MARINE PASTURES: A BY-PRODUCT OF LARGE (100 MEGAWATT
OR LARGER) FLOATING OCEAN THERMAL POWER PLANTS

PROGRESS REPORT

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ABSTRACT

Computer programs have been developed to define the temperature increase which would be needed to bring deep-ocean water into density equilibrium with surface water for locations where data are available. NODC data on file at Lamont was used as a data base. Our STIRP and CREMP computer programs can be used to map T' in a specified area, but with minor modifications, can be used to plot other parameters in any specified location.

A series of continuous-flow studies on phytoplankton blooms resulting from mixtures of 80% deep and 20% surface water in 2000-liter concrete culturing vessels ("reactors") has been completed. Data from these studies remain to be analyzed, but preliminary results indicate that in approximately half of these mixtures (those dominated by various species of Chaetoceros) blooms reached peak productivity within three days and could be maintained on continuous flow for an average of 40 days at one volume turnover per day. Almost complete uptake of dissolved inorganic nitrogen under these conditions has been obtained.

A quantitative determination of nutrient utilization and flow through a combined primary and secondary trophic level system has been completed. This study utilized the clam Tapes semidecussata, fed from phytoplankton grown in 80% deep and 20% surface water. Data analysis is not yet complete, but preliminary results indicate that for 140 g of animals in a 4-liter tray, fed at a rate of 1 ml/sec, over 45% of the dissolved inorganic nutrients in the deep and surface water mixture are converted into Tapes meat-nitrogen.

An analysis of the fate of the deep water discharged from a floating OTEC plant indicates that horizontal containment of the resulting deep water : surface water mixture is necessary if conditions optimal for open-sea mariculture are to obtain. The design of a small open-ocean "pool" is in the final stages of completion.

Continuing work on structures suitable for growing bivalves in the open sea indicates that a hanging rope system for mussels, a mortar-covered plywood plate collector, and/or suspended shell system for oysters, and a PVC/plastic mesh cage system for clams, can be inexpensive and simple to construct and maintain. A combined mussel/oyster/clam system is in the final stages of design and will be placed in the ocean during April 1976.

Physico-Chemical Study of the Fate and Effects of

Deep Water Discharged at the Surface

(L. Van Hemelrijck and F. Aikman)

A set of computer programs have been developed and/or adapted to define the temperature increase which would bring deep-ocean water into density equilibrium with surface water, for locations where data are available. These programs have been used in conjunction with the NODC hydrographic data, obtained from NOAA's National Oceanographic Data Center, Rockville, Maryland.

The NODC file, available on tape at Lamont-Doherty Geological Observatory, was scanned for pertinent parameters within the area of interest. From the input data, the local values of T' , the amount of warming required to bring water taken from 800 m depth into equilibrium with surface water was determined, and the result stored on a summary tape. Both the data scan and evaluation of T' were performed by the STIRP program.

From this summary tape, the CREMP program plotted the values obtained for T' onto a Mercator grid, at the desired scale.

These programs have been used to map T' in a specified area. It is obvious, however, that they can be used to plot other parameters in any specified location, with minor modification.

Following is a list of the programs and subprograms used, their functions, and a computer printout of each program. The computer used is an IBM 1130.

<u>Program Name</u>	<u>Function</u>
(1) STIRP	Searches data tapes according to specifications, computes parameters, stores data on a summary

tape, lists summer and winter data on printer.

Called Subprograms*

MAGOP	113 tape read/write program.
IDATA	Function to construct decimal values from binary data on tape.
ACONV	Converts from alphameric to decimal and vice-versa.
TPOTL	Function computes potential temperature.
SIGMA	Function computes σ_t (density at constant pressure).

(2) CREMP Reads summary tape and plots any or all of the following: (a) surface temperature, salinity and σ_t ; (b) temperature, salinity and σ_t at a prescribed depth; (c) difference in σ_t -surface and σ_t -deep; (d) $\Delta\sigma_t$, the density difference between bottom water and surface water when the bottom water has come into temperature equilibrium with the surface water; (e) T', the warming required when bottom water is brought into density equilibrium with the surface water.

Called Subprograms

MEGRI**	Draws outlines of Mercator grid.
MEGRW	Annotates Mercator grid.
ALATI	Converts latitude Mercator scale to linear scale in inches.
ALONG	Converts longitude Mercator scale to linear scale in inches.

*Other subroutines are in the standard IBM 1130 FORTRAN package.

