The Optimal Survey Strategy, Volume 2

An in-depth guide to formulation of a data-specific cetacean survey

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CHAPTER ONE

Appendix

A) Photo-Identification

APPENDIX A1: References for Chapter 1: Table 1 – Photo identification on a Global Scale

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Appendix A2: World Wide Cetacean Identification Database

The World Wide Cetacean Identification Database is a work-in-progress and was formulated as a online identification database, utilising the prinicples seen within my Segmented Section Analysis (Chapter 2) and designed for use over all species types. The work within Appendix A2 covers basic principles and initial design ideas, not the completed proposal or database itself.

2016

World Wide Cetacean Identification Database (WWCID).

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Appendix 7: Cetacean Templates

INTRODUCTION

WWCID would be an online database of identified cetaceans following a formulated structure that is adaptable for all cetacean species. The database would rely on a computerised version of the segmented section analysis, following GUI protocol. If possible we will endeavour to adapt it even further in the future to include pigmentation and callosity differentiation analysis seen in programs such as the watershed algorithm and the Burnell/Shanaghan method.

PART 1: SUBMITTING A PHOTO INTO THE DATABASE

Step 1.1: Choosing to Perform Search

Upon logging onto the database you will be queried as to what you would like to do:

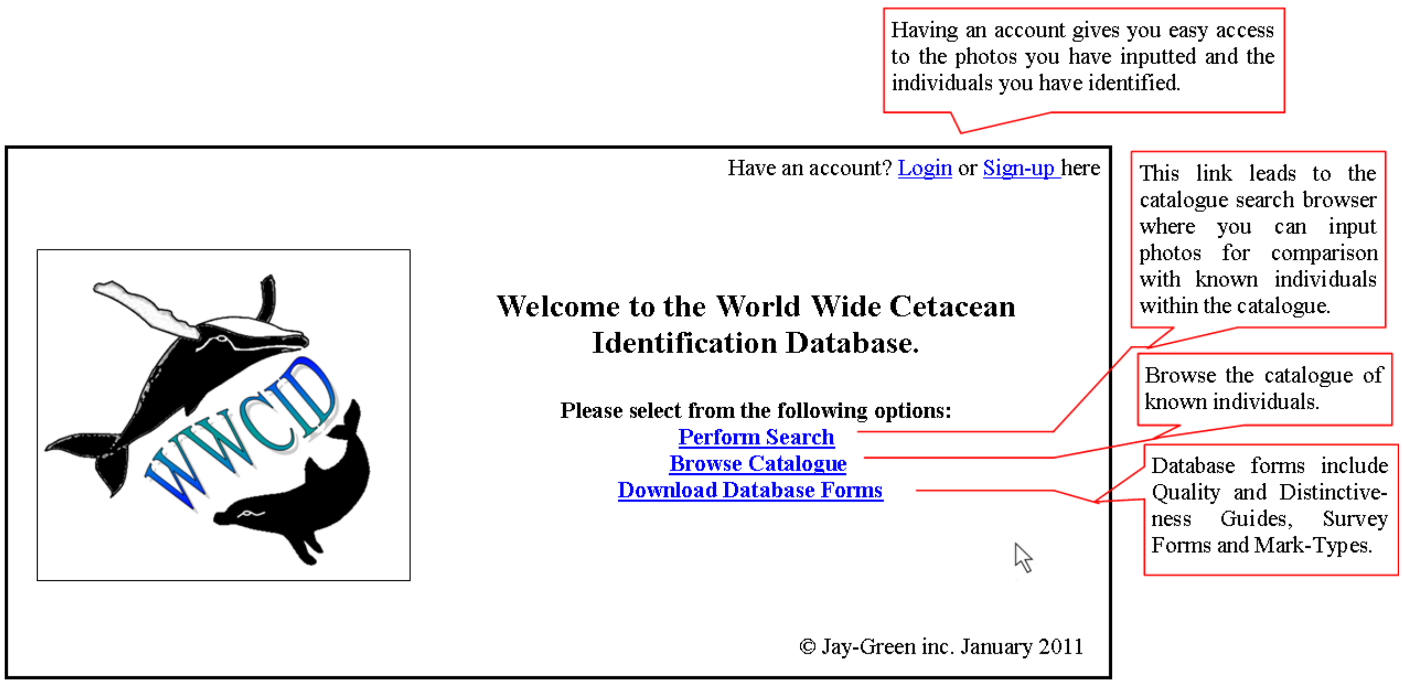


Figure 1. shows the initial page seen when logging on to the WWCID. There are four main choices: Log In, Perform Search (anomalously), Browse Catalogue and Download Database Forms.

There are four possible choices: '*Log In*', '*Perform Search*', '*Browse Catalogue*' and '*Download Database Forms*'. The '*Log In*' steps can be seen in Part 2. '*Browse Catalogue*' steps can be seen in Part 4 and '*Downloading Database Forms*' in Part 5. To begin performing a search the user can either click '*Perform Search*' or '*Log-In*'. If the user chooses to Log-In then any individuals they identify using WWCID will be added to their personal profile database.

Step 1.2: Choose a Species

Once you have clicked on 'Perform Search' a new window will appear asking you which species you would like to conduct a search on (Figure 2). A similar choice will be used when you choose to 'Browse' the catalogue of known individuals.

Figure 2. shows a 'screen shot' of how it would look when the user chooses a species. The database will note all species currently involved in photo-identification and can be expanded to include extra species as required by users.

Step 1.3: Initial Input

Once you have chosen the species a catalogue datapage for that species will come up. Every possible portion of this page should be filled in order to make the search results and the resulting information within the database as concise as possible (Figure 3). The datapage includes an upload area for survey information. A template of the survey form has been provided to ensure consistent information is recorded (see Appendix 3). User should fill out the datapage before adding the image for searching.

Once survey and the individuals details have been inputted the user needs to start the segmentation process. The first step is to select the corresponding morphological area tab. It will not affect the calculations what order the morphological features are inputted, if the user is inputting more than one.

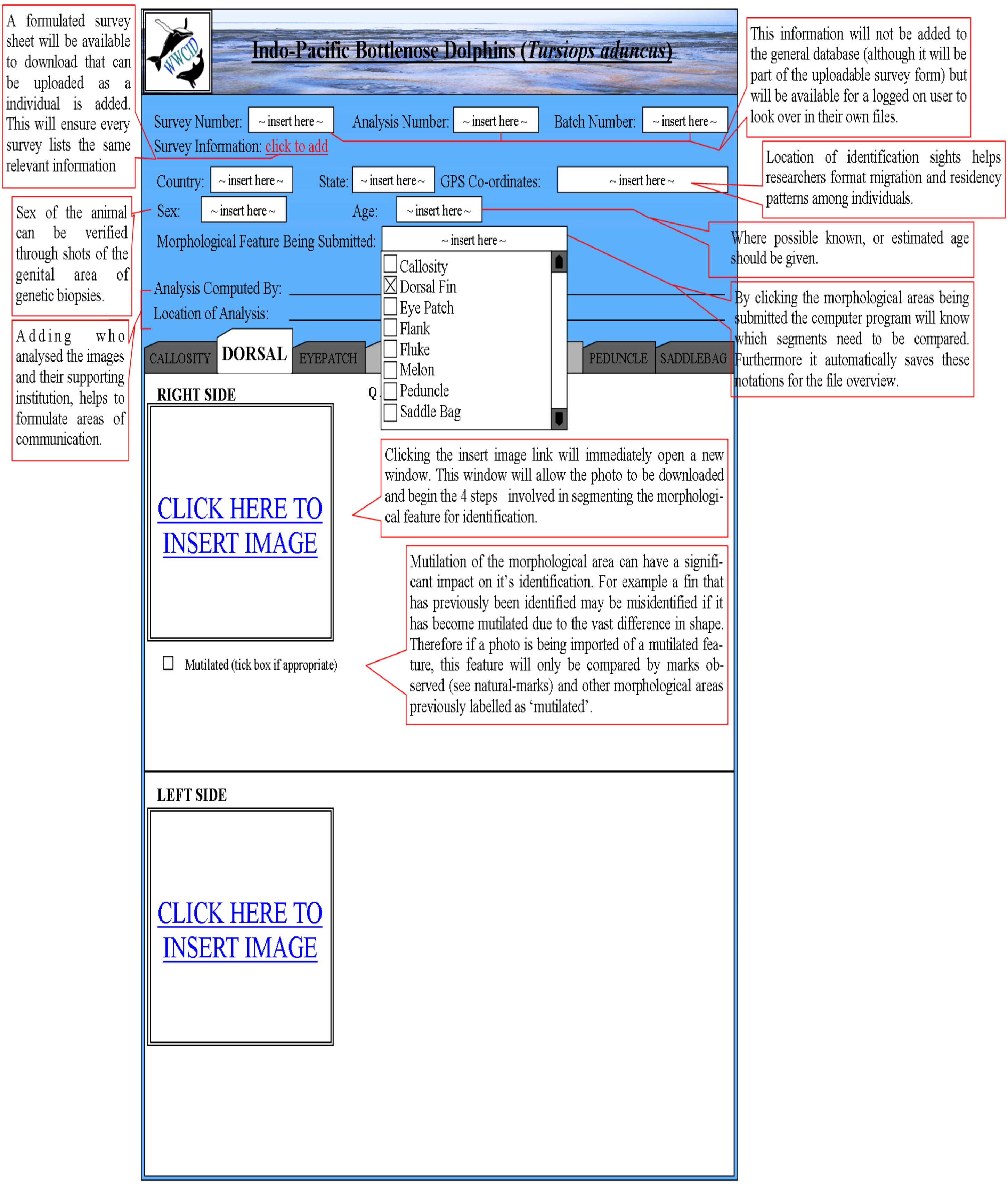


Figure 3. shows initial input page, including detailed explanations on the many page features that need to be filled in prior to the user commencing segmentation. Each individual datapage includes detailed

information on the survey conducted and the known information for the individual. Recorded details include: survey number, analysis number (if this varies from the survey number), batch number (if the used by the institute/user), survey information (a filled out copy of the downloadable survey form provided by WWCID), country (that the search was performed in), state (that the search was performed in), GPS co-ordinates (of where the photo was taken), sex (if known), age (if known), morphological feature being submitted (can be more than one), analysis computed by (the users name), location of analysis (the institute/company).

Step 1.4: the Segmentation Process

Once the image has uploaded into the new window, segmentation will begin (Figure 4). The user will need to input predefined control points on the image that will allow the program to create a digital outline of the morphological feature. Once this outline has been created the user can alter the line as needed, voiding inconsistencies caused by photo irregularities. From this outline the program is then able to determine morphological shape. This outline will be used in conjunction with mark types to determine cetacean identity. Next the program will use the outline and control points to segment the feature into predefined equally sized parts.

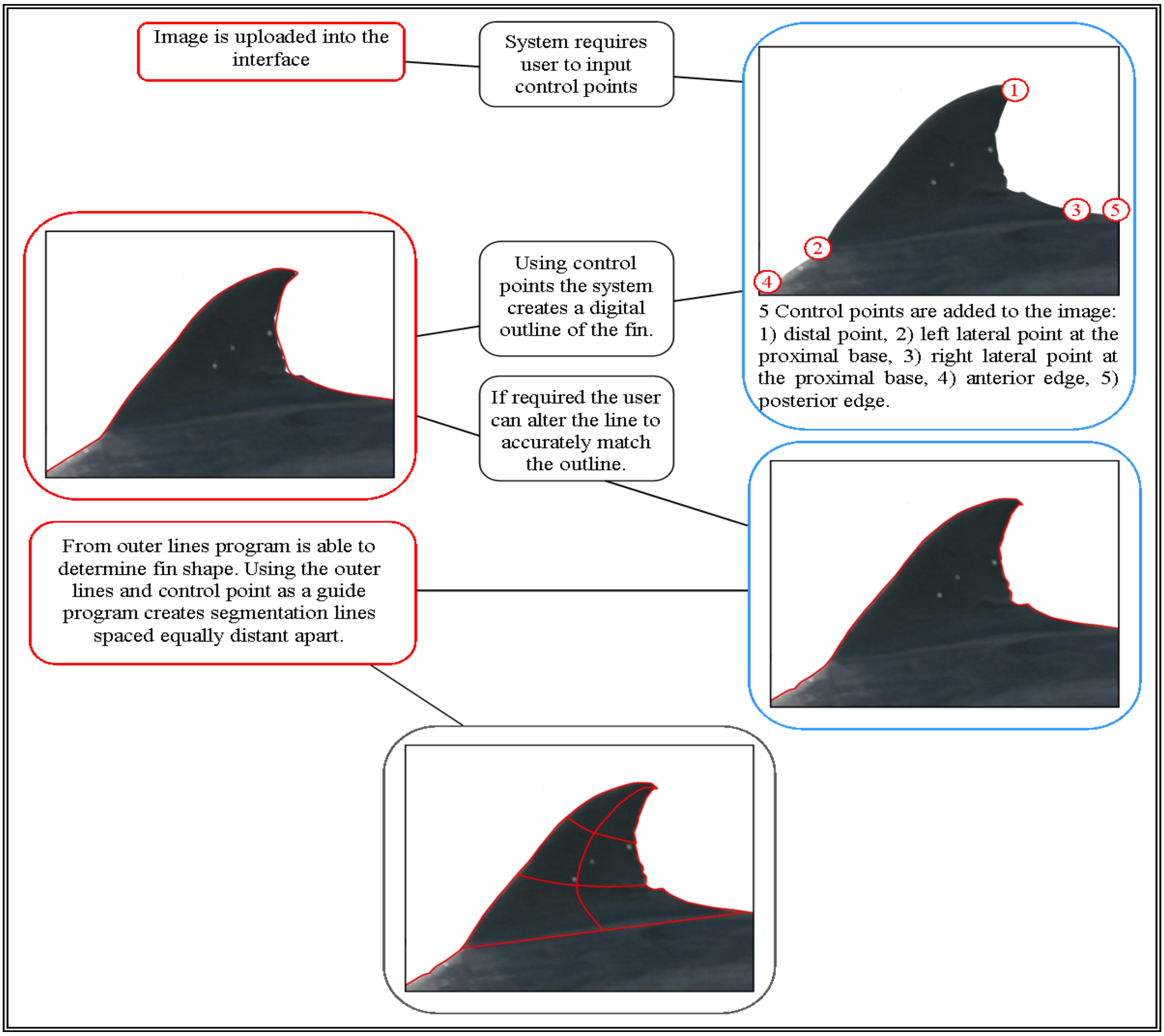


Figure 4. This figure shows a flow chart depicting the process of segmentation, detailing both the user and computer inputs. The GUI status of the program means there are user required inputs in the first initial steps towards creating the morphological feature outline. Once these steps are done however the program can run the rest of the segmentation process on its own.

