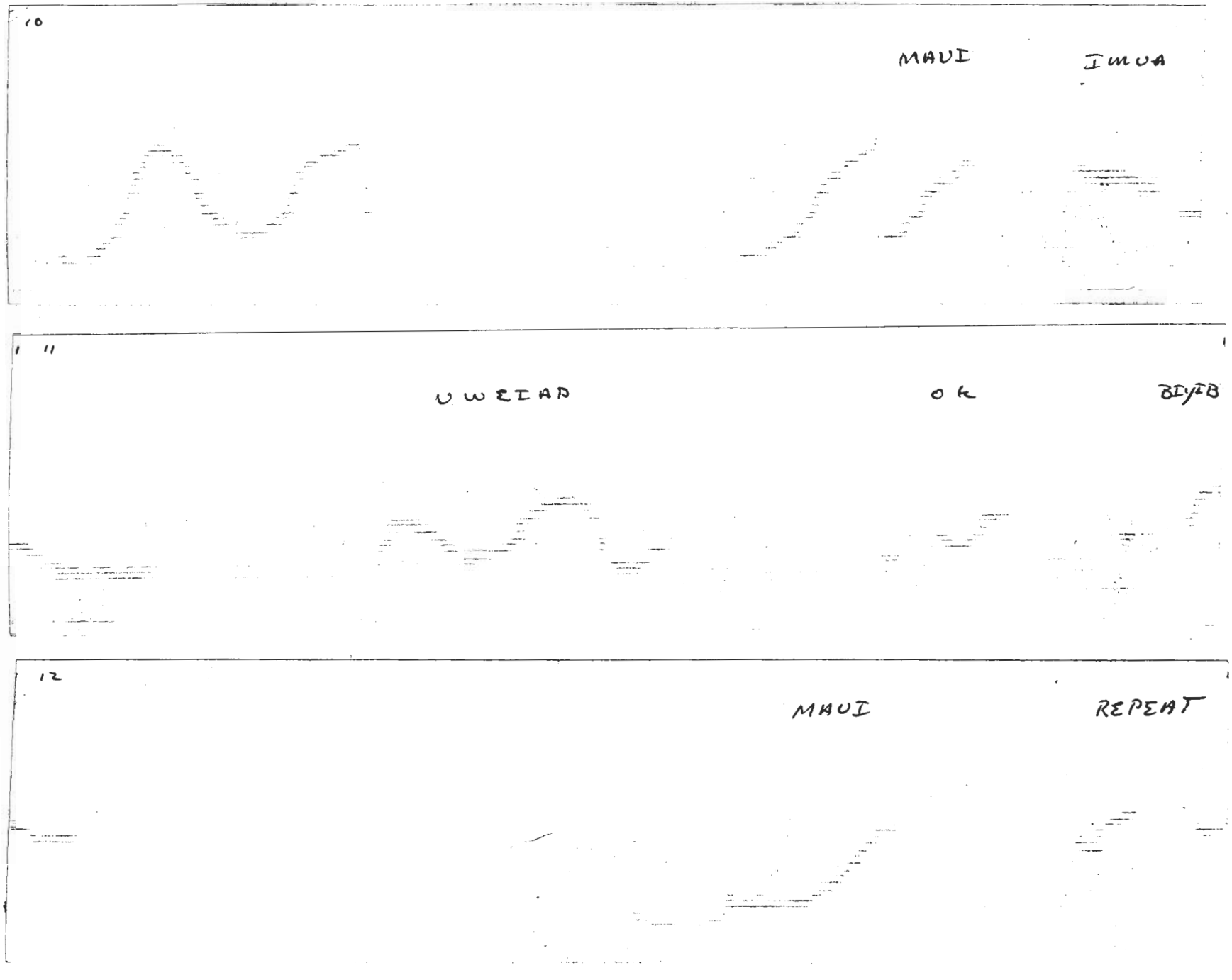
Table 4-13

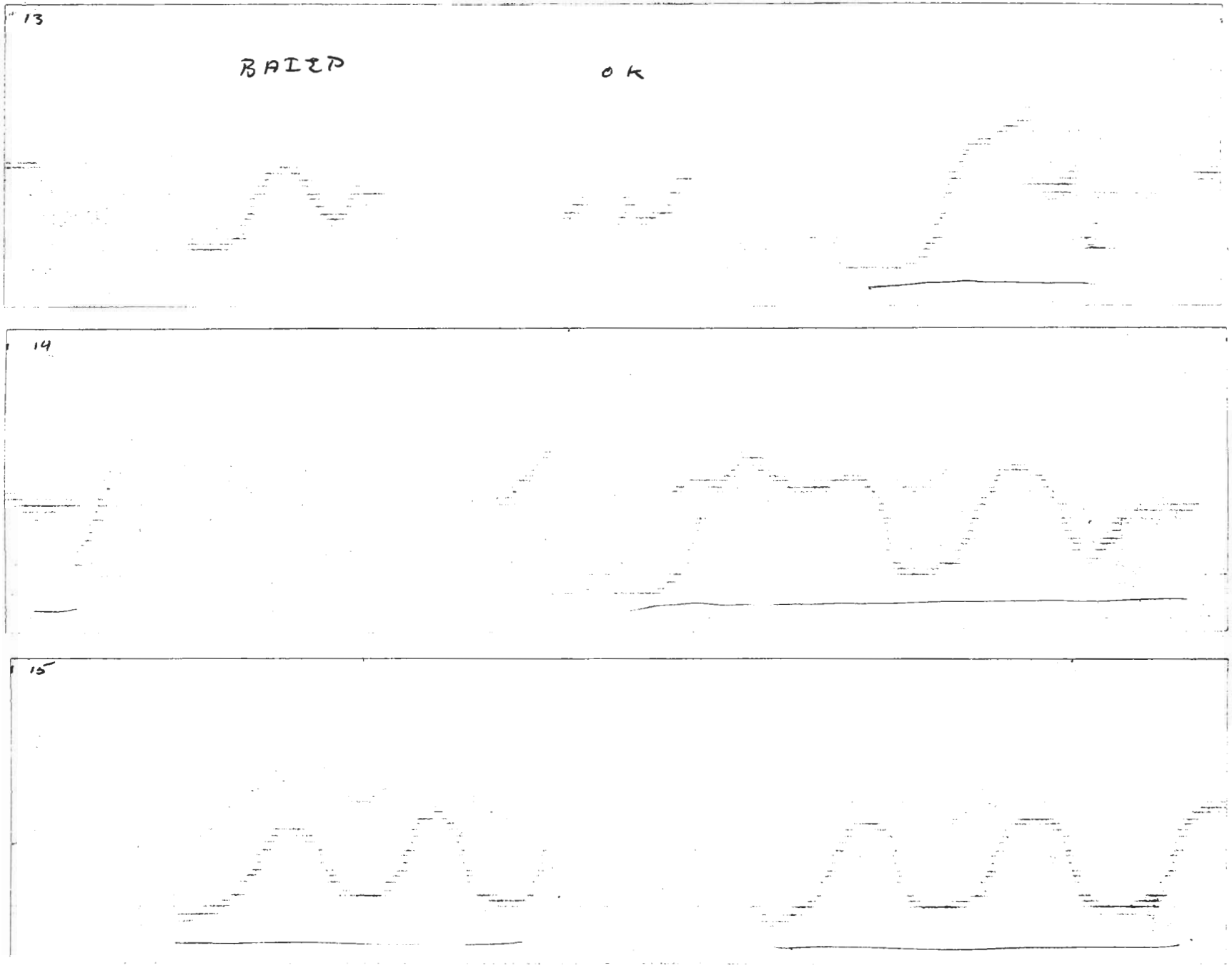
Maui's response to commands for non-vocal and vocal behavior recorded during the 5th session on 8 September 1967.