**These will work to nearest degree, but subroutines exist which can draw a grid to a fractional part of a degree.

```
// DUP
*DELETE STIRP
// FOR STIRP
*LIST ALL
*ONE WORD INTEGERS
*ASSIGNMENT TRACE
*TRANSFER TRACE
*IDCS(1403 PRINTER,TYPEWRITER,KEYBOARD,PAPER TAPE,CARD)
C ** PROGRAM TO SEARCH NODC TAPES FOR STATIONS WITH DEEPEST SAMPLE WITHIN
C ** 101 OF THE DEPTH OF THE OCEAN FLOOR AND RECORD SURFACE + BOTTOM
C ** DATA ON SUMMARY TAPE. *****
      DIMENSION IV(601)
      DATA ICOMP/200F0/
      PAUSE
      IS=0
      IW=0
      INDEX=0
C ** OPTION TO ACCESS SUMMARY TAPE IF DATA IS ALREADY ON TAPE
      CALL DATSW(1,11)
      GO TO(210,211),11
C ** READ NUMBER OF STATIONS ALREADY OF SUMMARY TAPE TO SKIP TO ****
C ** STARTING LOCATION *****
      210 READ(5,204)INDEX
      CALL MODE(1,0)
      CALL EDFZ(9)
      DO 213 I=1,INDEX
      213 READ(4,200)ISHIP,ICRJS,ISTA,IDAY,MONTH,IYEAR,XLAT,XLONG,MRS,IDPTH
      1,IDSF,TSJRF,SSJRF,SIGSF,IDEEP,TDEEP,SDEEP,SIGDP,TPOT,SIGPT,DIFSG,
      2TDIFF,SIGE,DIFFE
      200 FORMAT(A2,2I3,3I2,2F8.3,I3,I4,I5,F5.2,F5.3,F5.2,I4,F5.2,F6.3,7F5.2
      1)
      211 CALL MODE(0,18)
      IFIND=0
      MARS=-1
      LINES=55
      IV(601)=500
C ** READ ONE 1200-WORD BLOCK OF DATA FROM NODC TAPE
      1001 CALL MAGDP(352,1,IV(601),NERR)
C ** OPTION TO HALT PROCESSING AND TYPE OUT NO. OF STATIONS ON SUMMARY
C ** 1TAPE
      CALL DATSW(2,12)
      GO TO(202,203),12
      202 WRITE(1,204)INDEX
      204 FORMAT(15)
C      REWIND NODC TAPE
      CALL MAGTA(3,0)
C      REWIND SUMMARY TAPE
      CALL EDFZ(9)
      CALL REWZ(1)
      GO TO 1000
      203 K=650
      IF(NERR-1)50,10,50
C ** END OF TAPE SENSED. REWIND AND PAUSE TO RELOAD NEXT NODC TAPE
      10 CALL MAGTA(3,0)
      PAUSE
      GO TO 1001
      50 DO 700 N=1,10
      K=K-50
C ** CHECK FOR STATION HEADER, STANDARD LEVEL OF OBSERVED LEVEL
      IF(IDATA(0,0,IV(K-50)/256,IV(K-50))-10)11,12,12
C ** HEADER FOUND
```

```

11 IFIND=0
C ** COMPUTE SONIC DEPTH (TO NEAREST 100 METERS)
18 ITEST=(IDATA(IN(K-16),IN(K-17)/256,IN(K-17),IN(K-18)/256)+50)/100
C ** REJECT STATION IF SONIC DEPTH LISTED AS ZERO
C ** COMPUTE MAX SAMPLE DEPTH (TO NEAREST 100 M.)
C ** REJECT STATION IF MAX SAMPLE DEPTH IS 800 M. OR LESS
7001 MSD=IDATA(0,0,IN(K-18),IN(K-19)/256)
IF(MSD-8) 700,700,1100
C ** COMPUTE PERCENTAGE OF TOTAL DEPTH THAT MAX. SAMPLE DEPTH IS ABOVE BOTTOM
1100 PRCNT=IABS(ITEST-MSD)*100/ITEST
C ** REJECT STATION IF PERCENTAGE EXCEEDS 100
C ** STATION OK TO PROCEED SO FAR
21 IFIND=1
C ** COMPUTE HEADER DATA
20 IX=IAND(63,IN(K-1)/256)
IY=IAND(63,IN(K-1))
ISHIP=IEOR(ICOMP,IX)*256+IEOR(ICOMP,IY)
MRS=IDATA(0,IN(K-7),IN(K-8)/256,IN(K-8))
IF(MRS.NE.43)GO TO 1001
ICRJS=IDATA(0,IN(K-13),IN(K-14)/256,IN(K-14))
ISTA=IDATA(0,IN(K-15)/256,IN(K-15),IN(K-16)/256)
IDAY=IDATA(0,0,IN(K-11)/256,IN(K-11))
MONTH=IDATA(0,0,IN(K-10)/256,IN(K-10))
IYEAR=IDATA(0,0,IN(K-9)/256,IN(K-9))
LATDG=IDATA(0,0,IN(K-2)/256,IN(K-2))
LATMN=(IDATA(0,IN(K-3)/256,IN(K-3),IN(K-4)/256)+5)/10
LATDM=50*LATDG+LATMN
IF(LATDM.LT.1055)GO TO 1001
IF(LATDM.GT.1113)GO TO 1001
C ** ROUTINE TO DETERMINE IF LAT IS N OR S AND CONVERT TO CORRECT QUADRANT
MTPLY=1
IQJAD=14
IF(IDATA(0,0,0,IN(K-40)/256))301,301,300
300 MTPLY=-1
IQJAD=19
301 XLAT=LATMN
XLAT=XLAT/50.
XLAT=(FLOAT(LATDG)+XLAT)*MTPLY
LONDG=IDATA(0,IN(K-4),IN(K-5)/256,IN(K-5))
LONMN=(IDATA(0,IN(K-6)/256,IN(K-6),IN(K-7)/256)+5)/10
LONDM=50*LONDG+LONMN
IF(LONDM.LT.3367)GO TO 1001
IF(LONDM.GT.3904)GO TO 1001
C ** ROUTINE TO DETERMINE IF LONG IS E OR W AND CONVERT TO CORRECT QUAD
MTPLY=1
JQJAD=5
IF(IDATA(0,0,0,IN(K-40)))303,303,302
303 MTPLY=-1
JQJAD=23
302 XLONG=LONMN
XLONG=XLONG/50.
XLONG=(FLOAT(LONDG)+XLONG)*MTPLY
CALL ACONV(1,IQJAD,NS,IDJM)
CALL ACONV(1,JQJAD,IEW,IDJM)
IDPTH=IDATA(IN(K-16),IN(K-17)/256,IN(K-17),IN(K-18)/256)
LEVEL=0
GO TO 700
C ** OBSERVED LEVEL FOUND - DO NOT PROCESS IF STATION IS NOT WANTED
12 IF(IFIND)700,700,701
701 CONTINUE
LEVEL=LEVEL+1

```

```

C ** CHECK FOR FIRST OBSERVED LEVEL
  IF(LEVEL-1)42,42,43
C ** FIRST OBS. LEVEL FOUND - COMPUT SURF DENSITY
  42 SIGSF=IDATA(IN(K-21)/256,IN(K-21),IN(K-22)/256,IN(K-22))
  SIGSF=SIGSF/100.
  JEND = 0
C ** IF DENSITY ZERO - REJECT STATION
  IF(SIGSF)45,45,44
C ** COMPUTE DEPTH OF THE FIRST OBSERVED LEVEL
  44 IDSF=IDATA(IN(K-13),IN(K-14)/256,IN(K-14),IN(K-15)/256)
C ** IF DEPTH EXCEEDS 30 M. REJECT STATION
  IF(IDSF-30) 450,450,45
C ** COMPUTE SURF TEMPERATURE
  450 TSURF=IDATA(IN(K-16)/256,IN(K-16),IN(K-17)/256,IN(K-17))
  TSURF=TSURF/100.
  IF(IDATA(0,0,0,IN(K-43)/256)) 305,305,304
  304 TSURF=-TSURF
  305 SSURF=IDATA(IN(K-13),IN(K-19)/256,IN(K-19),IN(K-20)/256)
  SSURF=SSURF/100.+IAND(31,IN(K-20))*0.001
  GO TO 700
C ** LEVEL OTHER THAN 1ST OBSERVED - COMPUTE DEPTH
  45 IFIND=0
  GO TO 700
  43 IDEEP=IDATA(IN(K-13),IN(K-14)/256,IN(K-14),IN(K-15)/256)
  ITST = IDEEP
C ** IF DEPTH EQUALS OR EXCEEDS MAX SAMPLE DEPTH-THIS IS END OF STATION
  IF(ITST.LE.300) GO TO 700
  IF(JEND.EQ.1) GO TO 700
C ** END OF STATION - COMPUTE DENSITY
  702 SIGDP=IDATA(IN(K-21)/256,IN(K-21),IN(K-22)/256,IN(K-22))
  SIGDP=SIGDP/100.
C ** IF DENSITY IS ZERO- REJECT STATION
  IF(SIGDP)45,45,47
C ** COMPUTE TEMPERATURE
  47 TDEEP=IDATA(IN(K-16)/256,IN(K-16),IN(K-17)/256,IN(K-17))
C ** CHECK FOR NEGATIVE TEMPERATURE
  TDEEP=TDEEP/100.
  IF(IDATA(0,0,0,IN(K-43)/256))307,307,306
  306 TDEEP=-TDEEP
  307 DEEP=IDEEP
C ** SUBROUTINE TO COMPUTE POTENTIAL TEMPERATURE
  TPOT = TPOTL(TDEEP,DEEP)
C ** COMPUTE SALINITY
  SDEEP=IDATA(IN(K-13),IN(K-19)/256,IN(K-19),IN(K-20)/256)
  SDEEP=SDEEP/100.+IAND(31,IN(K-20))*0.001
C ** COMPUTE POTENTIAL DENSITY
  SIGPT=SIGMA(TPOT,SDEEP)
C ** COMPUTE DENSITY OF DEEP WATER AT SURF WATER TEMP
  SIGE=SIGMA(TSURF,SDEEP)
C ** COMPUTE DIFF BETWEEN TWO DENSITIES
  DIFFE=SIGE-SIGSF
C ** ROUTINE TO COMPUTE AMOUNT OF HEATING REQUIRED TO BRING DEEP WATER
  INTO SURF DENSITY EQUILIBRIUM
  DIFSG=0
  TDIFF=0
  IF(SIGDP-SIGSF)80,51,52
  80 TINC=-10.
  GO TO 54
  52 TINC=10.
  54 TEMP=TPOT
  TTEST=.1 *TINC