Segmentation varies for the different morphological areas. Specified control points for each feature focus on key points that allow the program to formulate the required outline (see Appendix 7 - for Fluke, Flank and Melon control points). For each feature the segmentation process is different, and each segmentation section is labelled accordingly (see Appendix 1).

Step 1.5: Inputting Mark-Types per Segment

Once segmentation is complete the program will input the segmented feature back into the original data page (Figure 5). The next step involves inputting the natural marks that can be seen by the user on the morphological feature. Each mark type needs to be labelled by its position (segmentation section), size color, strength and the direction it is facing (see Appendix 3).

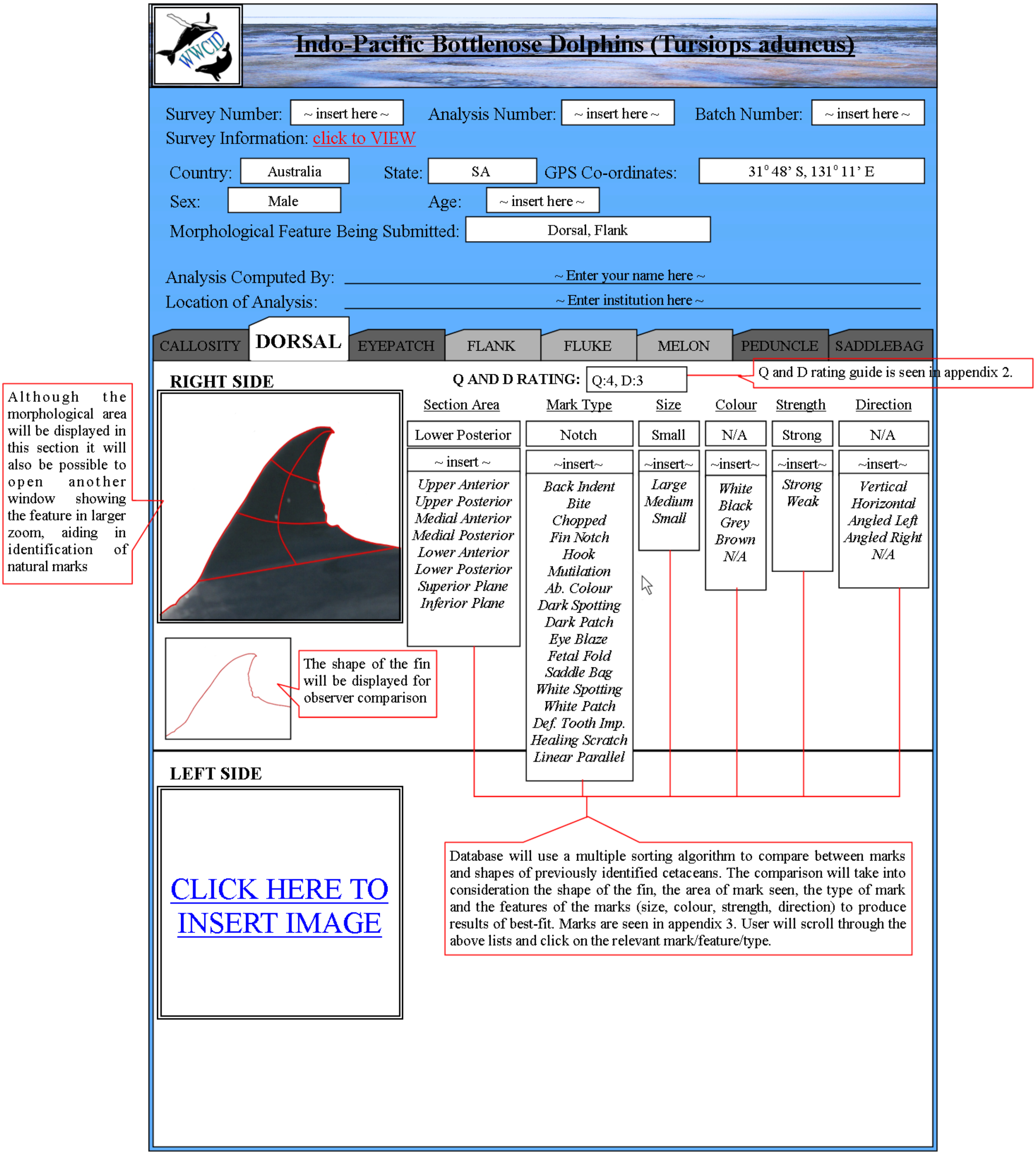


Figure 5. shows the datapage once the morphological feature has gone through the initial segmentation process. For each natural mark the segmentation section, size, color, strength and direction is recorded. The program also places the outline of the fin shape directly underneath the features photo.

Once these variables have been inputted the user either clicks the ‘search’ button or inputs the next morphological feature for segmentation. Once all sections are inputted the ‘search’ button is clicked and the program searches through the database and identifies those individuals with the closest match in features.

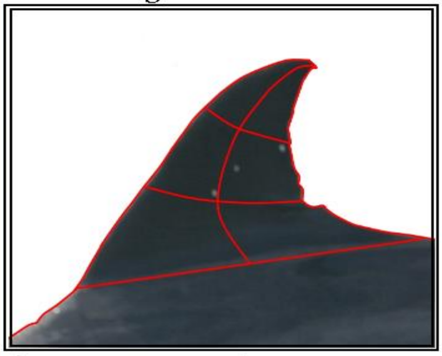
Step 1.6: Confirming Match

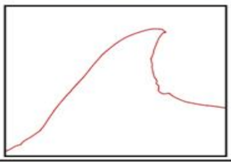
Once the user has submitted the image our database uses matching algorithms to determine closest probability of matches with individuals already located within our database. The program considers the recorded outline of the feature for similarities, as well as the natural mark-types observed per segmentation section. Each mark-type is further compared by the inputted size, color, direction and strength. For each mark-type the strength is one of the most important variables. The strength of a mark determines the likelihood it would fade over time. Weak marks can fade easily between identification shots. Strong marks have a much higher percentage of staying. Outlines are used during the comparison but have less of an impact during comparison then mark-types. If the user has inputted more than one morphological feature then the database searches all morphological features inputted.

The database will then present the user with a list of the closest matches down to a 35% probability of similarity (see Figure 6). If there is more than one morphological feature being searched then the probability is first calculated on the number of corresponding grouped morphological features that match, then by the individual morphological features. The user examines the findings and if they believe they have made a match, the user presses ‘confirm’. If there is no match then the user clicks on ‘No Match’ and a new file opens allowing them to register a new individual.

Indo-Pacific Bottlenose Dolphins (Tursiops aduncus)

Percentage Match: 90%





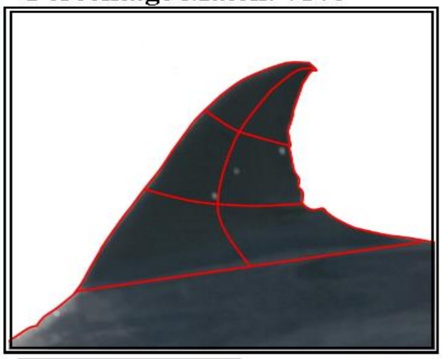
Name: Ballinga **Sex:** Male **Age:** 3 yrs

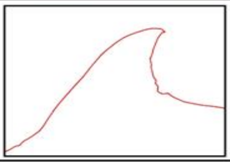
Q AND D RATING: Q:4, D:3

Section Area	Mark Type	Size	Colour	Strength	Direction
Lower Posterior	Fin Notch	Small	N/A	Strong	N/A
Medial Posterior	Fin Notch	Small	N/A	Weak	N/A
Upper Posterior	Fin Notch	Small	N/A	Weak	N/A
Upper Posterior	Fin Notch	Small	N/A	Weak	N/A
Anterior Fin	Back Indent	Small	N/A	Weak	N/A

CONFIRM

Percentage Match: 75%





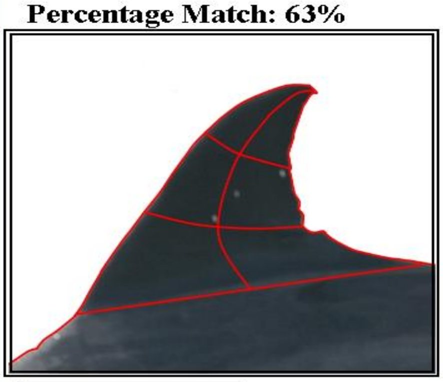
Name: Geralte **Sex:** unknown **Age:** 5 yrs

Q AND D RATING: Q:4, D:3

Section Area	Mark Type	Size	Colour	Strength	Direction
Lower Posterior	Fin Notch	Small	N/A	Strong	N/A
Medial Posterior	Fin Notch	Small	N/A	Weak	N/A
Medial Posterior	Fin Notch	Large	N/A	Strong	N/A

CONFIRM

Percentage Match: 63%



Name: Charlie **Sex:** Female **Age:** unknown

Q AND D RATING: Q:4, D:3

Section Area	Mark Type	Size	Colour	Strength	Direction
Lower Posterior	Fin Notch	Small	N/A	Strong	N/A
Upper Anterior	Mutilation	Large	N/A	Strong	N/A
Medial Posterior	Scratch Patch	Small	White	Weak	N/A

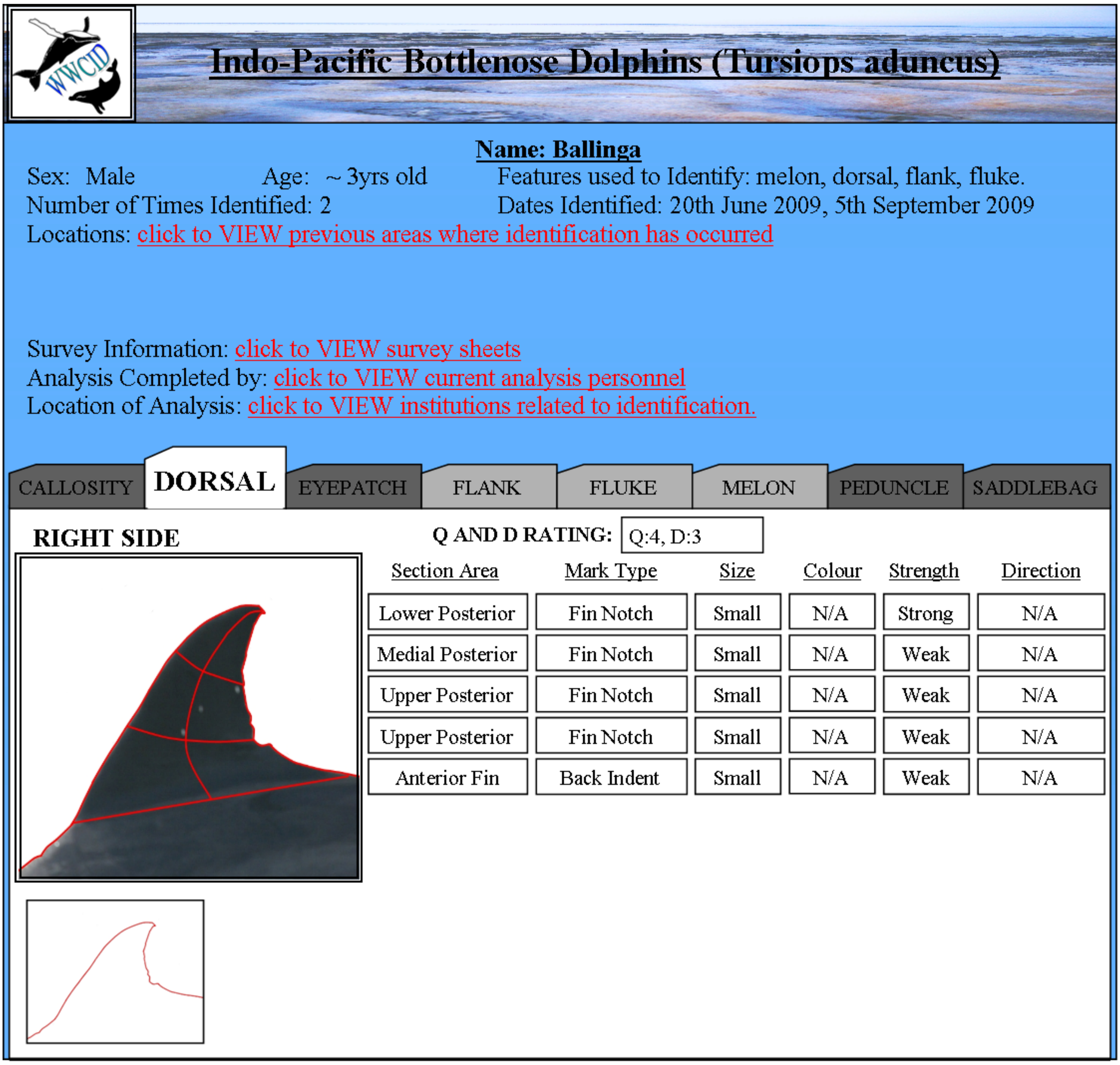
CONFIRM

NO MATCH

Figure 6. shows a theoretical example of what a researcher may get as a result of their identification search. As you can see individuals are listed via likelihood of percentage match. This match is deducted by a combination of morphological feature shape and comparison of recorded natural marks. Marks classified as 'strong' will have a high influence during the comparison, whereas marks recorded as 'weak' will have a much smaller percentage of influence on the final results.