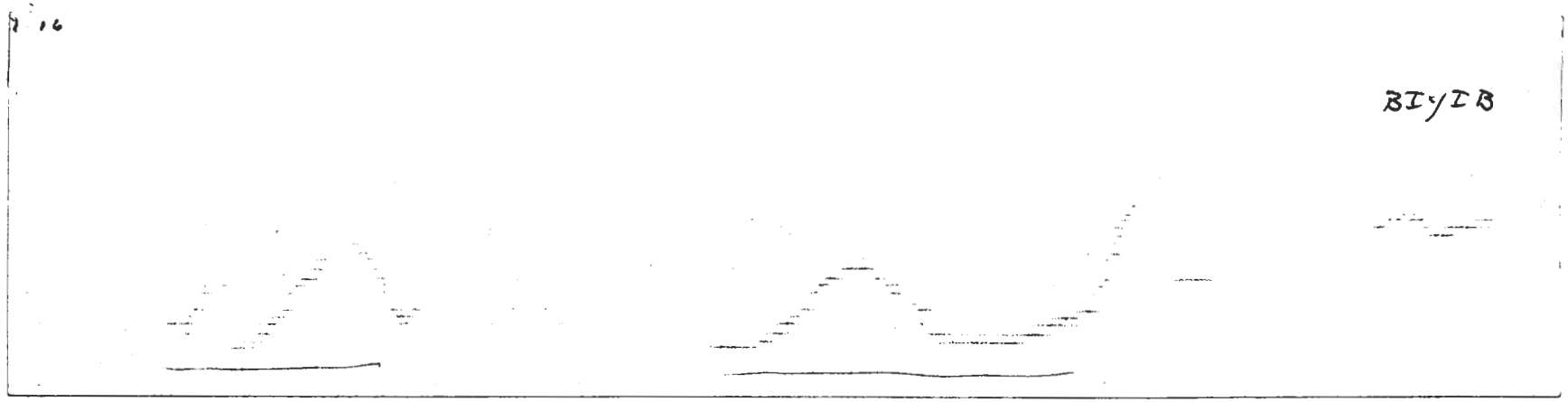

8 Sept 67
5th Session
MAUI Imua
+ Repeat
MAUI
IMUA
BAIEP
O K
BIyIB

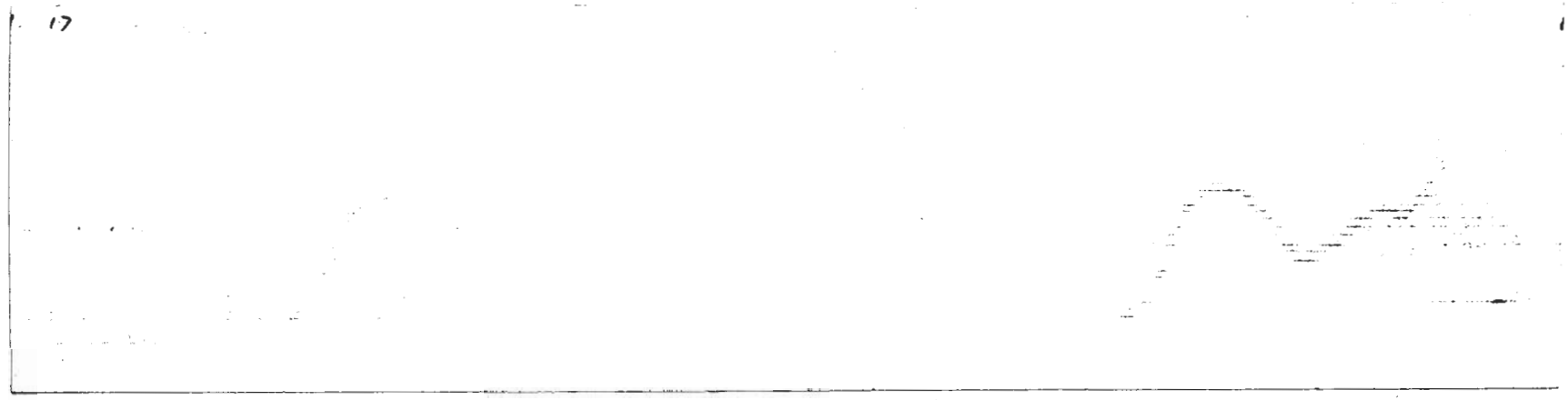

Spontaneous
MAOI
RE BEAT
BAIEP
OK


7
MAUI
8
REPEAT
BACK
OK
BYTE
9