```

10

```

ITMS=0
DO 53 II=1,300
TEMP=TEMP+TINCR
STEST=SIGMA(TEMP,SDEEP)
IF((STEST-SIGSF)+TTEST)55,55,53
55 ITMS=ITMS+1
IF(ITMS-3)205,205,255
205 TEMP=TEMP-TINCR
TINCR=TINCR*.1
53 CONTINUE
WRITE(1,70)
70 FORMAT(' ERROR OCCURRED IN COMPUTING TEMP FOR EQUILIBRIUM')
GO TO 700
C ** TDIFF = ACTUAL TEMP CHANGE REQUIRED
255 TDIFF=TEMP-TPOT
C ** COMPUTE DENSITY DIFF BETWEEN SURF AND DEPTH
DIFS3=SIGDP-SIGSF
51 IF(LINES-54) 60,60,61
61 LINES=2
WRITE(5,52)
62 FORMAT(141', CRUISE STA DATE LAT LONG MRS DPTH DEPTH
1 TEMP SALIN SIGMA POTMP POTDN DNSDF TEQUL DEQUL DANOM')
60 WRITE(5,155) ISHIP,ICRJS,ISTA,IDAY,MONTH,IYEAR,LATDG,LATMN,NS,LOND
13,LONMN,IEW,MRS,IDPTH,IDSF,TSURF,SSURF,SIGSF
155 FORMAT(1X,A2,2I4,5I3,A1,I4,I3,A1,I4,I5,I5,F6.2,F7.3,F6.2)
WRITE(5,156) IDEEP,TDEEP,SDEEP,SIGDP,TPDT,SIGPT,DIFS3,TDIFF,SIGE,
1DIFFE
155 FORMAT(48X,15,F6.2,F7.3,F6.2,F7.2,2F6.2,F6.1,2F6.2/)
LINES=LINES+3
C ** WRITE OUTPUT ON SUMMARY TAPE
CALL MODE(1,0)
CALL EOFZ(9)
INDEX=INDEX+1
WRITE(4,200) ISHIP,ICRJS,ISTA,IDAY,MONTH,IYEAR,XLAT,XLONG,MRS,IDPTH
1,IDSF,TSURF,SSURF,SIGSF,IDEEP,TDEEP,SDEEP,SIGDP,TPDT,SIGPT,DIFS3,
2TDIFF,SIGE,DIFFE
CALL MODE(0,18)
IFIND=0
JEND = 1
700 CONTINUE
GO TO 1001
1000 CALL EXIT
END
// DUP

```

// ASM

HDNG

SR TO RD OR WR MAG TAPE.
SEE TSX MAGT SR.MAGOP000
MAGOP010

* VALUE OF MODE PARAMETER - DECIMAL INTEGER

THREE BYTE/WORD				**TWO BYTE/WORD**		
PARITY				PARITY		
				ODD	EVEN	
* D	800	0	256	DRIVE 1	64	320
* E		1	257	DRIVE 2	65	321
* N						
* S	200	16	272	DRIVE 1	80	336
* I		17	273	DRIVE 2	81	337
* T						
* Y	556	32	288	DRIVE 1	96	352
		33	289	DRIVE 2	97	353

* CALLING SEQUENCE

* BSI	L	MAGOP
* I1	DC	LOC OF UNIT NO. (ODR 1)
* I2	DC	LOC OF OP CODE
		0 TEST
		1 READ W/RETRIES
* I3	DC	LOC OF WD CNT AND TABLE
* I4	DC	LOC OF ERROR CODE
		0 OK
		1 END OF FILE
		2 WRONG LENGTH
		4 ERROR

MAGOP020
MAGOP030
MAGOP040
MAGOP050
MAGOP060
MAGOP070
MAGOP170
MAGOP180
MAGOP190
MAGOP200
MAGOP210
MAGOP230
MAGOP240
MAGOP250
MAGOP260
MAGOP270
MAGOP280
MAGOP290
MAGOP300

MAGOP	ENT	MAGOP
	DC	0
	LDX	I1 MAGOP
	LD	I1 1
	SLA	12
	OR	I1 0
	AND	H1001
	STO	SCTL
	STO	LCTL
	SRA	16
	STO	I1 3
	LD	I1 1
	BSC	L LONG,Z

SET ODD PARITY 3 BYTES.

MAGOP320
MAGOP330
MAGOP420
MAGOP430
MAGOP360

SHORT	LIBF	MAGT	0, 5-10 EXECUTE
SCTL	DC	0	
	NOP		
	MDX	CHK	

MAGOP380
MAGOP390
MAGOP400
MAGOP410
MAGOP440
MAGOP450
MAGOP480
MAGOP490
MAGOP500
MAGOP510
MAGOP520
MAGOP530
MAGOP540
MAGOP550
MAGOP560
MAGOP570

LONG	LD	L1 2	EXECUTE
	STO	AREA	RD/WR 1-4
	LIBF	MAGT	
LCTL	DC	0	
AREA	DC	0	
	DC	SPEC	
CHK	LIBF	MAGT	WAIT
TEST	DC	0	
	MDX	CHK	

	MDX	L	MAGOP, 4	
	BSC	I	MAGOP	MAGOP580
				MAGOP590
				MAGOP600
* SEVN	DC		15	
MTST	DC		/FFF	MAGOP630
H1001	DC		/1001	
SPEC	DC		0	MAGOP650
	AND		SEVN	
	STO		*+1	
	LDX	L1	*--*	
	LD	L1	TABLE	
	LDX	I1	MAGOP	
	STO	I1	3	
	SLA		16	
	BSC	I	SPEC	
TABLE	DC		0	
	DC		4	
	DC		1	
	DC		0	
	DC		0	
	DC		0	
	DC		1	
	DC		2	
	DC		2	

```
// FOR
*ONE WORD INTEGERS
*LIST ALL
FUNCTION IDATA(M1,M2,M3,M4)
  IF(IAND(15,M1)-10)11,12,12
12 K1=0
   GO TO 112
11 K1=IAND(15,M1)
112 IF(IAND(15,M2)-10)13,14,14
14 K2=0
   GO TO 114
13 K2=IAND(15,M2)
114 IF(IAND(15,M3)-10)15,16,16
16 K3=0
   GO TO 115
15 K3=IAND(15,M3)
115 IF(IAND(15,M4)-10)17,18,18
18 K4=0
   GO TO 118
17 K4=IAND(15,M4)
118 IDATA=K1*1000+K2*100+K3*10+K4
  RETURN
END
// DUP
```


14
// DUP
*DELETE ACONV

// FOR
*ARITHMETIC TRACE
*TRANSFER TRACE
*LIST ALL
*ONE WORD INTEGERS

SUBROUTINE ACONV(INDEX, INPUT, IOUT1, IOUT2)