Step 1.7: Identification Complete

Once identification is confirmed the database displays the file on the individual allowing the user to see where the cetacean has been previously identified, by whom, and obtain all known details on the individual. If the users photo is flagged as being of a higher quality and distinction rating the photo currently used for the display then a notification is sent to the database users who will then either confirm or deny this and may replace the current photo with the users. The database will keep a store of the 5 best shots of the cetacean for each morphological feature, which users can examine.



Indo-Pacific Bottlenose Dolphins (Tursiops aduncus)

Name: Ballinga

Sex: Male Age: ~ 3yrs old Features used to Identify: melon, dorsal, flank, fluke.

Number of Times Identified: 2 Dates Identified: 20th June 2009, 5th September 2009

Locations: click to VIEW previous areas where identification has occurred

Survey Information: click to VIEW survey sheets

Analysis Completed by: click to VIEW current analysis personnel

Location of Analysis: click to VIEW institutions related to identification.

CALLOSITY | DORSAL | EYEPATCH | FLANK | FLUKE | MELON | PEDUNCLE | SADDLEBAG

RIGHT SIDE

Q AND D RATING: Q:4, D:3

Section Area	Mark Type	Size	Colour	Strength	Direction
Lower Posterior	Fin Notch	Small	N/A	Strong	N/A
Medial Posterior	Fin Notch	Small	N/A	Weak	N/A
Upper Posterior	Fin Notch	Small	N/A	Weak	N/A
Upper Posterior	Fin Notch	Small	N/A	Weak	N/A
Anterior Fin	Back Indent	Small	N/A	Weak	N/A

Figure 7: An example of an identified individual's data sheet. You can clearly see both a segmented fin and, underneath it, the outline created during the identification process. The known natural marks are recorded and you can see from the light grey tabs that this cetacean has also had identifying photos taken of its flank, fluke and melon. From this data sheet you can access the areas that the cetacean has been observed, uploaded survey sheets, who completed the analysis and the institution/location where the analysis was undertaken.

PART 2: CREATING AN ACCOUNT

Creating an account with the WWCID is done in one simple step. The user starts up the database and clicks on 'sign-up'. A new window will appear showing the profile sign up form (see Figure 8). Although the user must fill out all sections of the sign-up form they can choose through their privacy settings what information they would like to appear on their profile. Username, institution and country will be automatically added to the public profile. First and last name, address, affixation, state, email and work and mobile phone numbers are optional additions to the profile. Only one phone number is required of the two options. This information is primarily used just by the creators of the database so that, if need be, they can get in contact with the user should any problems occur. It also helps to verify that the system is only accessed by legitimate personnel. If the user wishes they can add phone numbers, addresses and emails that are different to their personal details as 'contact information'. This allows other users who access their profiles or find their identified photos in the database to contact them and exchange information and/or data if the user wishes. Once the user submits their information an email is sent to the personal email address provided to confirm their sign up and their profile goes up on the database.

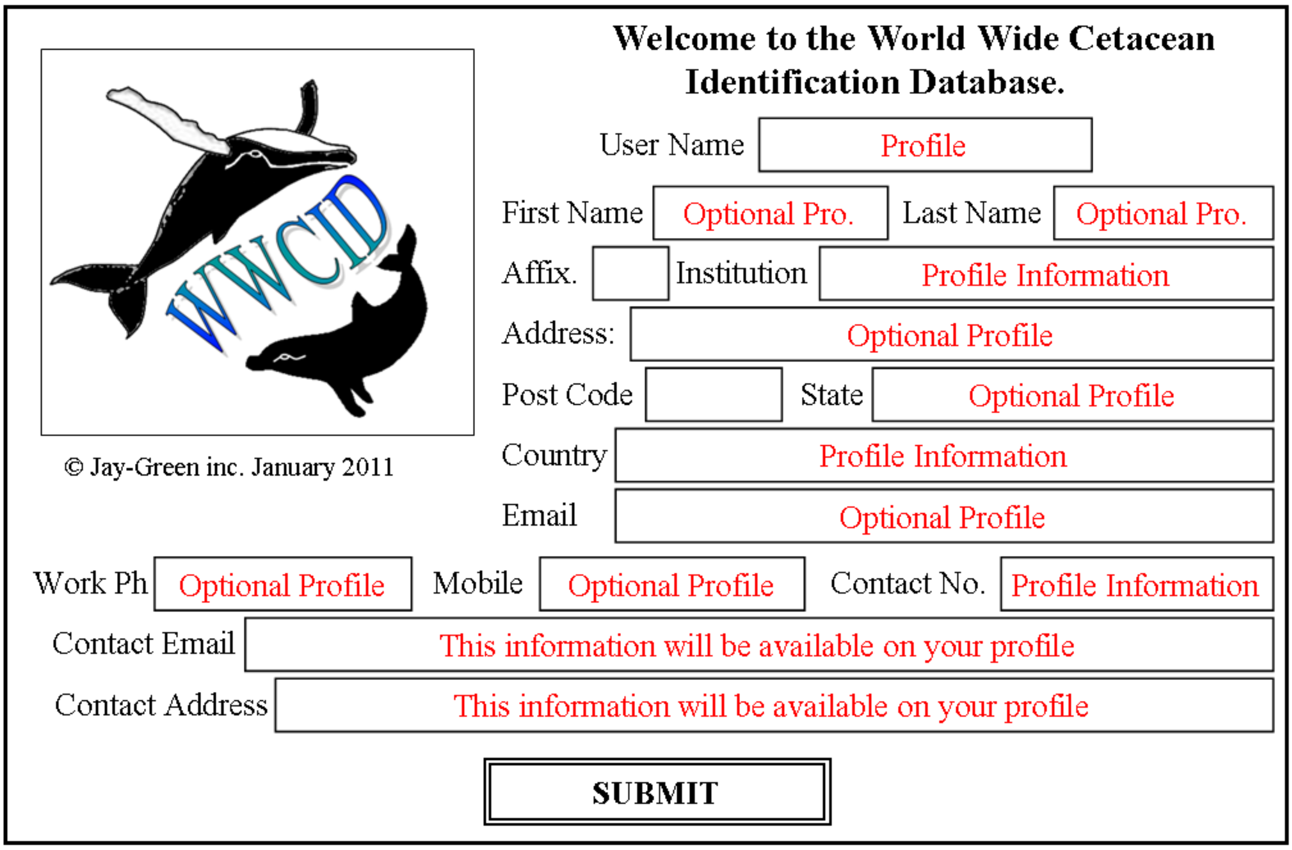


Figure 8: shows the basic information submitted by the user upon logging into WWCID. User name, first name, last name, affixation, institution, address, post code, state, country, email, work ph, mobile, contact no., contact email, contact address are all inputted into the system, although the user may choose which information is publicly available on their profile.

Once the information is submitted the users profile appears on the system (see Figure 9). The profiles can then be further altered to present information on either the user or institute using WWCID, as well as the work they are doing. Profiles allow users to see which institutes/personnel are using the WWCID, increases information sharing and provides a revenue for scientists to share the work they are doing with other scientists, institutions and possible areas of employment.

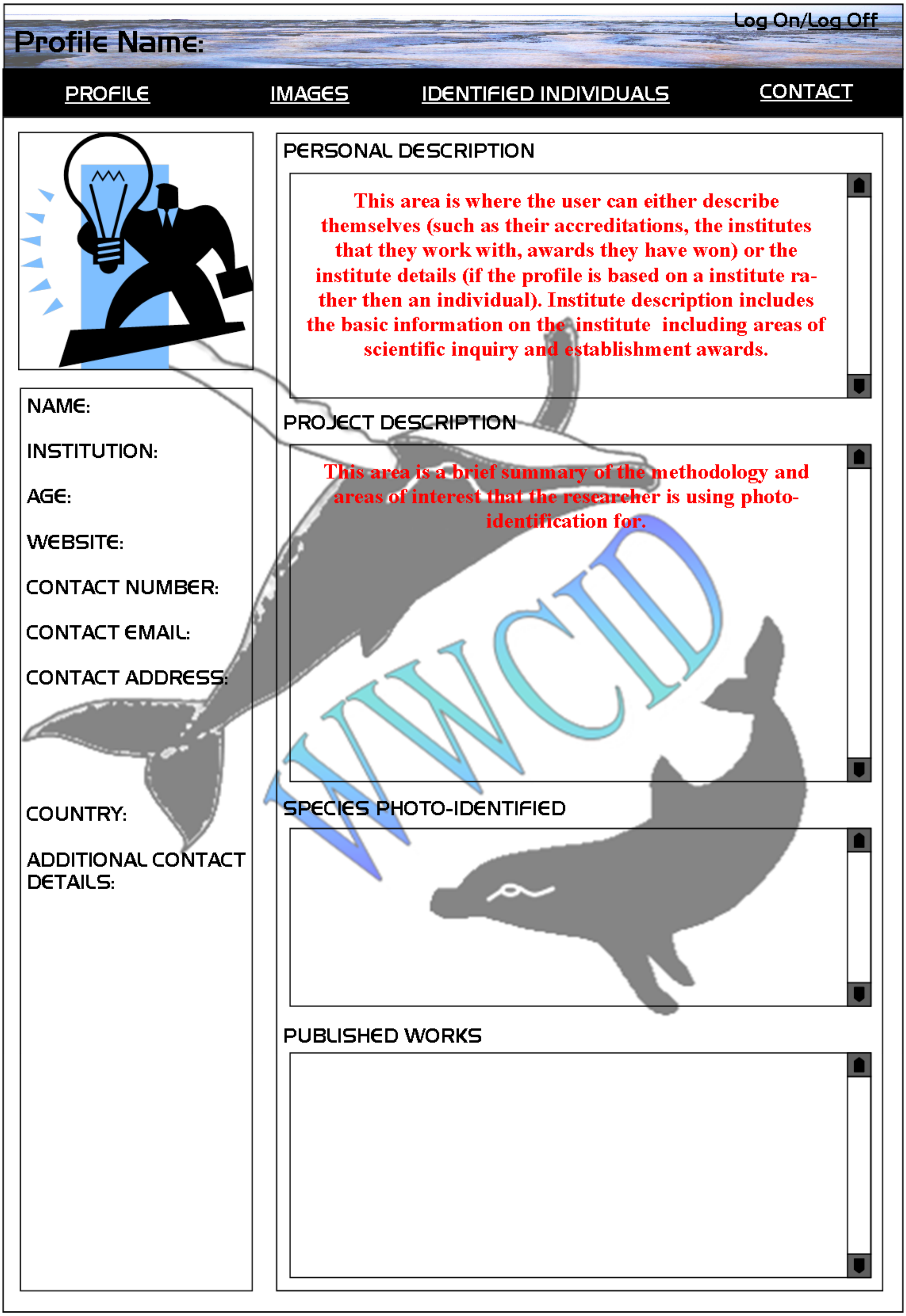

Log On/Log Off
Profile Name:
PROFILE
IMAGES
IDENTIFIED INDIVIDUALS
CONTACT
PERSONAL DESCRIPTION
This area is where the user can either describe themselves (such as their accreditations, the institutes that they work with, awards they have won) or the institute details (if the profile is based on a institute rather then an individual). Institute description includes the basic information on the institute including areas of scientific inquiry and establishment awards.
PROJECT DESCRIPTION
This area is a brief summary of the methodology and areas of interest that the researcher is using photo-identification for.
WWCID
SPECIES PHOTO-IDENTIFIED
PUBLISHED WORKS
NAME:
INSTITUTION:
AGE:
WEBSITE:
CONTACT NUMBER:
CONTACT EMAIL:
CONTACT ADDRESS:
COUNTRY:
ADDITIONAL CONTACT DETAILS:

Figure 9: shows an example of the basic profile set up for a registered user. Basic information is inputted into the profile: user name, real name, institute, contact number, email, address, country and additional contact details. Additional information areas to be filled in include personal description, project description, species photo-identified and published works. The user can additionally upload a profile picture, and other photos from their investigations. The profile also provides links to individuals the user has identified using WWCID.