Spontaneous


10
MAUI
IMUA
11
UWEIAD
OK
BIYIB
12
MAUI
REPEAT


13
BAIED
OK
14
15


16
BIyIB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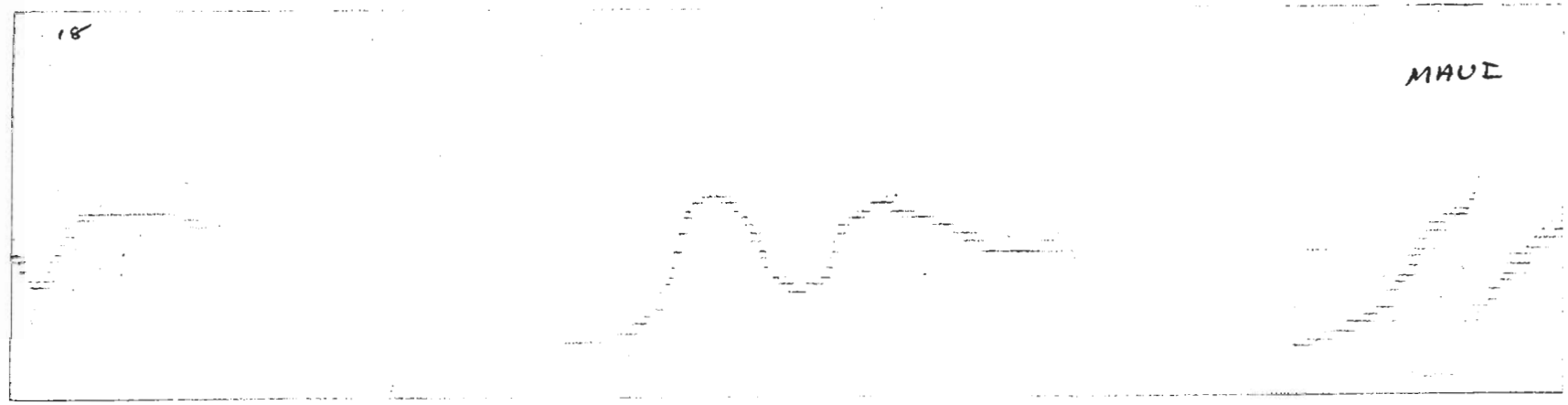
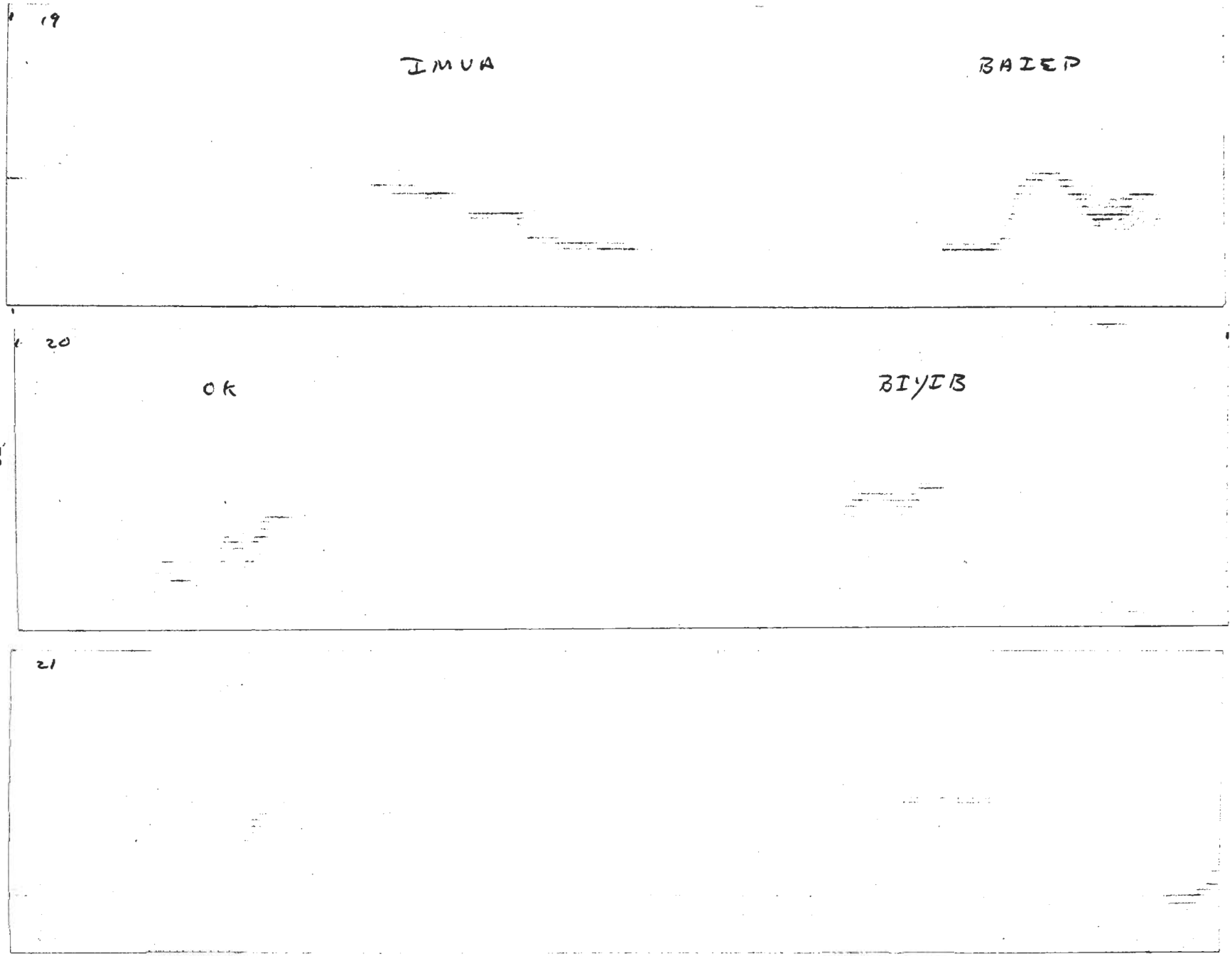