DIMENSION KEY(53), IALPH(47)

DATA KEY/0,1,2,3,4,5,6,7,8,9,0,37,0,38,39,2*0,10,11,12,13,14,15,16
1,17,18,2*0,40,41,2*0,42,43,19,20,21,22,23,24,25,26,0,44,4*0,27,28,
229,30,31,32,33,34,35,36,3*0,45,46/

DATA IALPH/0,1,2,3,4,5,6,7,8,9,17,18,19,20,21,22,23,24,25,34,35,36
1,37,33,39,40,41,43,49,50,51,52,53,54,55,56,57, 11,13,14,28,29,32,
233,43,51,52/

***** ARGUMENTS AND THEIR FUNCTIONS *****

	I	J	K	L	OPERATION
1	NUM.	INPUT	ALPH.	OUTPUT	NOT USED
2	NUM.	INPUT	ALPH.	OUTPUT	NOT USED
3	ALPH.	INPUT	NUM.	OUTPUT	NOT USED
4	ALPH.	INPUT	NUM.	OUTPUT	NUM. OUTPUT
5	ALPH.	OUTPUT	NUM.	INPUT	NUM. INPUT

CONVT NUM. TO ALPH. (A1 LEFT JUST)
CONVT NUM. TO ALPH. (A2 RIGHT JUST)
CONVT ALPH. INPUT (A1) TO NUM.
CONVT ALPH. INPUT (A2) TO 2 NUMBERS
CONVT 2 NUMBERS TO ALPH. OUT (A2)

GO TO (10,10,12,12,13), INDEX

**** FIND BINARY REPRESENTATION OF NUMERIC INPUT ****

10 IOUT1=IALPH(INPUT+1)

**** ADD BLANK FOR LEFT JUSTIFIED ALPH A1 OUTPUT ****

IOUT1=IOUT1*256+64

IF(INDEX-1) 11,11,15

**** CHANGE ALPH OUTPUT TO RIGHT JUSTIFIED A2 OUTPUT ****

15 IOUT1=IAND(-256,IOUT1)/256+16384

GO TO 11

**** MASK ALPH. INPUT TO PRODUCE NUMERIC REPRESENTATION ****

12 MASK=IAND(16191,INPUT)

**** SHIFT RIGHT TO ELIMINATE SECOND CHARACTER OF WORD ****

IOUT1=MASK/256

**** FIND UNIQUE NUMERIC TO REPRESENT CHARACTER ****

IHOLD=IOUT1

IOUT1=KEY(IOUT1+1)

IF(INDEX-4) 11,18,18

**** SHIFT LEFT TO ELIMINATE FIRST CHARACTER OF WORD ****

18 IOUT2=MASK-IHOLD*256

IOUT2=KEY(IOUT2+1)

GO TO 111

**** CONSTRUCT A2 WORD FROM TWO NUMERIC INPUTS ****

13 INPUT=IALPH(IOUT1+1)*256+IALPH(IOUT2+1)-16192

GO TO 111

11 IOUT2=0

111 RETURN

END

```

// DJP
*DELETE          TPOTL
// FOR TPOTL
*LIST ALL
*ONE WORD INTEGERS
*ASSIGNMENT TRACE
*TRANSFER TRACE
C ***** COMPUTE POTENTIAL AS A FUNCTION OF IN-SITU TEMPERATURE AND DEPTH *****
C ***** USES DATA FROM HELLAND-HANSEN, 1930 *****
      FUNCTION TPOTL(TEMP,DEPTH)
      DIMENSION CD3(13),CD2(13),CD1(13)
      DATA CD3/-.1666652E-13,-.1666642E-13,-.1447162E-13,-.1493777E-13,-
1.1503495E-13,-.1456875E-13,-.1462699E-13,-.2499999E-13,-.8333486E-
214,-.2500014E-13,-.2500038E-13,-.3333367E-13,-.3333341E-13/
      DATA CD2/.1017855E-8,.9999977E-9,.9484253E-9,.928845E-9,.9032631E-
19,.8728436E-9,.8484258E-9,.8857141E-9,.7357151E-9,.8142866E-9,.800
20023E-9,.8214305E-9,.8000003E-9/
      DATA CD1/.1527383E-5,.2516672E-5,.3535976E-5,.4416865E-5,.5299884E-
1-5,.5168998E-5,.5997672E-5,.7732143E-5,.8765474E-5,.9417855E-5,.10
217493E-4,.1039761E-4,.1163333E-4/
C ***** COEFFICIENTS ARE DERIVED FOR 13 CURVES OF ADIABATIC COOLING *****
C ***** AS A FUNCTION OF DEPTH AT 1 DEG. INTERVALS FROM -2 TO +10 DEG. *****
C ***** FIND THE TWO WHOLE DEGREE VALUES BRACKETING THE IN-SITU TEMPERATURE *****
      ITMP1=TEMP+3
      ITMP2=ITMP1+1
      TMP=ITMP1-3
      IF(TEMP.GE.10.) GO TO 100
C ***** COMPUTE ADIABATIC COOLING FOR THESE TWO TEMPERATURES AT DEPTH *****
      T1D=(CD3(ITMP1)*DEPTH**3+CD2(ITMP1)*DEPTH**2+CD1(ITMP1)*DEPTH)*10.
      T2D=(CD3(ITMP2)*DEPTH**3+CD2(ITMP2)*DEPTH**2+CD1(ITMP2)*DEPTH)*10.
C ***** INTERPOLATE FOR TEMPERATURE AND SUBTRACT FROM TEMP FOR POTENTIAL TEMP **
      TPOTL=TEMP-(T1D+(TEMP-TMP)*(T2D-T1D))
      RETURN
C ***** TEMP EXCEEDS 10 DEG. *****
100 TPOTL=TEMP
      RETURN
      END

// DJP
*STORE          WS  JA  TPOTL

// FOR
*LIST ALL
*ONE WORD INTEGERS
*IOCS(TYPEWRITER,KEYBOARD)
100 READ(5,101)TEMP,DEPTH
101 FORMAT(F6.2,F6.0)
      POTEM=TPOTL(TEMP,DEPTH)
      DIFF=TEMP-POTEM
      WRITE(1,102) POTEM ,DIFF
102 FORMAT('THETA=',F7.3,'COOLING=',F7.3)
      GO TO 100
1000 CALL EXIT
      END
// XEQ

```

PAGE 1

// JOB OBF5

LOG DRIVE	CART SPEC	CART AVAIL	PHY DRIVE
0000	OBF5	OBF5	0000
		5555	0001

V2 M11 ACTUAL 16K CONFIG 16K

// FOR

*ONE WORD INTEGERS

*LIST ALL

FUNCTION SIGMA(TEMP,SALIN)

CL=SALIN/1.30655

SGNOT=-.069+1.4708*CL-.001*1.57*CL**2+ 1.E-5*3.98*CL**3

SIGMT=-((TEMP-3.98)**2)*(TEMP+283.)/(503.57*(TEMP+67.26))

AT=.001*TEMP*(4.7867-.098185*TEMP+.001*1.0843*TEMP**2)

BT=1.E-6*TEMP*(12.03-.8164*TEMP+.01667*TEMP**2)

SIGMA=SIGMT+(SGNOT+.1324)*(1.-AT+BT*(SGNOT-.1324))