Basic information taken from the sign-up sheet (Figure 8) is automatically inputted into the profile: user name, real name, institute, contact number, email, address, country and additional contact details. The user can choose to block personal details (see Figure 8). Additional information that can be inputted include a personal description of either the user (if it is a personal profile) or the institute (if the profile is for an institute or business), describing accreditations, awards, institutes that are involved and scientific areas of interest. Project description can be added detailing the methodology, aims, hypothesis and expected out comes from the photo-identification investigation. Published works include all works published by the user or relevant works published by the institute. The user can also choose to upload a profile picture, as well as other photos related to their investigation. In addition the profile provides links to individual cetaceans identified using the WWCID.

PART 3: YOUR ACCOUNT

Once the users profile is set up, as explained in Part 2 (see Figures 8 and 9), all individuals identified by the user will be automatically added to the users profile. When a user signs into their profile they can then click onto the ‘identified individuals’ tab (see Figure 9) and be taken to a page that lists all the individuals they have identified (see Figure 10). Users can access this information directly from a users profile or by conducting a search on another user.

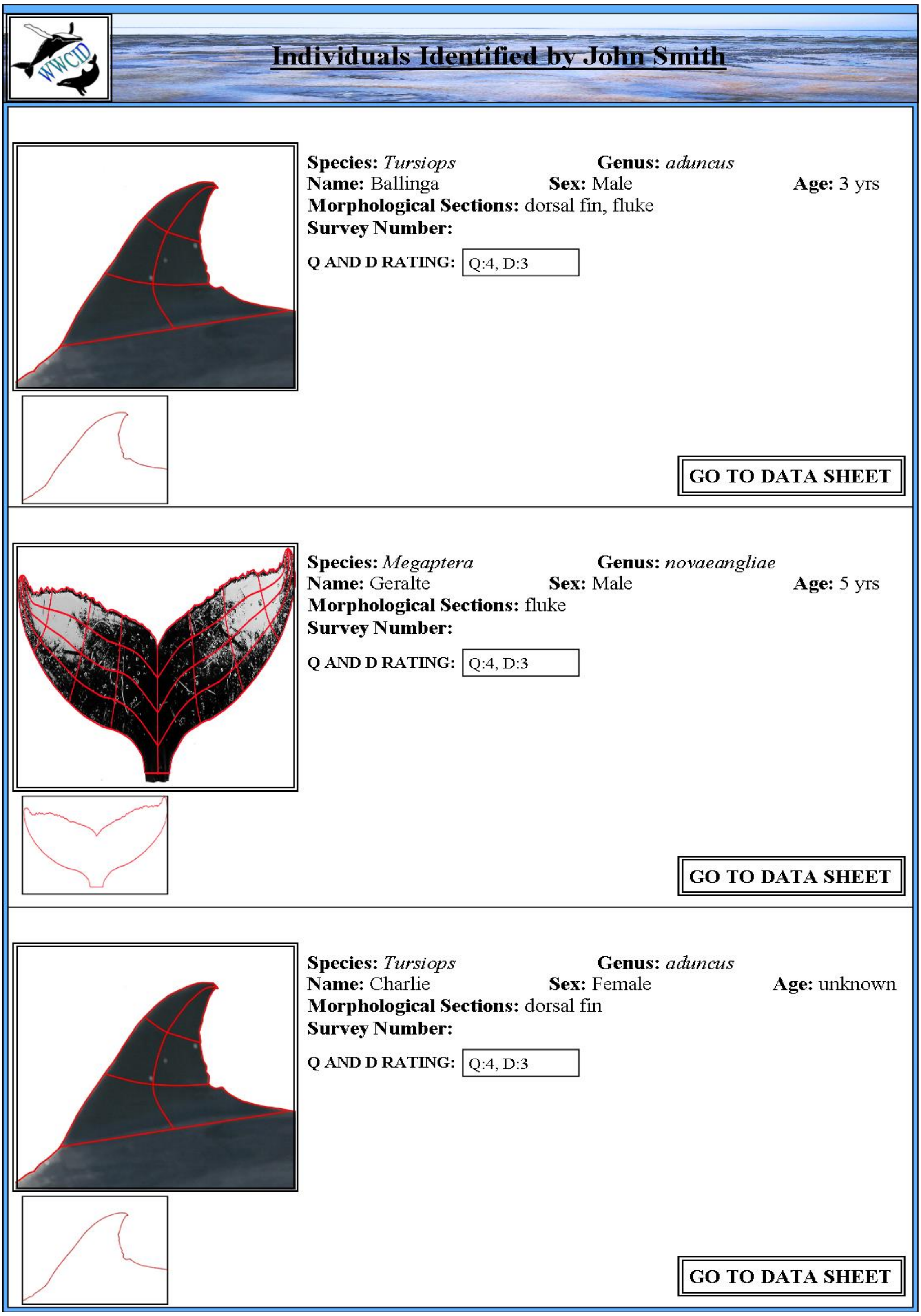


Figure 10: shows the page layout of individuals identified by a certain user. It depicts a brief summary of the

individuals, including species, given name, sex, age, morphological features identified, survey numbers, Q and D rating, a picture of one of the morphological features used and the outline of the shape. The user can then go to the full data sheet for the individual.

PART 4: SEARCHING FOR AN INDIVIDUAL/AREA

Upon logging onto the WWCID database (see Figure 1) and clicking '*Browse Catalogue*' a new search window will open (see Figure 11). The user can then choose to fill out all sections within the search windows or only those pertinent to their investigation. For example a user needing data on individuals of the species *Tursiops aduncus* from Australian waters would only fill out the '*Species*' and '*Area*' sections of the search engine. Users looking for data compiled by a certain user or institute would enter the user/institute name into the '*User*' section. Users searching for individuals of a certain species, geographical area and morphological feature for identification would fill in the '*Species*', '*Area*' and '*Morphological Feature*' sections.

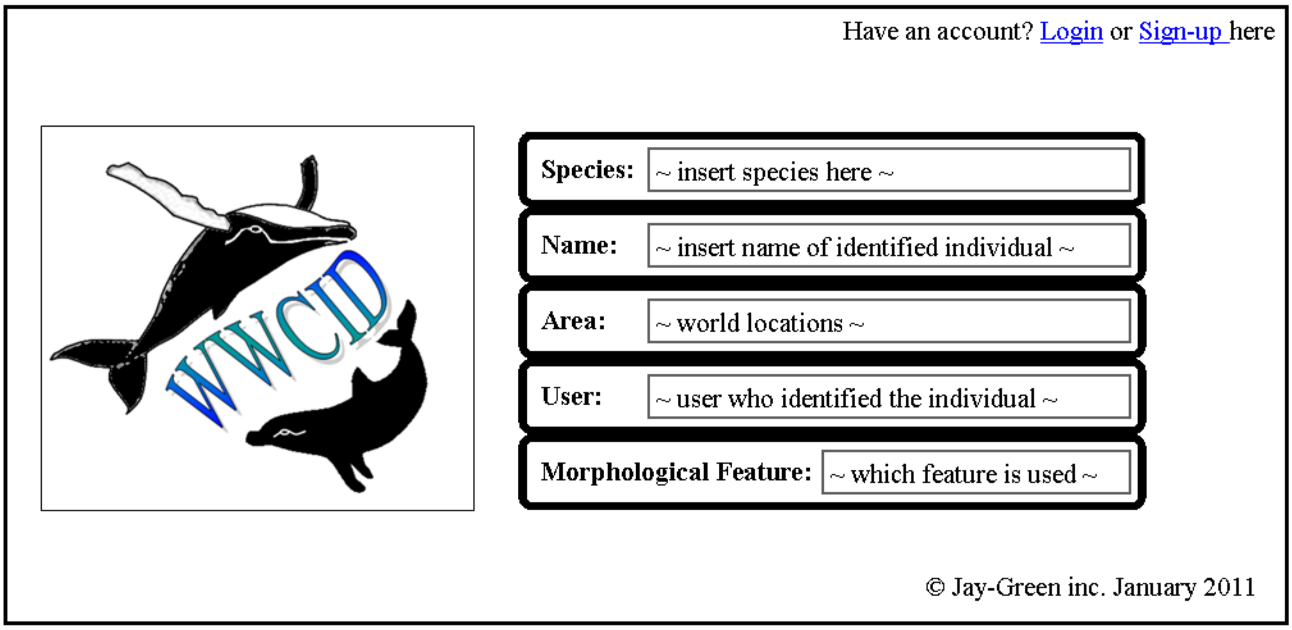


Figure 11: shows the search engine users can use to find certain individuals depending on required parameters. The engine selects individuals depending on specifications listed under the categories: Species, Name, Area, User and Morphological Feature.

PART 5: DOWNLOADING DATABASE FORMS

There are 6 database forms that can be downloaded from the WWCID (see Figure 12). Two forms: 'Survey Form' and 'Photographic Survey Information' are data forms to be filled out during and after photo-identification surveys. They contain all relevant information that should be recorded by the user when taking photos for photo-identification. The 'Survey Form' can then be uploaded to the database during identification of individuals.

Four other forms are all supplied by the database: 'Segmentation of Morphological Features', 'Quality Ratings and Distinctiveness Categories', 'Mark-Types' and 'Natural Mark-Type Categories'. These four sheets provide detailed information on the segmentation process, natural mark-types and photographic qualifications used by the WWCID database. 'Segmentation of Morphological Features' details how segmentation is done, as well as the name and corresponding affixation for each of the segmented areas per morphological feature. 'Quality Ratings and Distinctiveness Categories' details how photographs used in photo-id should be categorized in order to obtain the greatest accuracy in results. 'Mark-Types' shows a listing of the natural mark types that are used in identification, along with photographic examples. 'Natural Mark-Type Categories' shows the same natural mark types but additionally lists the observations that need to be recorded along with the mark types, namely; size, color, strength and direction.

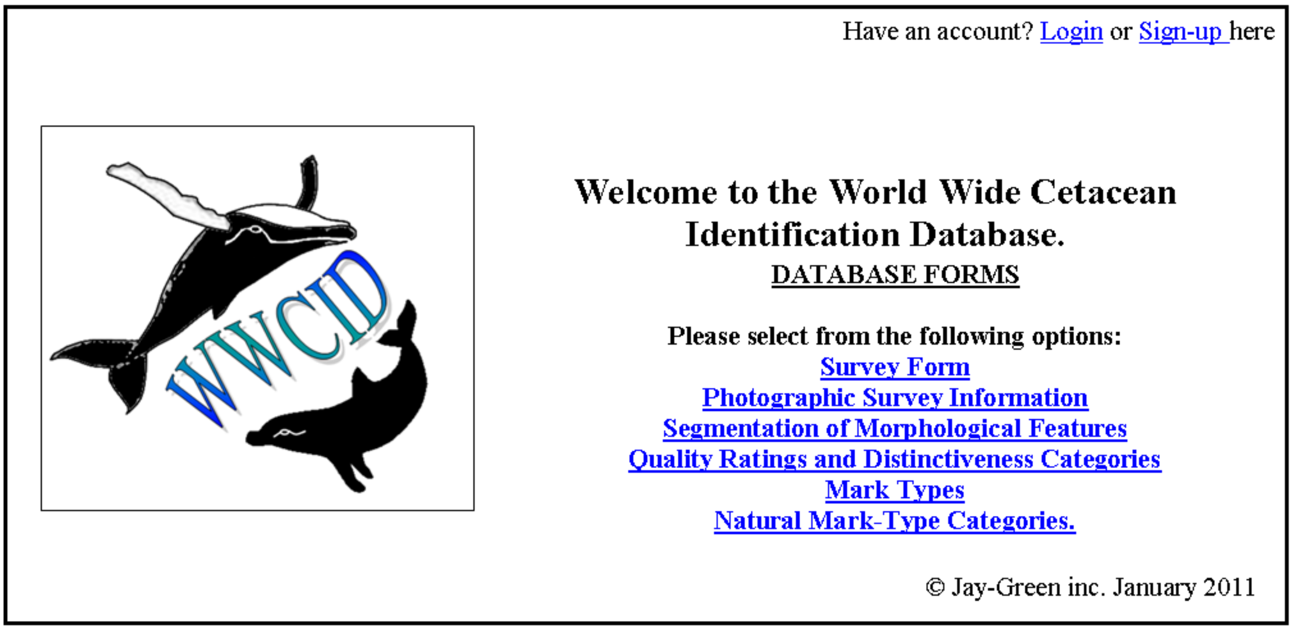


Figure 12: shows the database forms download page. From here the user can download six data forms to be used in conjunction with the WWCID identification process: survey form, photographic survey information, segmentation of morphological features, quality ratings and distinctiveness categories, mark types and natural mark-type categories.