18
MAUI

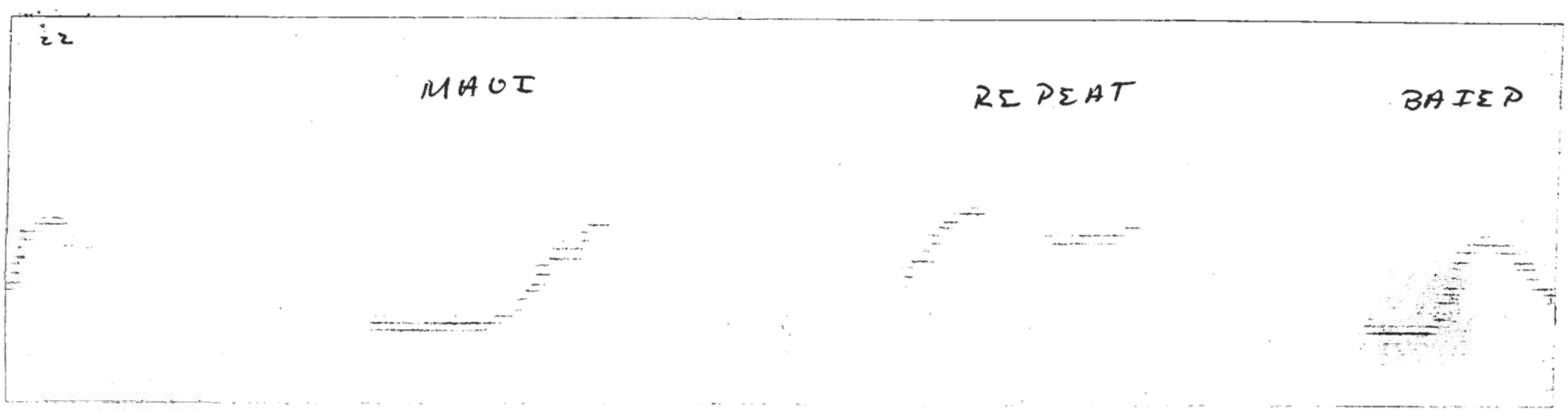

19
IMUA
BAIEP
20
OK
BIYIB
21

22

MAUI

REPEAT

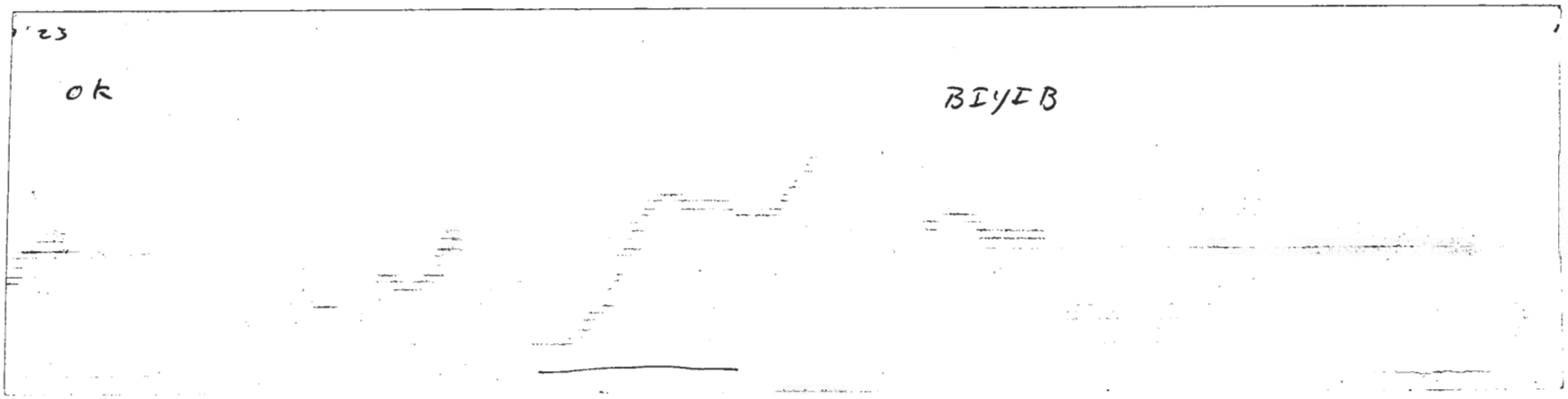
BAIED



23

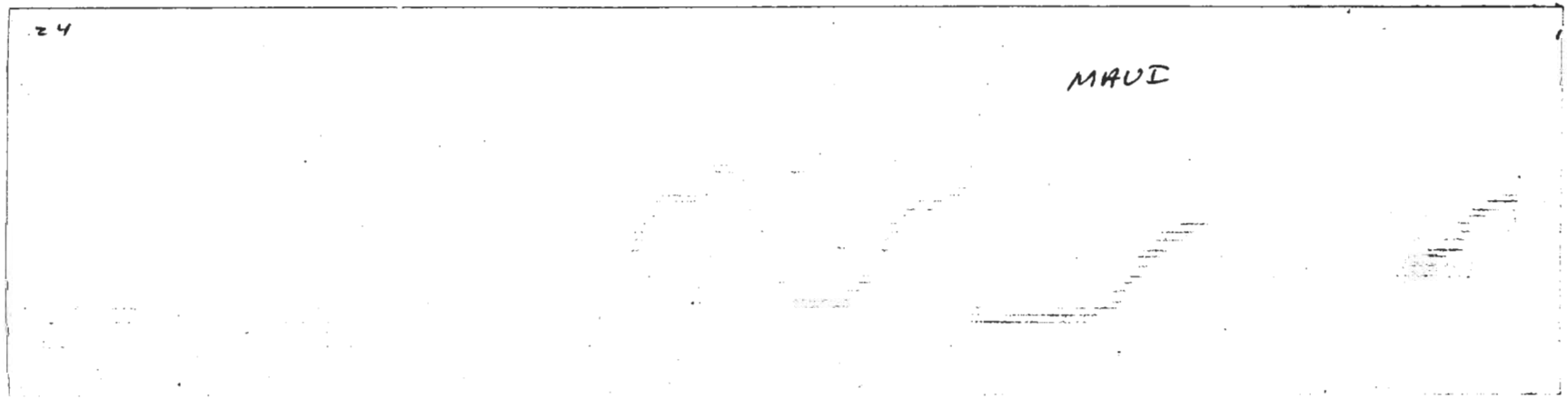
ok

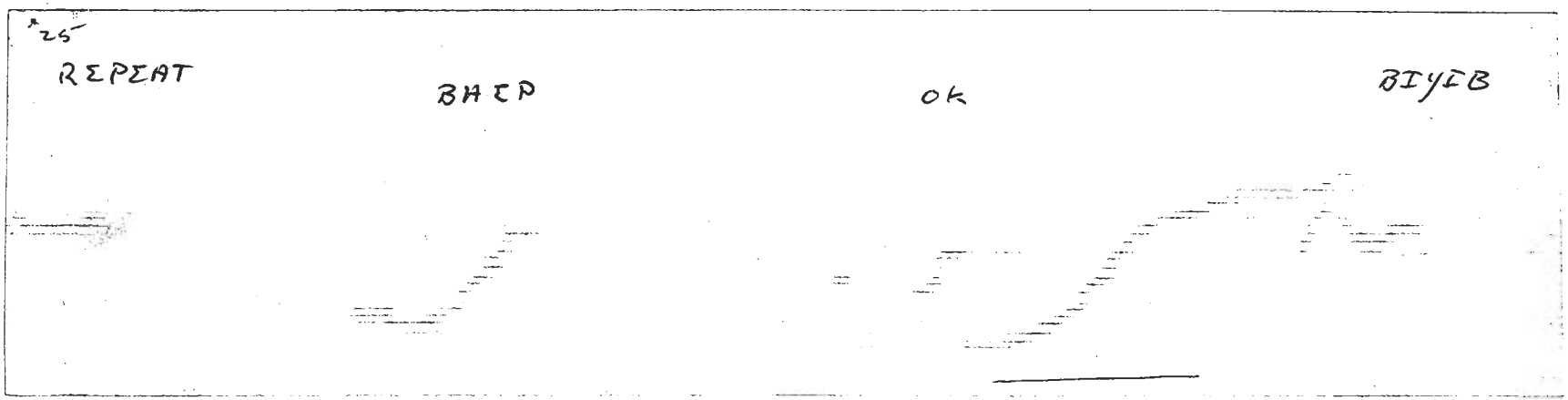