RETURN

END

// DJP

```

// DUP
*DELETE                                CREMP
// FOR CREMP
*ONE WORD INTEGERS
*IOCS(1403 PRINTER,CARD,KEYBOARD,TYPEWRITER,PLOTTER,PAPER TAPE,DISK)
*LIST ALL
*TRANSFER TRACE
*ASSIGNMENT TRACE
      COMMON AM(12),AY(24),B(160),SCALE,WLONG,ELONG,SLAT,ANLAT
      ROUND(X,Y)=X+Y*X/ABS(X)
      CALL MODE(1,0)
      CALL EDFZ(9)
122  READ(2,21)INDEX,IPLDT
      PAUSE
21   FORMAT(15,12)
      GO TO(1,2,1,2,1,2,1,1,1),IPLDT
1   ITIMS=2
      GO TO 3
2   ITIMS=1
3   DO 121 K=1,ITIMS
      READ(2,700)WLONG,ELONG,SLAT,ANLAT,SCALE,IGRI,IMIN,IGG,JG
700  FORMAT(5F10.1,4I5)
      CALL MGR1(WLONG,ELONG,SLAT,ANLAT,SCALE)
      IF(JG)901,902,901
901  CALL MGRW(IGRI,IMIN,IGG,WLONG,ELONG,SLAT,ANLAT,SCALE)
902  CALL FPLDT(1,0,0,0)
40   DO 1000 I=1,INDEX
      READ(4,200)ISHIP,ICRUS,ISTA,IDAY,MONTH,IYEAR,XLAT,XLONG,MRS,IDPTH
      1,IDSF,TSJRF,SSJRF,SIGSF,IDEEP,TDEEP,SDEEP,SIGDP,TPOT,SIGPT,DIFSG,
      2TDIFF,SIGE,DIFFE
200  FORMAT(A2,2I3,3I2,2F8.3,I3,I4,I5,F5.2,F6.3,F5.2,I4,F5.2,F6.3,7F5.2
1)
      GO TO(4,5,4,5,4,5,4,4,4),IPLDT
5   IF IND=K
4   IF(IDSF-30)221,221,1000
221 IF(IDPTH-200)30,30,301
30  IF(1ABS(IDPTH-IDEEP)-50)31,31,1000
31  IF(TDEEP+TDIFF-TSJRF)32,32,33
33  TDIFF=TSJRF-TDEEP
32  IPLJS=0
      IF(MRS-300)45,45,45
46  XLAT=-XLAT
      XLUS=299
45  MARS=MRS-IPLJS
      DO 47 L=1,5
      MARS=MARS-35
      IF(MARS)48,48,47
47  CONTINUE
48  MARS=MARS+35
      IF(MARS-18)50,50,49
49  XLONG=-XLONG
50  XLAT=ALATI(XLAT,SLAT,ANLAT)
      IF(XLAT)1000,10,10
10  XLONG=ALONG(XLONG,WLONG,ELONG,SCALE)
      IF(XLONG)1000,11,11
11  CALL FPLDT(1,XLONG,XLAT)
      CALL FPLDT(-1,XLONG,XLAT)
      CALL FCHAR(XLONG,XLAT,.05,.05,0.)
      TDIFF=ROJND(TDIFF,.05)
      DIFSG=SIGSF-SIGE
      DIFSG=ROJND(DIFSG,.05)

```

```
SIGDP=SIGMA(TDEEP,SDEEP)
GO TO(12,13,14,15,16,17,18,19,20),IPLDT
12 WRITE(7,22)TSURF
22 FORMAT(F5.1)
GO TO 1000
13 WRITE(7,22)TDEEP
GO TO 1000
14 WRITE(7,22)SSURF
GO TO 1000
15 WRITE(7,22)SDEEP
GO TO 1000
16 WRITE(7,22)SIGSF
GO TO 1000
17 WRITE(7,22)SIGDP
GO TO 1000
18 WRITE(7,22)DIFSG
GO TO 1000
19 WRITE(7,22)TDIFF
GO TO 1000
20 WRITE(7,22)SIGE
1000 CONTINUE
121 CALL REWNZ(1)
GO TO 122
1001 CALL EXIT
END
// DUP
*STORE WS JA CREMP
// J03 1AFA
// XEQ CREMP 1
*FILES(1,TPTOK)
```

```
// DJP
*DELETE          MEGRI
// FOR
*ONE WORD INTEGERS
*LIST ALL
SUBROUTINE MEGRI(MLONG,ELONG,SLAT,ANLAT,SCALE)
  DIMENSION A(81)
  COMMON CC(35),B(160)
  SUBROUTINE SETS MERCATOR GRID ,STORES B(160) IN COMMON,THE FIRST 23
  PLACES OF THE COMMON AREA ARE RESERVED FOR COMPATIBILITY WITH NAVIGATION P
  PROGRAMS ,AT BEGINNING OF PROGRAM SCALE IS REDIFIED
  AN DJTLINE IS DRAWN
  BLUE CHART SCALE 0.3574
  FREEZEN SCALE 0.43
  A(1)=0.9933
  A(2)=0.9937
  A(3)=0.9943
  A(4)=0.9952
  A(5)=0.9964
  A(6)=0.9980
  A(7)=0.9998
  A(8)=1.0020
  A(9)=1.0045
  A(10)=1.0073
  A(11)=1.0105
  A(12)=1.0139
  A(13)=1.0170
  A(14)=1.0219
  A(15)=1.0264
  A(16)=1.0313
  A(17)=1.0365
  A(18)=1.0421
  A(19)=1.0481
  A(20)=1.0545
  A(21)=1.0613
  A(22)=1.0686
  A(23)=1.0762
  A(24)=1.0843
  A(25)=1.0928
  A(26)=1.1019
  A(27)=1.1114
  A(28)=1.1215
  A(29)=1.1320
  A(30)=1.1431
  A(31)=1.1548
  A(32)=1.1671
  A(33)=1.1801
  A(34)=1.1937
  A(35)=1.2079
  A(36)=1.2229
  A(37)=1.2388
  A(38)=1.2552
  A(39)=1.2726
  A(40)=1.2909
  A(41)=1.3101
  A(42)=1.3303
  A(43)=1.3515
  A(44)=1.3739
  A(45)=1.3875
  A(46)=1.4121
  A(47)=1.4482
```

21

```

A(48)=1.4758
A(49)=1.5049
A(50)=1.5355
A(51)=1.5581
A(52)=1.6024
A(53)=1.5388
A(54)=1.5774
A(55)=1.7185
A(56)=1.7621
A(57)=1.8085
A(58)=1.8580
A(59)=1.9108
A(60)=1.9674
A(61)=2.0280
A(62)=2.0932
A(63)=2.1633
A(64)=2.2389
A(65)=2.3208
A(66)=2.4096
A(67)=2.5062
A(68)=2.6118
A(69)=2.7275
A(70)=2.8547
A(71)=2.9954
A(72)=3.1516
A(73)=3.3251
A(74)=3.5222
A(75)=3.7440
A(76)=3.9924
A(77)=4.2822
A(78)=4.6189
A(79)=5.0145
A(80)=5.4863
A(81)=6.0580
CALL SCALF(1.,1.,0.,0.)
DLONG=ELONG-WLONG
IF(DLONG)10,10,11
10 DLONG=DLONG+360.
ELONG=WLONG+DLONG
11 XM=DLONG*SCALE
LATD=ANLAT-SLAT+1.
3(1)=0.
AL=SLAT
DO 15 J=2,LATD
BL=AL+1.
IF (ABS(AL)-ABS(BL))12,12,13
12 LC=ABS(BL)
GO TO 14
13 LC=ABS(AL)
14 B(J)=B(J-1)+A(LC)*SCALE
AL=BL
IF(B(J)-58.0)15,15,16
15 CONTINUE
GO TO 17
16 ANLAT=ANLAT-1.
GO TO 11
SETTING GRID
FIRST SET OUTLINE
17 CALL FPLDT(2,0.,0.)
CALL FPLDT(0,XM,0.)
CALL FPLDT(0,XM,B(LATD))