<u>PART 6: VARIABLES TO BE INCLUDED IN CALCULATING PERCENTAGE OF ACCURACY</u>

Common Name	Species Name	Number
Amazon River Dolphin	*Inia geoffrensis*	0
Atlantic Spotted Dolphin	*Stenella frontalis*	1
Atlantic White-Sided Dolphin	*Lagenorhynchus acutus*	2
Australia Snubfin	*Orcaella heinsohnl*	3
Baiji	*Lipotes vexillifer*	4
Beluga Whale	*Delphinapterus leucas*	5
Blainvilles Beaked Whale	*Mesoplodon denisoristris*	6
Blue Whale	*Balaenoptera musculus*	7
Bottlenose Dolphin	*Tursiops* spp.	8
Bowhead Whale	*Balaena mysticetus*	9
Bryde's Whale	*Balaenoptera edeni*	10
Commerson's Dolphin	*Cephalorhynchus commersonii*	11
Cuvier's Beaked Whale	*Ziphius cavirostris*	12
Dall's Porpoise	*Phocoenoides dalli*	13
Dusky Dolphin	*Lagenorhynchus obscurus*	14
False Killer Whale	*Psuedorca crassidens*	15
Fin Whale	*Balaenoptera physalus*	16
Grey Whale	*Eschrichtius robustus*	17
Harbour Porpoise	*Phocoena phocoena*	18
Heavisides Dolphin	*Cephalorhynchus heavisidii*	19
Hectors Dolphin	*Cephalorhynchus hectori*	20
Humpback Dolphin	*Sousa chinensis*	21
Humpback Whale	*Megaptera novaeangliae*	22
Long-Beaked Common Dolphin	*Delphinus capensis*	23
Long-Finned Pilot Whale	*Globicephala melas*	24
Minke Whale	*Balaenoptera acutorostata*	25
North Atlantic Right Whale	*Eubalaena glacialis*	26
North Bottlenose Whale	*Hyperoodon ampullatus*	27
Orca	*Orcinus orca*	28
Pacific White-Sided Dolphin	*Lagenorhyncus obliquidens*	29
Pantropical Spotted Dolphin	*Stenella attenuate*	30
Pygmy Killer Whale	*Feresa attenuate*	31
Risso's Dolphin	*Grampus griseus*	32
Rough-Toothed Dolphin	*Steno bredoriensis*	33
Sei Whale	*Balaenoptera borealis*	34
Short-Beaked Common Dolphin	*Delphinus delphis*	35
Short-Finned Pilot Whale	*Globicephala macrorhyrichus*	36
Southern Right Whale	*Eubalaena australis*	37
Southern Right Whale Dolphin	*Lissodelphis peronii*	38
Sperm Whale	*Physeter macrocephalus*	39
Spinner Dolphin	*Stenella longirostris*	40
Tucuxi Dolphin	*Sotalia fluriatilis*	41

Figure 13: shows the initial choice of species. By assigning them a number the program can determine which species is being used for the comparison.

After the initial segmentation process the program must then sort through the different variables to identify the individual. Firstly, the program must identify which species is being analysed (see Figure 13). Next the program notes the sex and age of the cetacean (if known). As many photo-ID investigations do not involve shots of genitalia or genetic biopsying this will not often be used.

Sex	Number
Female	0
Male	1

Age	Number
>1	0
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	9
10	10
11	11
12	12
13	13
14	14
15	15
16	16
17	17
18	18
19	19
20	20

Q:D Rating	Number
Q1:D1	0
Q1:D2	1
Q1:D3	2
Q1:D4	3
Q1:D5	4
Q2:D1	5
Q2:D2	6
Q2:D3	7
Q2:D4	8
Q2:D5	9
Q3:D1	10
Q3:D2	11
Q3:D3	12
Q3:D4	13
Q3:D5	14
Q4:D1	15
Q4:D2	16
Q4:D3	17
Q4:D4	18
Q4:D5	19
Q5:D1	20
Q5:D2	21
Q5:D3	22
Q5:D4	23
Q5:D5	24

Figure 14: shows the different variables that need to be taken into consideration. By assigning them a number the program can compare the findings for corresponding variables in order to make a match. Each individual is matched by sex and age (if known). Quality rating of the photo is also taken into consideration when determining accuracy of observations.

Quality and distinction ratings have a different impact on the comparison. The higher the number of quality rating the more likely the comparison is going to be correct. In order to determine natural marks present on the morphological feature, high-quality photographs are a necessary facet of photo-ID. The use of photos that are blurred, out of focus, overly dark or bright, and/or do not fully show the morphological feature can result in misidentification. Therefore the database identifies photographs with higher quality ratings and gives a greater percentage of likelihood in matching success (see Figure 14).

Morphology	Number
dorsal	0
flank	1
fluke	2
melon	3

Segment Section	Number
dorsal upper anterior dUA	0
dorsal upper posterior dUP	1
dorsal medial anterior dMA	2
dorsal medial posterior dMP	3
dorsal lower anterior dLA	4
dorsal lower posterior dLP	5
dorsal superior plane dSP	6
dorsal inferior plane dIP	7
dorsal anterior dA	8
flank upper left lateral flaULL	9
flank upper left medial flaULM	10
flank upper right medial flaURM	11
flank upper right lateral flaURL	12
flank lower left lateral flaLLL	13
flank lower left medial flaLLM	14
flank lower right medial flaLRM	15
flank lower right lateral flaLRL	16
fluke upper left lateral left fin fluULLlf	17
fluke upper left medial left fin fluULMlf	18
fluke upper right medial left fin fluURMlf	19
fluke upper anterior left fin fluUAlf	20
fluke upper posterior right fin fluUPrf	21
fluke upper left medial right fin fluULMrf	22
fluke upper right medial right fin fluURMrf	23
fluke upper right lateral right fin fluURLrf	24
fluke second left lateral left fin fluSLLlf	25
fluke second left medial left fin fluSLMlf	26
fluke second right medial left fin fluSLMlf	27
fluke second anterior left fin fluSAlf	28
fluke second posterior right fin fluSPrf	29
fluke second left medial right fin fluSLMrf	30
fluke second right medial right fin fluSRMrf	31
fluke second right lateral right fin fluSRLrf	32
fluke third left lateral left fin fluTLLlf	33
fluke third left medial left fin fluTLMlf	34
fluke third right medial left fin fluTRMlf	35
fluke third anterior left fin fluTAlf	36
fluke third posterior right fin fluTPrf	37
fluke third left medial right fin fluTLMrf	38
fluke third right medial right fin fluTRMrf	39
fluke third right lateral right fin fluTRLrf	40
fluke lower left lateral left fin fluLLLlf	41
fluke lower left medial left fin fluLLMlf	42
fluke lower right medial left fin fluLRMlf	43
fluke lower anterior left fin fluLAlf	44
fluke lower posterior right fin fluLPrf	45
fluke lower left medial right fin fluLLMrf	46
fluke lower right medial right fin fluLRMrf	47
fluke lower right lateral right fin fluLRLrf	48
melon upper cranium mUC	49
melon medial cranium mMC	50
melon lower cranium mLC	51
melon upper melon mUM	52
melon medial melon mMM	53
melon lower melon mLM	54
melon upper rostrum mUR	55
melon medial rostrum mMR	56
melon lower rostrum mLR	57

Figure 15: shows the different variables that need to be taken into consideration. By assigning them a number the program can compare the findings for corresponding variables in order to make a match. Each individual is matched by morphological appendage used and the segment section marked.

Once these basics have been identified the program next catalogues which morphological areas are to be used in the comparison (see Figure 15). From these morphological features the program then identifies which segmented sections the user has noted to be 'marked' (see Figure 16).

Mark Types	Number
back indent	0
bite	1
chopped	2
fin notch	3
hook	4
mutilation	5
abnormal color	6
dark spotting	7
dark patch	8
eye blaze	9
fetal fold	10
saddle bag	11
white spotting	12
white patch	13
defined tooth imprint	14
healing scratch	15
linear parallel	16
linear single	17
multitude scars	18
scratch patch	19
skin scarring	20
squid marks	21
tooth rake	22
white scarring	23
bacteria discolouration	24
fungus	25
lumps	26
open sores	27
swelling	28

Mark Size	Number
large	0
medium	1
small	2

Direction	Number
vertical	0
horizontal	1
angled left	2
angled right	3

Colour	Number
white	0
black	1
grey	2
brown	3

Strength	Number
strong	1
weak	0

Figure 16: shows the different variables that need to be taken into consideration. By assigning them a number the program can compare the findings for corresponding variables in order to make a match. Each individual is matched by mark type per segment section, mark size, direction and color. Strength will be judged on whether a mark is strong or weak.

Next the program identifies which segmented sections have been identified as having marks. Then for each segment marked the program identifies a) the natural mark recorded b) the mark size, c) direction the mark is facing, d) color of the mark and e) the strength of the mark (where applicable, see appendix 6) (see Figure 16). These variables enable the program to compare individuals and determine which individuals amongst those in the database have the closest matching variables. The program also determines the percentage of probability of a match (depending on how many of the variables match between individuals). The strength of the mark, much like the photos quality rating, effects the percentage of impact a mark has. Marks labelled as 'strong' are much less likely to have faded in the time between id's. Therefore if the database contains an individual with 'weak' markings and the user is trying to identify and individual with 'no markings' the database will still consider the possibility of there being a match.

To Summarise: the program compares individuals in the following order: By Species, By Sex (Age may be dismissed as it is difficult to determine accurately), morphological feature, segment section, mark-type, mark size, direction the mark is facing and finally, color of the mark. The photo's quality rating and the strength of the observed mark can affect the probability of a correct match. When compiling matches, the database will not provide a match for the user when there is a lower then 35% likelihood.

CONCLUSION

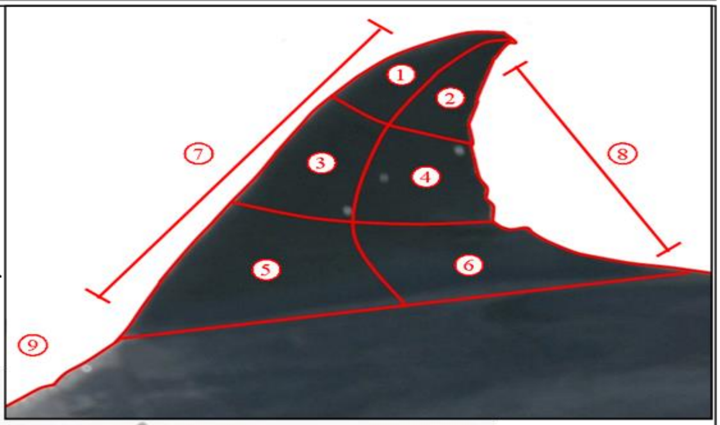
Variation of method of analysis during photo-ID affects the ability of researchers to amalgamate and compare catalogues. By recording different morphological features and alternate labels and stipulations for natural marks comparisons between studies or investigator findings is difficult. To this end we created the WWCID as a online source for photo-ID that can be used on a species wide basis. In addition the WWCID can also be utilized in other investigative methods that do not require set mark-type parameters (such as FinScan or WhaleNet in comparison to FinBase which inputs specific mark attributes).

APPENDICIES

APPENDIX 1: SEGMENTATION OF MORPHOLOGICAL FEATURES

When recording a morphological area for photo-ID it is imperative that investigators note whether it is the left or right, caudal or ventral side being used. Any variations in marks seen from different areas, such as the difference between the left and ride side of the dorsal fin, will affect comparison results.

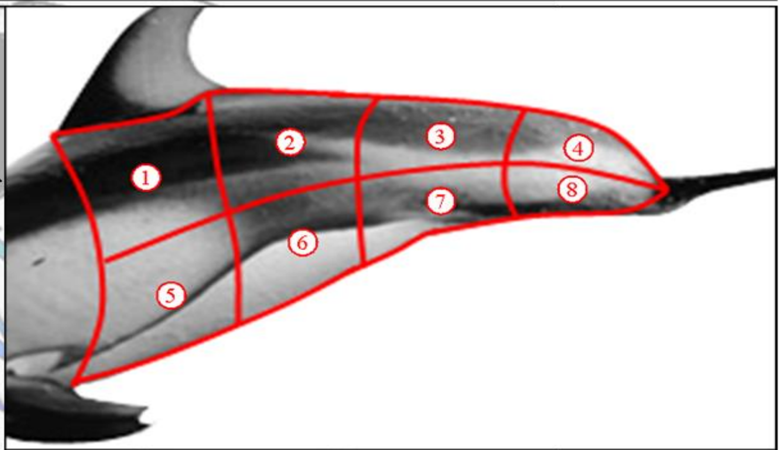
<u>Dorsal Segmentation</u>



For dorsal segmentation a horizontal line is made from the lower anterior point of the dorsal fin (where it connects to the body of the cetacean) to the lower posterior point of the fin. The dorsal fin is then divided into equal thirds with horizontal lines from the proximal to the distal point of the fin. A further vertical division is made half way between the left lateral and right lateral points of the fin base, up to the distal point of the dorsal (see Figure 1).

Dorsal fin segments are labelled by number with each number corresponding to a different area description as follows: 1. upper anterior (UA), 2. upper posterior (UP), 3. medial anterior (MA), 4. medial posterior (MP) 5. lower anterior (LA), 6. lower posterior (LP), 7. superior plane (SP), 8. inferior plane

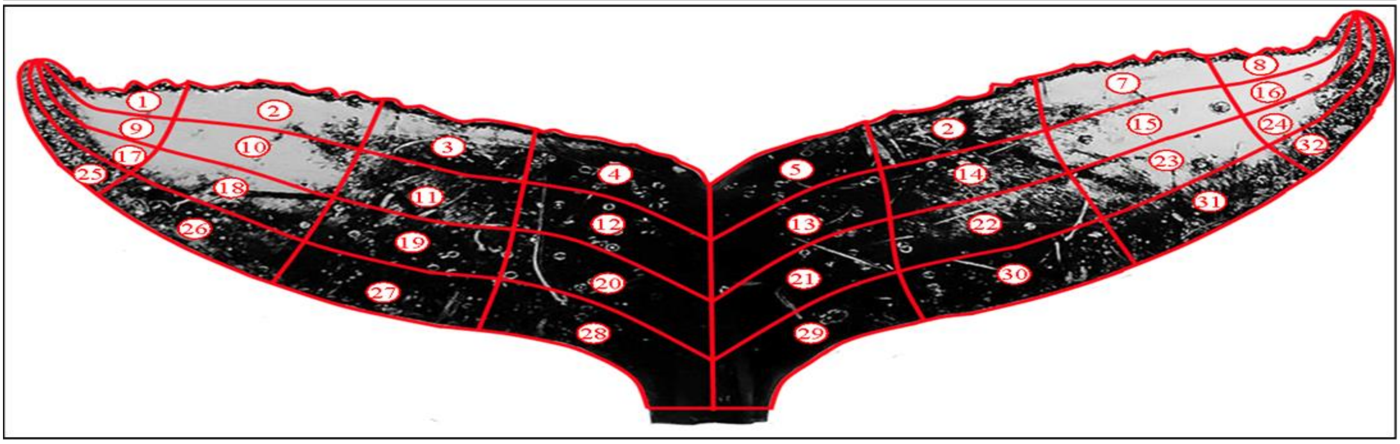
<u>Flank Segmentation</u>



Flank identification is not often considered as a primary form of identification, due to a general lack of discernable natural marks and limited flank flashing behavior seen in cetaceans. In addition the primary feature of identification along the body is the saddlebag, which is often considered as a separate morphological area in itself. However scarring and differing pigmentation patterns along the flank can be used both for identification and to determine effects of anthropogenic threats .