BIYIB

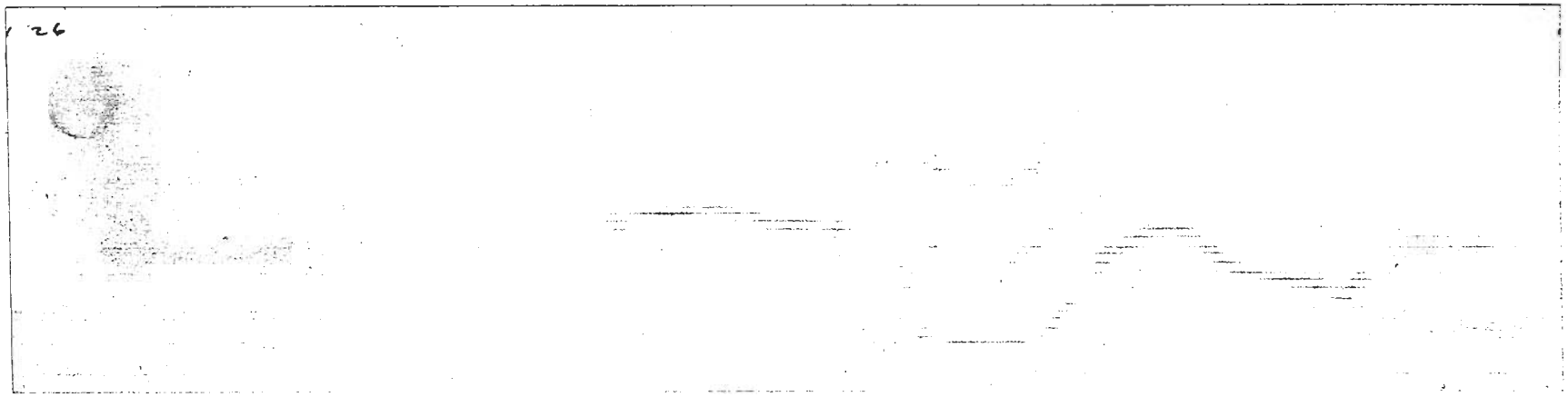


24

MAUI




25
REPEAT
BHCP
OK
BIYCB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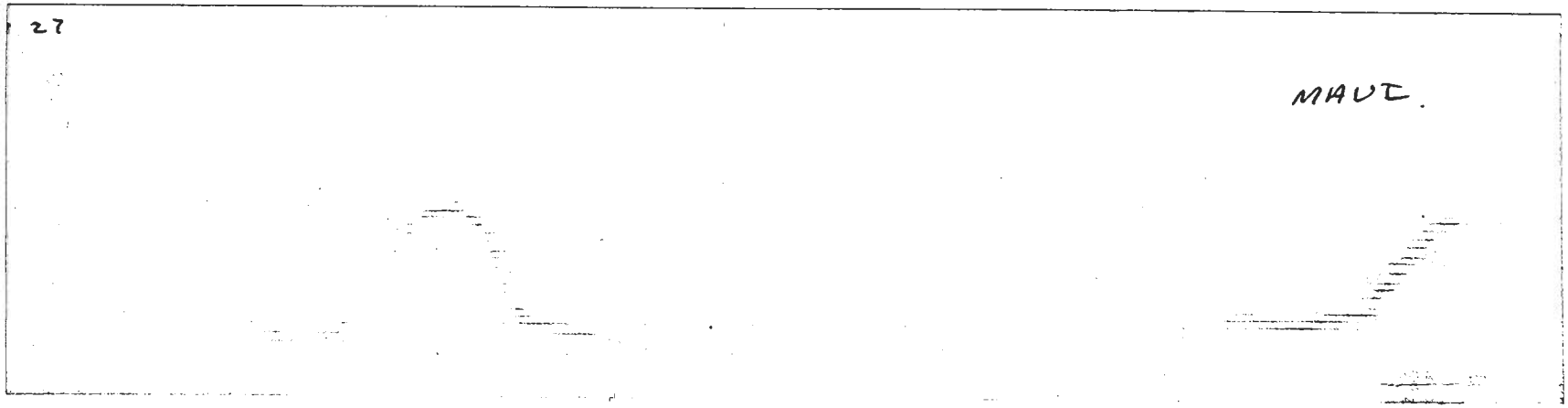
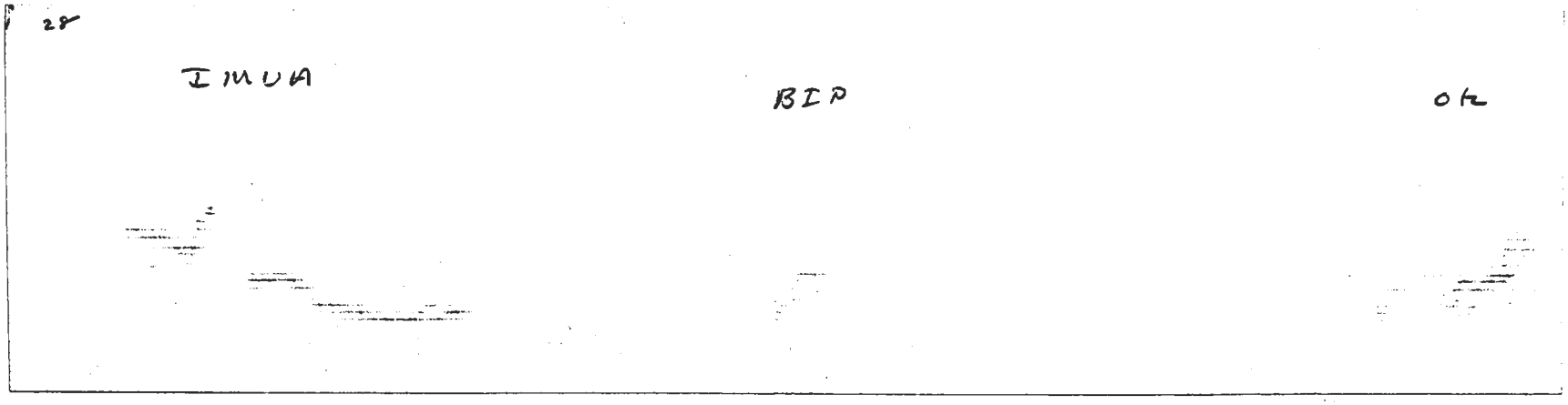