```



```
CALL FPLDT(0,0,B(LATD))  
CALL FPLDT(0,0,0.)  
CALL FPLDT(1,0,0.)  
RETURN  
END
```

```
// DJP  
*STORE
```

```
WS UA MEGRI
```

// FOR

*ONE WORD INTEGERS

*ARITHMETIC TRACE

*TRANSFER TRACE

C SUBROUTINE MEGRW (IGRI,IMIN,IGG,WLONG,ELONG,SLAT,ANLAT,SCALE)

C SUBROUTINE TO BE USED ONLY AFTER MEGRI HAS BEEN CALLED FOR DRAWING

C INSIDE GRID, MAKING ANNOTATIONS ETC.

C THREE KINDS OF ANNOTATION SCALES ARE SELECTED, DEPENDING ON WHETHER

C VALUE OF SCALE * IGG IS LESS THAN 1, BETWEEN 1 AND 2 OR GREATER THAN 2

C IGRI = 0 FOR NO INSIDE GRID, 1 FOR LATITUDES ONLY, 2 FOR BOTH

C LATITUDES AND LONGITUDES TO FORM INSIDE GRID.

C GRID LINES ARE AT INTERVALS OF IGG DEGREES.

C IMIN = 0 FOR NO MINUTE MARKS, 1 FOR MARKS ALONG LATITUDE, 2 FOR MARKS

C ALONG LATITUDE AND LONGITUDE.

C NO MINUTE MARKS ARE DRAWN IF SCALE IS LESS THAN 4 INCHES PER DEGREE.

C LATITUDE AND LONGITUDE ARE ANNOTATED AT INTERVALS OF IGG DEGREES

C WHETHER OR NOT THERE IS ANY INSIDE GRID.

C PROGRAM ALSO DRAWS TICK MARKS ALONG BORDER FOR EACH DEGREE OF LATITUDE

C AND LONGITUDE IF THERE IS NO INSIDE GRID OR IF GRID SPACING IS MORE

C THAN 1 DEGREE.

C WLONG, ELONG, SLAT, ANLAT DEFINE IN DEGREES THE WESTERN, EASTERN,

C SOUTHERN AND NORTHERN BOUNDARIES OF GRID.

C SCALE IS NUMBER OF INCHES PER DEGREE LONGITUDE.

SUBROUTINE MEGRW(IGRI,IMIN,IGG,WLONG,ELONG,SLAT,ANLAT,SCALE)

COMMON CC(36),B(160)

IF(IGG)56,56,55

56 IGG=1

55 KIG=SLAT/IGG

TC=SCALE*IGG

IF(TC-2.)2005,2006,2006

2005 JGT=1

GO TO 2007

2006 IF(TC-4.)2009,2009,2008

2008 JGT=3

GO TO 2007

2009 JGT=2

2007 GO TO (2010,2011,2012),JGT

2012 H1=1.30

H2=0.15

H3=0.30

H4=0.75

H5=-.20

H6=0.50

H7=0.20

GO TO 57

2011 H1=0.86

H2=0.10

H3=0.20

H4=0.50

H5=-.14

H6=0.33

H7=0.13

GO TO 57

2010 H1=0.44

H2=0.05

H3=0.10

H4=0.25

H5=-.06

H6=0.17

H7=0.07

57 NNNN=SLAT-KIG*IGG

24

```

      IF (NNNN) 7000, 7000, 7001
7000 NNNN=IGG+NNNN
7001 KIG=1+IGG-NNNN
      KOG=WLONG/IGG
      NNNN=WLONG-KOG*IGG
      IF (NNNN) 7002, 7002, 7003
7002 NNNN=IGG+NNNN
7003 KOG=1+IGG-NNNN
      DLONG=ELONG-WLONG
      LONGD=DLONG
      LONGF=LONGD+1
      XM=DLONG*SCALE
      LATD=ANLAT-SLAT+1.
C     TRACE GRID EVERY IGG
      IF (IGRI-1) 1100, 1000, 1010
1000 IB=KIG
      BC=0.
      BD=XM
      CALL FPL0T(1, BC, B(IB))
      I=-2
1001 Y=B(IB)
      CALL FPL0T(1, BC, Y)
      I=0
      CALL FPL0T(1, BD, Y)
      AD=BC
      BC=BD
      BD=AD
      IB=IB+IGG
      IF (LATD-IB) 1100, 1100, 1001
1010 BB=(KOG-1)*SCALE
      BC=0.
      BD=B(LATD)
      CALL FPL0T(1, BB, BC)
      I=-2
1011 CALL FPL0T(1, BB, BC)
      I=0
      CALL FPL0T(1, BB, BD)
      AD=BC
      BC=BD
      BD=AD
      BB=BB+IGG*SCALE
      IF (XM -BB) 1000, 1000, 1011
1100 IF (SCALE-2.) 1200, 1901, 1901
C     TEST FOR STANDARD SCALE
1901 IF (IMIN-1) 1200, 1102, 1902
C     DRAW MINUTES MARKS
1902 DD=SCALE/60.
      DO 1903 K=1, 59
      XK=K
      X=DD*XK
      IF (K-30) 1904, 1905, 1904
1904 KK=XK/10.
      XKK=KK*10
      IF (XK-XKK) 1906, 1907, 1906
1906 KK=XK/5.
      XKK=KK*5
      IF (XK-XKK) 1908, 1909, 1908
1908 Y=0.1
      GO TO 1910
1909 Y=0.12
      GO TO 1910