A curved vertical line is made between the lower anterior point of the dorsal fin to the posterior point of the flipper, where it connects to the cetaceans body. A horizontal line is then used to separate the upper and lower areas of the flank, connected between the fluke and the line just drawn. Then three vertical lines are added to separate the flank into 8 different segments (see Figure 2).

Segments are labelled as follows. 1. upper left lateral (ULL), 2. upper left medial (ULM), 3. upper right medial (URM), 4. upper right lateral (URL), 5. lower left lateral (LLL), 6. lower left medial (LLM), 7. lower right medial (LRM), 8. lower right lateral (LRL).



Fluke Segmentation

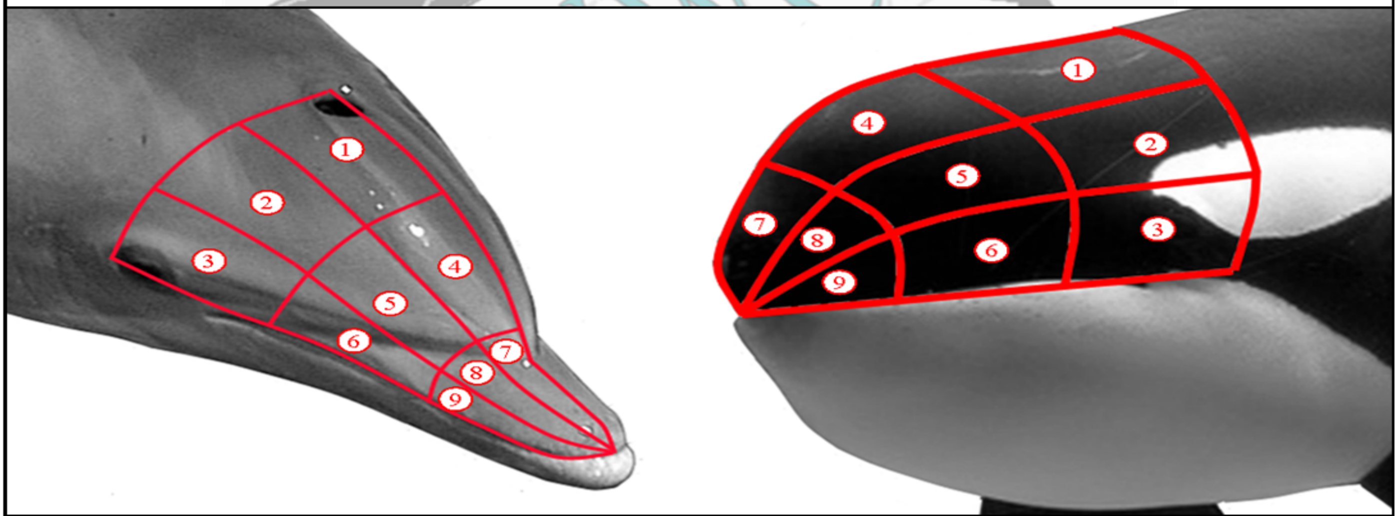
Fluke identification predominantly relies on pigmentation patterns, making segmentation un-necessary. Pigmentation however has been seen to alter during youth, and after death, making recording of marks in addition to pigmentation patterns worthwhile. With this in a segmentation pattern for flukes was formulated that can be used on both the ventral and caudal side of the fluke. Initial division is a vertical line from the median notch to the proximal base of the fluke. The left and right segments of the fluke are then further separated. Three horizontal lines are placed an equal distance from each other running from the vertical medial line to the distal point of the fluke peak. A further three vertical lines are inserted from the trailing edge of the fluke to the side plane (see Figure 3).

Segments are labelled as follows: 1. upper left-lateral (ULL), 2. upper left medial (ULM), 3. upper right medial (URM), 4. upper anterior (UA), 5. upper posterior (UP), 6. upper left medial (ULM), 7. upper right medial (URM), 8. upper right lateral (URL), 9. second left lateral (SLL), 10. second left medial (SLM), 11. second right medial (SRM), 12. second anterior (SA), 13. second posterior (SP), 14. second left medial (SLM), 15. second right medial (SRM), 16. second right lateral (SRL), 17. third left lateral (TLL), 18. third left medial (TLM), 19. third right medial (TRM), 20. third anterior (TA), 21. third posterior (TP), 22. third left medial (TLM), 23. third right medial (TRM), 24. third right lateral (TRL), 25. lower left lateral (LLL), 26. lower left medial (LLM), 27. lower right medial (LRM), 28. lower anterior (LA), 29. lower posterior (LP), 30. lower left medial (LLM), 31. lower right medial (LRM), 32. lower right lateral (LRL).

Due to the fluke being separated into two halves each segment has the additional label of right fin (rf) or left fin (lf). In order to determine the difference between fins each segment acronym will be labeled with the corresponding fin acronym. For example the upper left medials (ULM) for the left and right fins would be labeled ULMlf and ULMrf respectively.

Melon Segmentation

Melon division is difficult due to species variation in morphological features. I have compiled a basic template of division for a side segmentation of two different species melons (see Figure 3). The sections can be used on either side of the melon or placed together to format complete coverage of the cranial area in photo-id's taken from a top view. In these cases it will be necessary to label each section as being either the left or right side of the melon (lm and rm respectively) as is done in fluke segmentation.



Segmentation starts with a horizontal line running from the rostrums proximal point, to just behind the eye (usually following the mouth in dolphin species). The next segment line runs from the rostrum proximal point through the blow-hole to the end of the cranium. A curved line joins the two distal points of these lines connecting them into a border of one side of the head region. The melon is mapped with three horizontal lines running from the rostrum proximal point to the cranium distal line at an equal distance from each other. A further three vertical lines (placed an equal distance apart) join the lowest horizontal line along the jaw to the upper horizontal line through the blowhole.

Segments are labelled as follows. 1. upper cranium (UC), 2. medial cranium (MC), 3. lower cranium (LC), 4. upper melon (UM), 5. medial melon (MM), 6. lower melon (LM), 7. upper rostrum (UR), 8. medial rostrum (MR), 9. lower rostrum (LR).

APPENDIX 2: QUALITY RATINGS, DISTINCTIVENESS CATEGORIES AND CRITERIA.

Criteria: From papers reviewed we have formulated criteria's to be used to determine photographic quality. C1) angle of the body relative to the photo frame – *a*. half or partial view, *b*. full, C2) proportion of feature visible – *a*. half, *b*. full, C3) proportion of the frame filled by the fin – *a*. one third, *b*. two thirds, *c*. full, C4) clear focus, C5) clear contrast between morphological feature and background, C6) clear exposure (excellent view of colors, without being too bright or dark).

Photo Quality Ratings: Each quality rating must fulfill certain portions of the above criteria. Q1) 'terrible' – C: 1a and 2a, Q2) 'poor' – C: 1a, 2a, 3a and 4, Q3) 'good' – C: 1b, 2b, 3a, 4 and 5, Q4) 'very good' – C: 1b, 2b, 3b, 4 and 5, Q5) 'excellent' – C: 1b, 2b, 3c, 4, 5 and 6. Under these guidelines it would be advisable not to use photos under the quality ratings of 'terrible' or 'poor'. If they are used flag should be placed on their quality rating within catalogues.

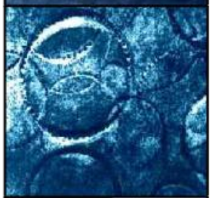
Distinctiveness Categories: It is important to determine each photos distinctiveness. D1) no marks, D2) 1-2 notches, D3) large and small notches, D4) natural-marks and notches, D5) distinctive mutilation, multiple large notches and/or multiple distinctive natural-marks. By labeling photos by distinctiveness category in photo-identification databases it will ease time taken in matching photos caused by differences in noted markings. For example two D5 categories with different markings can be easily verified as two individuals, where as a photo marked as D5 can be linked to a photo with D3 markings that are similar, if less extensive.

Therefore each photo will be sorted by both photo quality rating (composed of listed criteria) and distinctiveness categories. For example a photo that is labeled Q4D3 will fulfill criteria's C1b, C2b, C3b, C4 and C5 and, following distinctiveness categories stipulated above, clearly show both large and small notches. Another example would be a photo labeled Q3D4 which would fulfill criterias C1b, C2b, C3a, C4 and C5 and display both natural-marks and notches.

APPENDIX 3: MARK TYPES

MARK CATEGORY	IMAGE	Sub-MARK TYPE & DESCRIPTION	MARK CATEGORY	IMAGE	Sub-MARK TYPE & DESCRIPTION
Notch		*Back Indent*			*Fetal Fold* Markings along the side and dorsal fin from birth.
		*Bite* Segment of fin removed in the shape of a large bite mark.			*Saddlebag* Large pigment patch on the region posterior to the dorsal.
		*Chopped* Segment of fin completely removed.			*White Spotting* Several white spots.
		*Fin Notch* Small notch segment missing.			*White Patch* Singular area of white pigmentation.
		*Hook* Dorsal fin distal point is hooked over.	**Scarring**		*Defined Tooth Imprint* Teeth mark imprints are visible within scarring.
		*Mutilation*			*Healing Scratch* Light scratch that is healing.
Pigmentation		*Abnormal Colour*			*Linear Parallel*
		*Dark Spotting* Several dark spots.			*Linear Single*
		*Dark Patch* Singular area of dark pigmentation.			*Multitude Scars* Areas with multiple scars of differing size, depth and direction.
		*Eye Blaze*			*Scratch Patch* Several scratch marks overlying each other so that singular scars cannot be determined.

APPENDIX 3: MARK TYPES CONTINUED

MARK CATEGORY	IMAGE	Sub-MARK TYPE & DESCRIPTION	MARK CATEGORY	IMAGE	Sub-MARK TYPE & DESCRIPTION
Scarring		*Skin Scarring* Scars the same colour as the skin.			*Fungus*
		*Squid Marks*			*Lumps*
		*Tooth Rake* Marks raked over the body from teeth.			*Open Sores*
		*White Scarring*			*Swelling*
Skin Lesion		*Bacteria Discolouration*			

APPENDIX 4: INDIVIDUAL SURVEY INFORMATION

Survey Information

Survey Number: ___ Survey Type: ___ Area: ___ Platform: ___

Survey Hours: ___ Distance Travelled: ___ Base No: ___ GPS: ___

Cetacean Information

Species: ___ Genus: ___

Common Name: ___

Age: ___ Sex: ___

Basic Information

Date: ___

Time: ___

Temperature: ___

Form Filled Out By: ___

Equipment

Camera Type: ___

Quality Rating: ___

Distinctiveness Category: ___

Camera Operator: ___

Survey Members

Crew 1: ___

Crew 2: ___

Crew 3: ___

Crew 4: ___

Boat Operator: ___

Conditions

- ☐ Clear skies
- ☐ Low Glare
- ☐ High Glare
- ☐ Cloudy
- ☐ Overcast
- ☐ Stormy
- ☐ Small Breeze
- ☐ High Breeze
- ☐ Gusty
- ☐ High Wind
- ☐ Calm/Flat
- ☐ Ripples
- ☐ Waves
- ☐ White Caps

Individuals

Adults No.: ___

Calf No.: ___

Others: ___

Behaviours Observed

___

Morphologies	(Yes/No)	No. of Photos	Photo Id Used	Quality Rating
Melon				
Dorsal				
Peduncle				
Flank				
Fluke				

Batch No.		Analysis No.		D.O.A	
Analysis Completed By					
Location of Analysis					

APPENDIX 5: PHOTOGRAPHIC SURVEY INFORMATION

Date: **Survey Number:** **Location:** **Base No.:** **GPS:** **Temperature:**
Recorder(s): **Weather:**

Start Time	Serial Number	Photo Numbers	NSIS	Behaviour	Comments	End Time
:	/ / / / /					:
:	/ / / / /					:
:	/ / / / /					:
:	/ / / / /					:
:	/ / / / /					:
:	/ / / / /					:
:	/ / / / /					:
:	/ / / / /					:

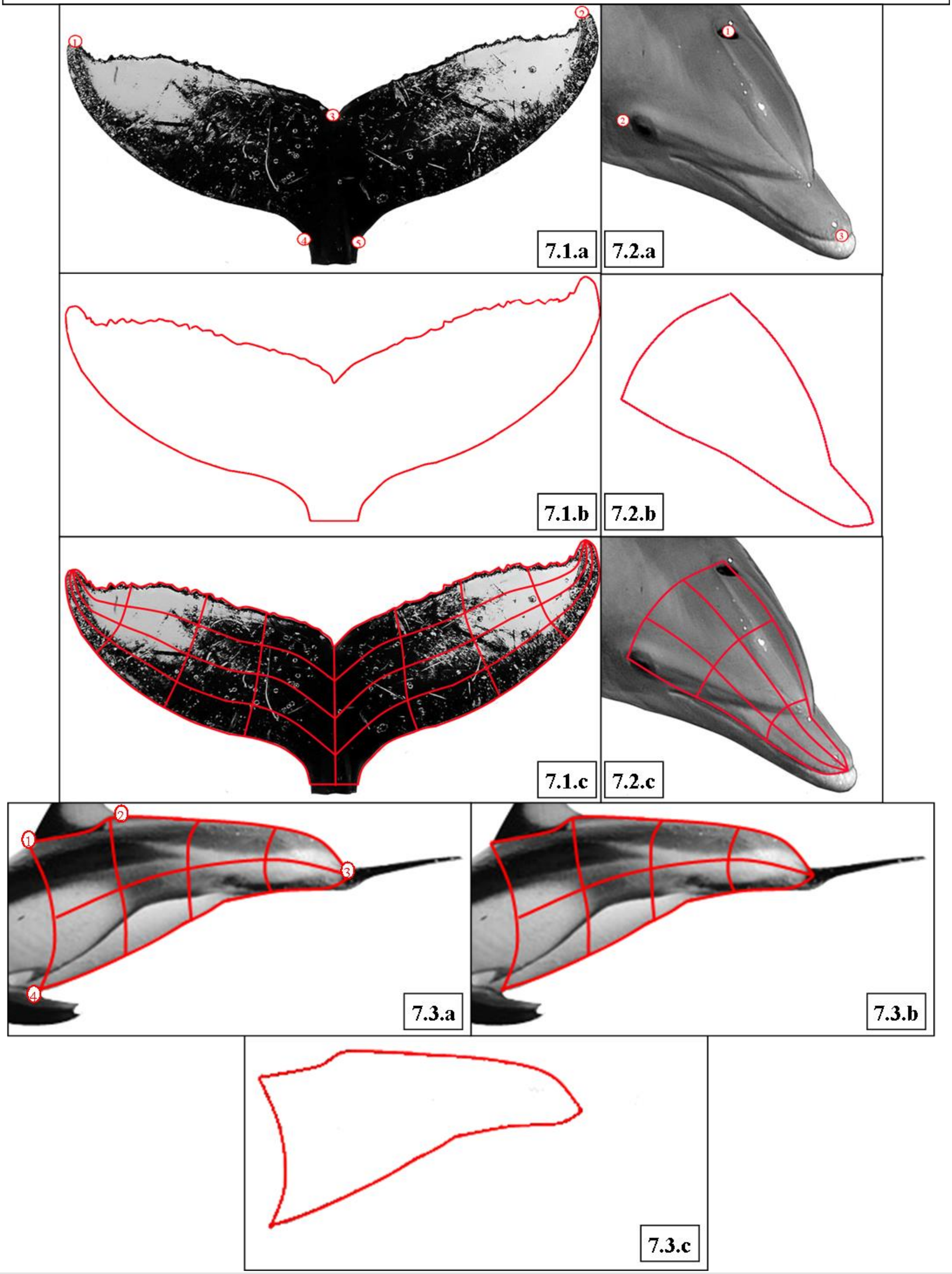
APPENDIX 6: SUMMARY OF TOTAL NATURAL-MARK TYPES LISTED BY CATEGORY AND SUB-MARK TYPE

Note: *(L/M/S):* Indicates Size. L = Large, M = Medium, S = Small. *(W/B/G/Br):* Indicates Color of Mark. W = white, B = black, G = grey and Br = Brown. *(S/W):* Indicates Strength. S = Strong, W = Weak. *(V/H/L/R/):* Indicates Direction. V = Vertical, H = Horizontal, L = Angled Left (\), R = Angled Right (/). *(A):* Applicable **(-):** Not Applicable.

MARK CATEGORY	Sub-MARK TYPE	ADDITIONAL NOTES (L/M/S)	(W/B/G/Br)	(S/W)	(V/H/L/R)	DESCRIPTION
Notch	*Back Indent*	-	-	-	-	-
	Bite	-	-	-	-	Segment of fin removed in the shape of a large bite mark.
	Chopped	-	-	-	-	Segment of fin completely removed.
	Fin Notch	-	-	-	-	Small segment is missing.
	Hook	-	-	-	-	Dorsal fin distal point is hooked over.
	Mutilation	A	-	-	-	-
Pigmentation	*Abnormal Color*	-	A	A	-	-
	Dark Spotting	-	A	A	-	Several white spots.
	Dark Patch	-	A	A	A	Singular area of dark pigment.
	Eye Blaze	-	A	A	-	-
	Fetal Fold	-	A	A	-	Markings along the side and dorsal fin from birth.
	Saddle Bag	-	A	A	-	Large pigment patch on the region posterior to the dorsal.
	White Spotting	-	A	A	-	Several white spots.
	White Patch	-	A	A	A	Singular area of white pigment.
Scarring	*Defined Tooth Imprint*	-	A	A	-	Teeth mark imprints are visible within scarring.
	Healing Scratch	A	A	A	A	Light scratch that is healing.
	Linear Parallel	A	A	A	A	-
	Linear Single	A	A	A	A	-
	Multitude Scars	A	A	A	A	-
	Scratch Patch	A	A	A	A	Several scratch marks overlying each other in a single area.
	Skin Scarring	A	A	A	A	Scars the same color as the skin.
	Squid Marks	-	A	A	-	-
	Tooth Rake	A	A	A	A	Marks raked over the body from teeth.
	White Scarring	A	A	A	A	-
Skin Lesion	*Bacteria Discol.*	-	A	A	A	-
	Fungus	-	-	-	-	-
	Lumps	-	A	-	-	-
	Open Sores	-	-	-	-	-
	Swelling	-	-	-	-	-

Note: sub-Marks such as 'saddlebag' and 'eye blaze' vary from morphological areas of analysis, when their presence is unusual or not of focus.

APPENDIX 7: CETACEAN TEMPLATES



Appendix A3: Southern Right Whale Photographs

a: Photograph Information

Date: 20/06/2011 **Survey Number:** 1-11

Location: Great Australia Bight **GPS:** 31° 48’ S, 131° 11’ E **Base No.:** 1

Recorder(s): Krystal Jay **Survey Hours:** 6

Camera: Pentax SLR K100 D Super with 300mm f4-5.8 telephoto lens

Weather: gusty, bright, slight waves

Temperature:

ST	Serial Number	Age	Photo Number	NSIS	Behavior	Comment	ET
	1-11/1/1/1/KJ/1	Mother	1189-1268, 1290-1292	1 Calf	Travelling/Socializing/Hugging/Resting [S:UW]		
	1-11/1/1/1/KJ/2	Calf	1189-1268, 1290-1292	1 Mother	Travelling/Socializing/Hugging/Resting [S:UW]		12:10
	1-11/1/1/1/KJ/3	Mother	1277-1288	1 Calf			
	1-11/1/1/1/KJ/4	Calf	1277-1288	1 Mother			
	1-11/1/1/1/KJ/5	Adult	1298-1304				
11:20	1-11/1/1/1/KJ/6	Mother	1344-1348	1 Calf			
11:20	1-11/1/1/1/KJ/7	Calf	1344-1348	1 Mother			
12:07	1-11/1/1/1/KJ/8	Mother	1360-1394	1 Calf	Interaction	8 Whales	
12:07	1-11/1/1/1/KJ/9	Calf	1360-1394	1 Mother	Interaction	8 Whales	
	1-11/1/1/1/KJ/10	UnAcc. Male	1399-1417				
	1-11/1/1/1/KJ/11	UnAcc. Adult	1424-1434		Breaching		

1:31	1-11/1/1/1/KJ/12	Mother	1437-1455	1 Calf			
1:31	1-11/1/1/1/KJ/13	Calf	1437-1455	1 Mother			
1:40	1-11/1/1/1/KJ/14	Unacc. Adult	1473-1486	1 Juvenile, 1 Adult	Interaction [H]		
	1-11/1/1/1/KJ/15	Unacc. Adult	1492-1500				
	1-11/1/1/1/KJ/16	Amalg.	1502-1544	½ Adults?	Interaction [H]		
	1-11/1/1/1/KJ/17	Amalg.	1502-1544	½ Adults?	Interaction [H]		
	1-11/1/1/1/KJ/18	Amalg.	1502-1544	½ Adults?	Interaction [H]		
	1-11/1/1/1/KJ/19	Juvenile	1551-1559	1 Juvenile	Interaction [H]	With Vicki	
	1-11/1/1/1/KJ/20	Unacc. Adult	1562-1566		Breaching		
	1-11/1/1/1/KJ/21	Unacc. Adult	1574-1588			With Fred	
	1-11/1/1/1/KJ/22	Mother	1594-1613				
	1-11/1/1/1/KJ/23	Mother	1618-1623				
	1-11/1/1/1/KJ/24	Mother	1626-1661	1 Calf			
	1-11/1/1/1/KJ/25	Calf	1626-1662	1 Mother			

Date: 20/06/2011 **Survey Number:** 1-11

Location: Great Australia Bight **GPS:** 31o 48’ S, 131o 11’ E **Base No.:** 1

Recorder(s): Victoria Ferguson **Survey Hours:** 6

Camera: Canon EOS 40D 18-200 zoom SIGMA lens

ST	Serial Number	Age	Photo Number	NSIS	Behavior	Comment	ET
11:55	1-11/1/1/1-2/VF/1	1 Mother	5220-5264	1 Calf	Resting/Travelling[UW]/Socialising		12:32

11:55	1-11/1/1/1-2/VF/2	1 Calf	5220-5264	1 Mother	Rolling/Travelling/Socialising		12:32
12:23	1-11/1/1/1-2/VF/3	1 Adult	5282-5294	1 Juvenile	Surface/Travelling/Socialising		12:44
12:23	1-11/1/1/1-2/VF/4	1 Juvenile	5282-5294	1 Adult	Travelling/Surface/Rolling/SideFin/Social		12:44
12:44	1-11/1/1/1-2/VF/5	1 Mother	5295-5349	1 Calf	Resting/Socialising		2:12
12:44	1-11/1/1/1-2/VF/6	1 Calf	5295-5349	1 Mother	Side Fin/Socialising		2:12
2:12	1-11/1/1/1-2/VF/7	1 Juvenile	5350-5353		Resting/Socialising/Travelling		2:15
2:45	1-11/1/1/1-2/VF/8	Unacc. Adult	5355		Travelling		
3:43	1-11/1/1/1-2/VF/9	Adult	5360-5362		Side Fin		3:43

Date: 21/06/2011 **Survey Number:** 2-11

Location: Great Australia Bight **GPS:** 31o 48’ S, 131o 11’ E **Base No.:** 2

Recorder(s): Krystal Jay **Survey Hours:** 5

Camera: Pentax SLR K100 D Super with 300mm f4-5.8 telephoto lens

Weather: white caps, large waves, gusty, windy, really high waves

ST	Serial Number	Age	Photo Number	NSIS	Behavior	Comment	ET

11:03	2-11/2/1/1-2/KJ/1	Calf	1671-1685,1717-1746	1 Mother	Resting, travelling	11:22
11:05	2-11/2/1/1-2/KJ/2	Mother	1686-1716,1717-1746	1 Calf	Resting, travelling	11:22
11:15	2-11/2/1/1-2/KJ/3	Juvenile	1747-1805,1805-1817-1826		Resting, fluke floating [S]	12:04
11:28	2-11/2/1/1-2/KJ/4	Mother	1827-1900	2 calf, 2 whales, 1 mum	Resting, interaction [M/H], Fluke [DD], Resting [S], Travelling	12:02
11:28	2-11/2/1/1-2/KJ/5	Calf	1827-1900	2 calf, 2 whales, 1 mum	Resting, interaction [H], Spyhopping, Travelling	12:02
12:10	2-11/2/1/1-2/KJ/6	Juvenile	1922-1955	1 mother, 1 calf	Interaction [M], resting	12:12
12:21	2-11/2/1/1-2/KJ/7	Juvenile	1956-1966			12:21
2:20	2-11/2/1/1-2/KJ/8	Mother	2000-2013			2:21
2:20	2-11/2/1/1-2/KJ/9	Calf	2000-2013			2:21
2:29	2-11/2/1/1-2/KJ/10	Mother	2014-2077			2:31
2:29	2-11/2/1/1-2/KJ/11	Calf	2014-2077			2:31
2:32	2-11/1/1-2/KJ/12	Mother	2078-2090			2:32
2:32	2-11/1/1-2/KJ/13	Calf	2078-2090			2:32
2:32	2-11/1/1-2/KJ/14	Juvenile	2091-2104			2:32