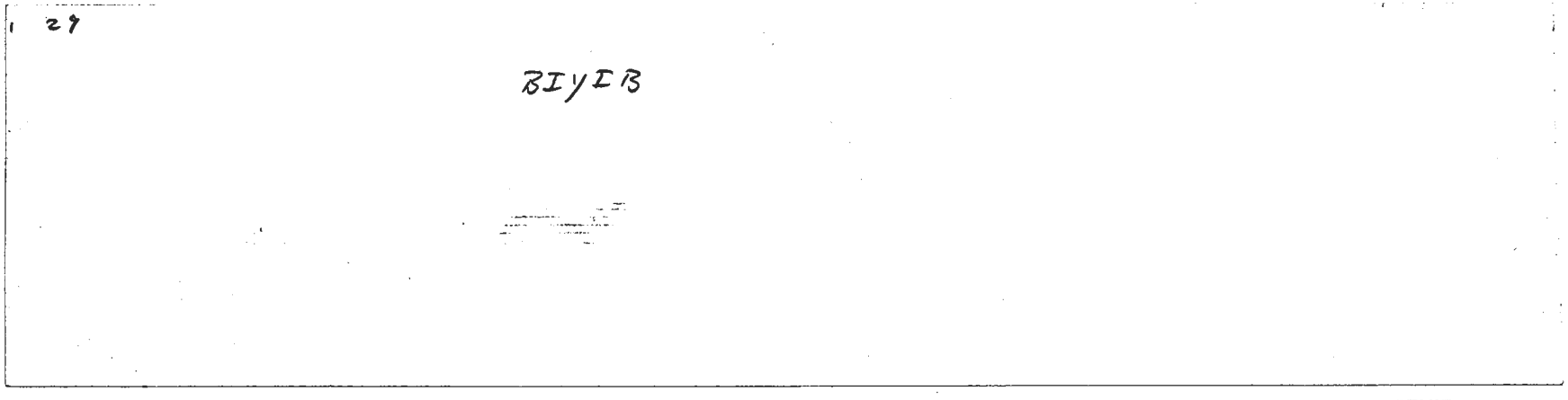
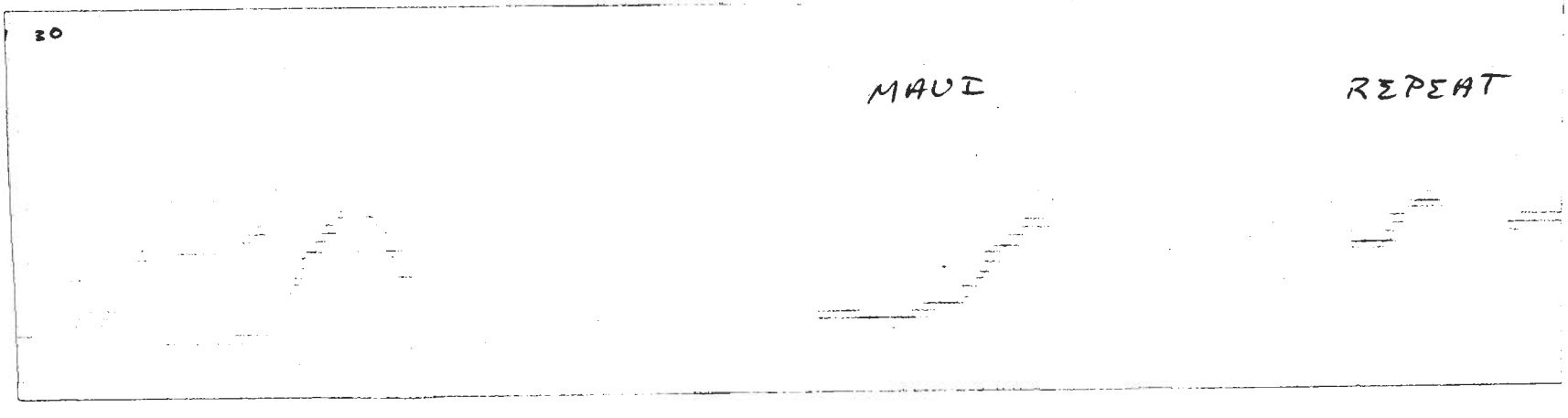

27
MAUC.


28
IMUA
BIP
OK


29
BIYIB


30
MAUI
REPEAT

BAIEP
OK
31
BIYIB
32

V DISCUSSION

In the course of investigation conducted over a three year period to determine the extent to which a language approaching English between man and dolphin might be developed, a channel of communication was established which provided necessary transformations of acoustically carried information.