```

```

1907 Y=0.15
      GO TO 1910
1905 Y=0.2
      GO TO 1910
1910 CALL FPLLOT(1,X,0.)
1903 CALL FPLLOT(2,X,Y)
1102 DO 1110 J=2,LATD
      DD=(B(J)-B(J-1))/60.
      DO 1110 K=1,59
      XK=K
      Y=B(J-1)+DD*XK
      IF(K-30)1111,1112,1111
1111 KK=XK/10.
      XKK=KK*10
      IF(XK-XKK)1113,1114,1113
1113 KK=XK/5.
      XKK=KK*5
      IF(XK-XKK)1115,1116,1115
1115 X=0.1
      GO TO 1117
1116 X=0.12
      GO TO 1117
1114 X=0.15
      GO TO 1117
1112 X=0.2
1117 CALL FPLLOT(1,0.,Y)
1110 CALL FPLLOT(2,X,Y)
C    DRAW DEGREE TICKS AT IGG INTERVA. IF IGG NON ZERO ONLY DRAW TICKS IF IGG 1
1200 IF(IGG)2200,2200,2201
2200 JJK=0
      GO TO 2202
2201 JJK=1
2202 IF(IGG-JJK)1300,1300,1201
1201 X=0.2
      DO 1202 J=1,LATD
      CALL FPLLOT(1,0.,B(J))
1202 CALL FPLLOT(2,X,B(J))
      Y=B(LATD)-0.2
      DO 1203 J=1,LONGF
      X=(J-1.)*SCALE
      CALL FPLLOT(1,X,B(LATD))
1203 CALL FPLLOT(2,X,Y)
      X=XM-0.2
      DO 1204 J=1,LATD
      JJ=LATD-J+1
      CALL FPLLOT(1,XM,B(JJ))
1204 CALL FPLLOT(2,X,B(JJ))
      Y=0.2
      DO 1205 J=1,LONGF
      X=(LONGF-J)*SCALE
      CALL FPLLOT(1,X,0.)
1205 CALL FPLLOT(2,X,Y)
      WRITE DEGREE IDENTIFICATION
1300 AL=-41
      DO 2000 N=1,2
      DO 1301 J=KIG,LATD,IGG
      LAT=SLAT+J-1
      Y=B(J)-H2
      CALL FCHAR(AL,Y,H3,H3,0.)
1301 WRITE(7,100)LAT
100  FORMAT(I4)

```

```
2000 AL=ALONG(ELONG,WLONG,ELONG,SCALE)+H5
      Y=B(LATD)+H7
      DO 2001 NAP=1,2
      DD 1302 J=KJG, LONGF, IGG
      AL=(J-1)*SCALE-H4
      LONG=WLONG+J-1
      LLONG=LONG
      IF(LJNG-180)1310,1310,1311
1311 LLONG=LONG-360
1310 CALLFCHAR(AL,Y,H3,H3,0.)
1302 WRITE (7,100)LLONG
2001 Y=-45
      CALL FPL0T(-1,0.0,0.0)
      RETURN
      END
```

// DUP

*DELETE

MEGRW

*STORE

WS UA

MEGRW

```

// DUP
*DELETE          ALATI
// FOR
*ARITHMETIC TRACE
*TRANSFER TRACE
*ONE WORD INTEGERS
      FUNCTION ALATI(Y,SLAT,ANLAT)
C      THIS FUNCTION CHANGES LATITUDE MERCATOR SCALE TO LINEAR SCALE IN INCHES
C      FOR MEGRI OR MEPLD
C      ARGUMENT IS LATITUDE
C      IF OUTSIDE GRID LIMITS VALUE SET TO -1.
      COMMON CC(36),B(160)
      IF((Y+.00001)-SLAT)1,2,2
2      IF((Y+.00001)-ANLAT)3,3,1
3      YA=Y-SLAT+1.0001
      VY=YA
      YN=VY
      YB=YA-YN
      ALATI=B(NY)+YB*(B(NY+1)-B(NY))
      GO TO 5
1      ALATI=-1.
5      RETURN
      END

// DUP
*STORE          WS UA ALATI

```

```
// DUP
*DELETE          ALONG
// FOR
*ONE WORD INTEGERS
FUNCTION ALONG(X,WLONG,ELONG,SCALE)
THIS FUNCTION CHANGES LONGITUDE      SCALE TO LINEAR SCALE IN INCHES
FOR MEGRI OR MEPLD
ARGUMENT IS LONGITUDE
IF OUTSIDE GRID LIMITS VALUE SET TO -1.
COMMON CC(35),B(160)
C=X
IF((C+.0001)-WLONG)1,2,2
1 C=C+360.
2 IF((C+.0001)-ELONG)3,3,4
3 ALONG=(C-WLONG)*SCALE
GO TO 5
4 ALONG=-1.
5 RETURN
END

// DUP
*STORE          WS UA ALONG
```

```

// JOB          AFA
// DUP
*DELETE        WORLD
// FOR
*LIST ALL
*ONE WORD INTEGERS
SUBROUTINE WORLD(SLAT,ANLAT,WLONG,ELONG)
  DIMENSION X(80),Y(80)
  COMMON AM(12),AY(24),B(160),SCALE
  ISKIP=0
  ICORD=1
  INIT=0
60 DO 40 I=1,525
  READ(100,'I')(X(J),Y(J),J=1,80)
  DO 43 J=1,80
  IF(X(J))71,70,71
70 IF(Y(J))71,53,71
71 IF(X(J)-200.)44,45,44
44 X(J)=ALATI(X(J),SLAT,ANLAT)
  IF(X(J))53,46,46
46 Y(J)=ALONG(Y(J),WLONG,ELONG,SCALE)
  IF(Y(J))53,47,47
47 IF(INIT)48,48,51
48 CALL FPLLOT(-2,Y(J),X(J))
  INIT=1
  ISKIP=0
  GO TO 43
53 ISKIP=1
  GO TO 43
51 CALL FPLLOT(ISKIP,Y(J),X(J))
  IF(ISKIP)151,151,152
152 CALL FPLLOT(2,Y(J),X(J))
151 ISKIP=0
43 CONTINUE
40 CONTINUE
45 RETURN
END

```

```

// DUP
*STORE        WS  UA  WORLD          AFA

```


Primary and Secondary Production Resulting from Mixtures
of 80% Deep and 20% Surface Water
(Scott Laurence)

A general description and discussion of both primary and secondary production in a mariculture system utilizing mixtures of 80% deep and 20% surface water was presented at the conference on "Energy From The Oceans: Fact or Fantasy?", held in Raleigh, North Carolina on January 26-27, 1976. The text of that paper is included in this report as Appendix A. Results not summarized in that paper are provided below.

Phytoplankton and shellfish protein nitrogen analyses collected during this study have yet to be completed, and other data reduction and analysis also awaits completion. These analyses should be completed no later than March 15, 1976, and a paper suitable for publication will be written at that time.

SUMMARY OF PRIMARY PRODUCTIVITY RESULTS

Work to date has indicated that considerable variation exists in phytoplankton density and diversity in both surface and deep water, and that this variation leads to a lack of predictable phytoplankton growth from culture to culture. We have found that 80:20 mixtures of deep:surface water which contains a preponderance of various Chaetoceros species, usually attain peak density within a few days, utilize nearly all of the available nutrients, and can remain on continuous flow at 1.0 turnovers per day for up to 40 days. However, these species are often present in only low concentrations and the mixtures are often dominated by a variety of microflagellates; in such instances, the

cultures fail to bloom and they must be scrapped. In general, deep + surface water mixtures will fail to bloom in approximately one-half of the cases.

SECONDARY PRODUCTIVITY

A. Survival and Growth Studies

Secondary productivity in our surface water/deep water system involves a sequential series of studies designed to select the most suitable bivalve species for open-sea mariculture. The following decision levels are employed in this program:

(1) Initial Selection

Basis: Response of the bivalve in the deep-water mariculture system. Purview of scientific literature. Oral communication from mariculturists, bivalve specialists, etc.

Species Selected:

Clams - Tapes semidecussata, Mercenaria mercenaria

Oysters - Crassostrea gigas, Kumamoto variety of Crassostrea, Crassostrea rhizophorae, Crassostrea virginica

Mussels - Purina purina

Needs: Since the selection of suitable species depends upon a large number of factors including ease in growing and various harvesting and marketing conditions, it is desirable to have a variety of bivalves suitable for open-sea mariculture, and at least two or more species from each of the major groups listed above. For this reason, we still

require more clam and mussel species for initial screening in our system.

(2) General Adaptability (Survival)

Basis: General measures of growth (visual inspection) and mortality (periodic individual counts), over a one to two month period intended to serve as an initial screening period for suitability of actual growth in the deep- and surface-water mixtures of our system. In all cases, juveniles are used.

Species Tested: Tapes semidecussata, Crassostrea gigas, Crassostrea rhizophorae (all successful).

Upcoming Tests: Crassostrea virginica and Mercenaria mercenaria (begins 25 Feb 76), Kumamoto variety of Crassostrea (begins 1 Mar 76), Purina purina (begins 1 Apr 76).

(3) Parametric Determination and Growth

Basis: Growth (as measured by (1) length and (2) whole wet weight) as general function of phytoplankton assimilation, designed to determine the proper age, size, and total weight parameters (in relation to a given quantity of phytoplankton concentration at various flow rates) for the design of conversion efficiency studies described below.

Usual test period: 30 days.

Species Tested: Tapes semidecussata. In progress: Crassostrea rhizophorae.

Upcoming Tests: Crassostrea gigas (1 Mar 76).

(4) Quantitative Determination of Phytoplankton Conversion Efficiency

Goals: This phase is designed to obtain a quantitative determination of food conversion efficiency for those species which have demonstrated high growth potential through the first three decision levels.

Basis: Quantitative determination of: deep and surface water dissolved inorganic nutrients, protein nitrogen determinations in phytoplankton (primary production stage), protein nitrogen determinations on shellfish meat during various periods of growth, quantitative determination of total nutrient flow through both trophic levels. Duration: 36 days.

Species Completed: Tapes semidecussata.

Upcoming: Crassostrea gigas (1 Apr 76), Crassostrea rhizophorae (1 Apr 76).

(5) Growth to Market Size

Goals: Less intensive version of section (4), in which selected weight/food relationships are grown to market size. Involves infrequent but regular quantitative determinations of nutrient flow at all levels. Provides data on relative efficacy of DW/SW system, as opposed to deep-water system alone.

In Progress: Tapes semidecussata (60 days as of 15 Feb 76).

B. Open-Ocean Engineering

Our open-ocean engineering study designs and tests structures for the open-ocean growth and harvesting of bivalves. We are engaged in the design of three main types of structure, suitable for the growth of (1) oysters, (2) mussels, and (3) clams.

(1) Work Accomplished

We have already successfully tested a hanging-rope system for mussels. Tests showed that ropes could be hung from floats in the open sea and that their flexibility easily withstands the rigors of the open-ocean environment. With weights on each rope to simulate attaching bivalves, ropes could be easily attached to and removed from the floats by on-boat personnel. Under actual conditions, we expect hatchery-spawned mussels to set on ropes under controlled density and food conditions, and then to be removed to the open sea once a pre-determined size has been reached.

We have tested mortar-covered plate-collectors and hanging, threaded shells as a means of collecting and growing oyster spat. These studies are still in progress, but early results have demonstrated that both methods are clearly feasible and involve low cost.

We have designed and have nearly completed construction of PVC+plastic mesh containers for holding clams in the open sea. Early designs have been in the ocean for over three months as of this writing and have proved to be feasible.

(2) Ongoing Work

We are in the process of designing a modular, tri-partite growing structure which will test the basic engineering and

harvesting approaches we have adopted and which will form the basic experimental structure for our first growth studies in the open sea. This design will be completed by 15 March 1976. Installation is expected by 1 May 1976.

OPEN-OCEAN PHYTOPLANKTON CONTAINMENT SYSTEM

As a result of physical/chemical analysis of the fate of the water discharged from a floating sea-thermal power plant, it is likely that, although vertical migration can be easily determined and controlled, horizontal mixing will dilute the deep water to unacceptable levels, under "natural" conditions. Mechanical containment of the phytoplankton bloom is therefore necessary.

We have designed an open-ocean containment pool, and will install this structure on or about 1 March 1976. The design incorporates a semi-rigid PVC pipe frame (schedule 40 pipe, 2 inches in diameter), diamond-shaped to withstand wave action. Three-quarter-inch seine netting is used as a backing, and nylon-reinforced plastic is used for an inner liner. The plastic is designed to extend approximately one foot above sea level and five feet beneath the surface. The entire structure is approximately 32 feet in circumference, supported by four foam-filled galvanized steel floats, and is open at the bottom and top. The mooring system has yet to be designed.

Preliminary Economic Analysis

(a) DEEP WATER DISCHARGE (100 MW PLANT)¹ = $\underline{4.5 \times 10^7 \text{ liters/minute}}$

(b) MICROGRAM-ATOMS OF DISSOLVED

INORGANIC NITROGEN IN DEEP WATER = $32.0/\text{liter}^2$

(c) MILLIGRAMS OF DISSOLVED NITROGEN = $.448/\text{liter}^3$

(d) MILLIGRAMS OF NITROGEN PRODUCED

PER YEAR = $.448 \times 4.5 \times 10^7 \times 60 \times 24 \times 365 = 1.059 \times 10^6 \times 10^7$

(e) KILOGRAMS OF NITROGEN PRODUCED

PER YEAR = $\frac{1.059 \times 10^6 \times 10^7}{10^3} = 1.059 \times 10^7 \text{ kgN}$

(f) TONS OF NITROGEN PRODUCED

PER YEAR = $\frac{1.059 \times 10^7}{10^3} = 1.059 \times 10^4 \text{ or } \underline{10,590 \text{ tons}}$

(g) 45% OF THIS NITROGEN IS CONVERTED

INTO SHELLFISH MEAT NITROGEN.⁴

THEREFORE, THE AMOUNT, IN TONS OF

SHELLFISH MEAT NITROGEN PRODUCED

PER YEAR = $(1.059 \times 10^4) (.45) = 4,765.5 \text{ tons}$

(h) NITROGEN IN MEAT OF Tapes semi-

decussata IS 7.52% OF DRY

WEIGHT.⁵ TONS OF DRY WEIGHT

MEAT PRODUCED PER YEAR IS

THEREFORE: $\frac{4,765.5 \times 100}{7.52} = 63,371 \text{ tons}$

(i) DRY WEIGHT OF MEAT IS 22.5% OF WET

WEIGHT.⁶ TONS OF WET WEIGHT MEAT

PRODUCED PER YEAR = $\frac{63,371 \times 100}{22.5} = 281,648 \text{ tons}$

(j) 281,648 TONS x 2,200 = 6,196,256 or 6.19×10^8 lbs

(k) ASSUMING A MARKET VALUE OF

\$1.00 PER POUND, THE POTENTIAL

ECONOMIC YIELD IS THEREFORE = 61.9×10^7 dollars or

\$619,000,000.

Notes

- ¹ Based on proposed Lockheed design.
- ² Based upon weekly analysis of deep water pumped from 870 m at
St. Croix, U.S. Virgin Islands.
- ³ Based on atom number of 14 for nitrogen.
- ⁴ Based upon results obtained in a feeding study completed on
20 January 1976.
- ⁵ Based upon results obtained in a feeding study completed on
1 August 1975 (CHN analysis).
- ⁶ Based upon results obtained in a feeding study completed on
1 August 1975.