A device was developed to transform information (messages) carried as time delayed impulse sequences in human vowel sounds onto frequency modulations of constant amplitude sinusoidal whistles.

Development of a second device designed to provide the inverse to the above transformation was discontinued in favor of a device which presented the frequency modulated whistles visually.

Two dolphins, Tursiops truncatus (Montague), were trained to respond behaviorally to 35 response demand messages written on time variant sequences of acoustic events. The animals learned to transform these complex events, changes in their acoustic environment, into time ordered sequences of neuromuscular events.

Several tests were conducted to examine specific properties of the interacting man-dolphin system.

In late May 1967, two trainers using two different translators were able to address and elicit correct responses from the two dolphins during the same training session. This test demonstrated a degree of independence of the charcter of the speaker's voice necessary to a general linguistic system.

In June, three tests were conducted to examine the animals ability to respond to informative sequences.

First, Maui was asked to execute two behaviors in sequence. The commands used were "MAUI IMUA BIP BAIEP OK" and "MAUI IMUA BAIEP BIP OK." In both instances, the second behavior associated word released the first behavior and "ok" negated the response.

Second, Maui was asked to respond to sequences of up to six commands to test a hypothesis that receiving another command would reinforce prior behavior. Prior to this test, the animal's responses to the command used were stable at a 100% confidence level. They remained at this level through out the test period. It was concluded that the continued attention involved in issuing a second command may reinforce prior behavior if confidence is high and the behavior is stable.

The third test examined the hypothesis that the animal would respond to minimaly different behavior evoking frequency changes . These commands were used;"MAUI IMUA BAI OK" (BAIEP), "MAUI IMUA BEI OK" (BEIAP) and "MAUI IMUA UWE OK" (UWEIAP). Responses to all three commands were correct, thus substantiating the hypothesis.

A third test sequence intended to examine some aspects of the significance of place with respect to the command evoked behavior was conducted. In these tests, the aniamls were required to perform a behavior from a new starting point. They performed the correct response after two to five trials spaced over several sessions and eventually responded correctly from randomly selected starting points.

In September, Maui responded to the commands for roll over, raise his flukes and return to instation while stationed at the far side of the lagoon some seventy five yards away from the transmitting hydrophone.

The starting point or place of reception of command was demonstrated as not significant to the command response event.

Three behavioral responses were associated with positioned props, hit the ball (BIP),go through the hoop (BAIEP). and retrieve a bottle (RETRIEVE). The positions of the hoop and ball attached to the float circle were reversed before the first session of each day for several days.

Initally, performance on these behavior inverted. This inversion extinguished and a marked preference for one or the other prop appeared. After several days, Maui began responding correctly on the first trial of the day. This indicated that he had learned; 1) the rule for shift or 2) to associate the command with the prop rather than the place.

We attempted to randomize the shift of location but it became necessary to remove the float circle and this portion of the test sequence was discontinued.

When the retrieval behavior was introduced, however, we randomly placed the prop on the float circle. The animal was able to locate and retrieve it.

The results obtained in the above tests indicated that the animals had been conditioned to associate a command word with a location rather than an object.

Here we may hypothesize that proprioceptive information is perferred over enviornmental information since location may easily be defined in terms of what is done to get to a place.

Reversal of the props produced two kinds of confusions; first, the animal went to the correct object and performed the incorrect action, hit the hoop with its pectoral or swam under the ball. Second, the animal went to the incorrect object and performed the action associated with that object; went through the hoop on the command for hit the ball.

Generally, errors on the part of the animal were in the from of; 1) no observable response or 2) some other response within the communication set. Novel responses were infrequent. When the set of contigencies defining a particular behavior were modified in the direction of increasing generality of the response, confidence levels of other behaviors remained stationary. This indicated independence of points within the correct response set.

However, confusion occurred between two response points such as hoop and ball or raise flukes and roll over at unpredicted times. And at times, the animals showed a marked preference for a particular response.

A more rigorously controlled and detailed analysis of these error producing confusions is indicated as the observations acquired within this study are not sufficient for generalized conclusions.

In the final quarter of the report period, 14 Setpember - 13 December 1967, the animals were permitted to initiate or extend a session by emitting novel behavior. This, in effect, established a command - response point in a set assigned to the trainer. Attention was paid specifically to gross body motions since it was felt that the vocalizations were not, at that time, under adequate control. The novelty of an emitted behavior was judged as acceptable or not by the trainer. This rule permitted the dolphin to test the responding mechanism, the trainer, and allowed the trainer a degree of control by fixing the criteria of novelty.

Finally, in October, a test was conducted to examine the possibility that cross learning, one animal learning by observing the instruction of the other animal, could occur. Puka, who had not been taught to produce her sonar sound on command, was given the command;"PUKA IMUA BAEP OK". She responded with her sonar sound. A second test was then conducted. She was given the com-

mand; "PUKA IMUA BEIAP OK" to raise her flukes, which she also had not been taught to do. She responded by slaping her flukes. Maui had responded correctly to both of these commands just prior to Puka"s responde. In both tests, due to the probilities of response involved, the results were taken to be inconclusive.

In conclusion, the observation and discussion above indicate that a basis for the development of a language between man and dolphin has been established. The continuing work will be directed towards extension of vocabulary with emphasis on vocal rather than gross body responses and towards inclusion of the trainer as a responding element in the communicating system.

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