2:34	2-11/1/1-2/KJ/15		2096-2098				2:34

Date: 21/06/2011 **Survey Number:** 2-11

Location: Great Australia Bight **GPS:** 31o 48' S, 131o 11' E **Base No.:** 2

Recorder(s): Victoria Ferguson **Survey Hours:** 6

Camera: Canon EOS 40D 18-200 zoom SIGMA lens

Weather: partly cloudy & windy

ST	Serial Number	Age	Photo Number	NSIS	Behavior	Comment	ET
11:26	2-11/2/1/1-2/VF/1	Mother	5371-5391	1 Calf	Travelling/Resting/Sunbaking		11:42
11:26	2-11/2/1/1-2/VF/2	Calf	5371-5391	1 Mother	Socialising/Travelling/Resting		11:42
11:26	2-11/2/1/1-2/VF/3	Mother	5371-5377	1 Calf	Resting/Travelling		11:31
11:26	2-11/2/1/1-2/VF/4	Calf	5371-5377	1 Mother	Resting/Travelling		11:31
11:50	2-11/2/1/1-2/VF/5	Mother	5378-5418	1 Calf	Resting		12:11
11:50	2-11/2/1/1-2/VF/6	Calf	5378-5418	1 Mother	Side-Fluke		12:11
12:12	2-11/2/1/1-2/VF/7	Mother	5419-5433	1 Calf	Travelling/Resting		12:25
12:12	2-11/2/1/1-2/VF/8	Calf	5419-5433	1 Mother	Travelling/Resting		12:25

Date: 22/06/2011 **Survey Number:** 3-11

Location: Great Australia Bight **GPS:** 31o 48' S, 131o 11' E **Base No.:** 1

Recorder(s): Krystal Jay **Survey Hours:** 4

Camera: Pentax SLR K100 D Super

Weather: clear skies, medium waves

ST	Serial Number	Age	Photo Number	NSIS	Behavior	Comment	ET
11:03	3-11/1/1/1/KJ/1	Albino baby	2155-2299	1 mother			11:17
11:03	3-11/1/1/1/KJ/2	Mother	2155-2299	1 Calf (a)			11:17
11:20	3-11/1/1/1/KJ/3	Juvenile	2300-2332			Vicki's first	11:21
11:27	3-11/1/1/1/KJ/4	Mother	2338-2371		Interaction [M]	Juvenile within 100m	11:28
11:31	3-11/1/1/1/KJ/6	Juvenile	2373-2463			Fred recording	11:37
11:42	3-11/1/1/1/KJ/7	Mother	2466-2514				11:44
11:48	3-11/1/1/1/KJ/8	Amalgam.	2522-2544				11:49
11:48	3-11/1/1/1/KJ/9	Amalgam.	2522-2544				11:49
11:48	3-11/1/1/1/KJ/10	Amalgam.	2522-2544				11:49
11:50	3-11/1/1/1/KJ/11	Juvenile	2545-2565			Vicki's Recording	11:53
11:54	3-11/1/1/1/KJ/12	Mother	2567-2628	1 Calf			12:01
11:54	3-11/1/1/1/KJ/13	Calf	2567-2628	1 Mother			12:01
12:05	3-11/1/1/1/KJ/14	Mother	2629-2688	1 Calf, 2 Whales	first lot one of freds then after tails bent photo the rest are		12:07

					of the newbies		
12:05	3-11/1/1/1/KJ/15	Calf	2629-2688	1 Mother, 2 Whales	first lot one of freds then after tails bent photo the rest are of the newbies		12:07
12:05	3-11/1/1/1/KJ/16	Adult	2629-2688	1 whale, 1 calf, 1 mum	first lot one of freds then after tails bent photo the rest are of the newbies		12:07
12:05	3-11/1/1/1/KJ/17	Adult	2629-2688	1 whale, 1 calf, 1 mum	first lot one of freds then after tails bent photo the rest are of the newbies		12:07
12:12	3-11/1/1/1/KJ/18	Juvenile	2691-2711				12:13
12:18	3-11/1/1/1/KJ/19	Mother	2721-2734	1 Calf	1st lot M & C, then just M		12:19
12:18	3-11/1/1/1/KJ/20	Calf	2721-2734	1 Mother	1st lot M & C, then just M		12:19
12:20	3-11/1/1/1/KJ/21	Juvenile	2736-2763				12:21
12:28	3-11/1/1/1/KJ/22	Juvenile	2764-2774	1 Calf, 1 Mother			12:28
12:28	3-11/1/1/1/KJ/23	Mother	2764-2774	1 Calf, 1 Juvenile			12:28
12:28	3-11/1/1/1/KJ/24	Calf	2764-2774	1 Mother, 1 Juvenile			12:28
12:57	3-11/1/1/1/KJ/25	Juvenile	2776-2825				12:59
1:01	3-11/1/1/1/KJ/26	Mother	2827-2846	1 Calf		Most of mother	1:02
1:01	3-11/1/1/1/KJ/27	Calf	2827-2846	1 Mother		Most of Mother	1:02
1:11	3-11/1/1/1/KJ/28	Mother	2847-2927	1 Calf, 1 Juvenile	Interacted with Juvenile		1:17
1:11	3-11/1/1/1/KJ/29	Calf	2847-2927	1 Mother, 1 Juvenile	Breached, interacted with Juvenile		1:17
1:11	3-11/1/1/1/KJ/30	Juvenile	2847-2927	1 Mother, 1 Juvenile	Interacted with mother and calf		1:17
1:23	3-11/1/1/1/KJ/31	Adult	2931-2938			fluke shot for scars	1:23
1:45	3-11/1/1/1/KJ/32	Mother	2939-2989	1 Calf, 1 Juvenile			1:50
1:45	3-11/1/1/1/KJ/33	Calf	2939-2989	1 Mother, 1 Juvenile	Breach		1:50

ST	Serial Number	Age	Photo Number	NSIS	Behavior	Comment	ET
1:52	3-11/1/1/1/KJ/34		2991-3033	1 Mother, 1 Calf	Trying to interact with mother and calf		1:55
1:55	3-11/1/1/1/KJ/35		3036-3045				1:55
2:10	3-11/1/1/1/KJ/36	Unacc. Adult	3046-3063			Raining	2:12
2:14	3-11/1/1/1/KJ/37		3064-3091		avoidance	No hint, raining	2:16

Date: 22/06/2011 **Survey Number:** 4-11

Location: Great Australia Bight **GPS:** 31o 48’ S, 131o 11’ E **Base No.:** 2

Recorder(s): Victoria Ferguson **Survey Hours:** 4

Camera: Canon EOS 40D 15-200mm Zoom SIGMA lens

Weather: Cloudy

ST	Serial Number	Age	Photo Number	NSIS	Behavior	Comment	ET
1:22	3-11/1/1/1/VF/1	Mother	5442-5461	1 Calf	Hugging/Interaction		1:38
1:22	3-11/1/1/1/VF/2	Calf	5442-5461	1 Mother	Hugging/Interaction		1:38
1:50	3-11/1/1/1/VF/3	Mother	5464-5474	1 Calf			1:58
1:50	3-11/1/1/1/VF/4	Calf	5464-5474	1 Mother			1:58
2:13	3-11/1/1/1/VF/5	Mother	5463-5486	1 Calf			2:20
2:13	3-11/1/1/1/VF/6	Calf	5463-5486	1 Mother			2:20

Date: 23/06/2011 **Survey Number:** 4-11

Location: Great Australia Bight **GPS:** 31o 48’ S, 131o 11’ E **Base No.:** 1

Recorder(s): Krystal Jay **Survey Hours:** 6

Camera: Pentax SLR K100 D Super with 300mm f4-5.8 telephoto lens

Weather: Calm, overcast, slight swell

ST	Serial Number	Age	Photo Number	NSIS	Behavior	Comment	ET
10:52	4-11/2/1/1/KJ/1	Juvenile	3099-3118		Fin flapping, large exhale	Freds whale 1	10:53
10:58	4-11/2/1/1/KJ/2	Juvenile	3119-3124		Partial breech, slight slap, interaction [L]		10:59
11:13	4-11/2/1/1/KJ/3	Mother	3125-3144	1 Calf	Resting, travelling		11:15
11:13	4-11/2/1/1/KJ/4	Calf	3125-3144	1 Mother	Resting, travelling		11:15
11:26	4-11/2/1/1/KJ/5	Mother	3156-3159	1 Calf			11:26
11:26	4-11/2/1/1/KJ/6	Calf	3156-3159	1 Mother			11:26
11:46	4-11/2/1/1/KJ/7	Mother	3163-3180	1 Calf, 1 Juvenile			11:48
11:46	4-11/2/1/1/KJ/8	Calf	3163-3180	1 Mother, 1 Juvenile			11:48
11:46	4-11/2/1/1/KJ/9	Juvenile	3163-3180	1 Calf, 1 Mother			
11:48	4-11/2/1/1/KJ/10	Amalg.	3181-3184				11:49
11:50	4-11/2/1/1/KJ/11	Mother	3185 –3192	1 Calf			11:50
11:50	4-11/2/1/1/KJ/12	Calf	3185 –3192	1 Mother			11:50
11:54	4-11/2/1/1/KJ/13	Random	3193-3197				11:54
12:03	4-11/2/1/1/KJ/14	Adult	3198-3212	1 mother, 1 calf	Interaction [fast moving], travelling slow	Int. with freds whale	12:04
12:21	4-11/2/1/1/KJ/15	Adult	3219-3251		Breech		12:23
12:40	4-11/2/1/1/KJ/16	?	3252-3272	1 mother, 1 Calf	Resting, Interaction		12:43

12:49	4-11/2/1/1/KJ/17	Mother	3273-3297	1 mom, 1 calf, 1 juv, 1 adult	Interaction [H]		12:53
12:58	4-11/2/1/1/KJ/18	Mother	3299-3310	1 Calf		Left amalg. Inter.	12:58
12:58	4-11/2/1/1/KJ/19	Calf	3299-3310	1 Mother		Left amalg. Inter	12:58
12:59	4-11/2/1/1/KJ/20	Mother	3311-3331		sunbaking		1:07
2:14	4-11/2/1/1/KJ/21	Mother	3333-3339	1 Calf		Few whales	2:15
2:14	4-11/2/1/1/KJ/22	Calf	3333-3339	1 Mother		Few whales	2:15
2:26	4-11/2/1/1/KJ/23	Mother	3341-3349	1 Calf			2:26
2:26	4-11/2/1/1/KJ/24	Calf	3341-3349	1 Mother			2:26
2:50	4-11/2/1/1/KJ/25	Calf	3351-3358				2:51
2:55	4-11/2/1/1/KJ/26	Mother	3359-3368	1 Calf	Low travelling, WWP [I]	Can hear in rec.	2:57
2:55	4-11/2/1/1/KJ/27	Calf	3359-3368	1 Mother	Low travelling, WWP [I]	Can hear in rec.	2:57
3:07	4-11/2/1/1/KJ/28	Mother	3370-3380	1 Calf, 1 adult	Interaction [L]	No response	3:07
3:07	4-11/2/1/1/KJ/29	Calf	3370-3380	1 Mother, 1 adult	Interaction [L]	No response	3:07
3:07	4-11/2/1/1/KJ/30	Adult	3370-3380	1 mom, 1 calf	Interaction [L], Travelling	No response	3:07
3:24	4-11/2/1/1/KJ/31	Calf [A]	3385-3446			Far off shots	3:36
3:37	4-11/2/1/1/KJ/32	Group	3448-3453		Interaction [H]		3:37
3:37	4-11/2/1/1/KJ/33	Group	3448-3453		Interaction [H]		3:37
3:37	4-11/2/1/1/KJ/34	Group	3448-3453		Interaction [H]		3:37
3:38	4-11/2/1/1/KJ/35	Juvenile	3455-3471		Tail flip, Noise		3:39
3:40	4-11/2/1/1/KJ/36	Adult	3472-3524	1 mom, 1 calf	Interaction [H]	Pos. pregnant? Last.	3:49
3:40	4-11/2/1/1/KJ/37	Mother	3472-3524	1 calf, 1 adult	Interaction [H]		3:49

3:40	4-11/2/1/1/KJ/38	Calf	3472-3524	1 mom, 1 adult	Interaction [H]		3:49
3:58	4-11/2/1/1/KJ/39	Juvenile	3526-3531				4:06

Date: 23/06/2011 **Survey Number:** 4-11

Location: Great Australia Bight **GPS:** 31o 48' S, 131o 11' E **Base No.:** 1

Recorder(s): Victoria Ferguson **Survey Hours:** 6

Camera: Canon EOS 40D 15-200mm Zoom SIGMA lens

Weather: Calm, overcast, slight swell

ST	Serial Number	Age	Photo Number	NSIS	Behavior	Comment	ET
11:46	4-11/2/1/1/VF/1	Mother	5533-5544	1 Calf	Resting		11:53
11:46	4-11/2/1/1/VF/2	Calf	5533-5544	1 Mother	Resting		11:53
12:24	4-11/2/1/1/VF/3	?	5553-5641		Breeching		12:27
12:41	4-11/2/1/1/VF/4	Juvenile	5644-5652		Fin Slap		12:42
12:44	4-11/2/1/1/VF/5	Adult	5653-5656		Travelling		12:44
1:01	4-11/2/1/1/VF/6	Mother	5660-5707	1 Calf	Hugging, Interaction [H]		1:11
1:01	4-11/2/1/1/VF/7	Calf	5660-5707	1 Mother	Hugging, Interaction [H]		1:11
2:56	4-11/2/1/1/VF/8	Mother	5717-5721	1 Calf	Resting, Interaction [L]		2:58
2:56	4-11/2/1/1/VF/9	Calf	5717-5721	1 Mother	Resting, Interaction [L]		2:58
3:02	4-11/2/1/1/VF/10	Juvenile	5736-5744	1 Mother, 1 Calf	Travelling, Interaction [L]		3:11
3:16	4-11/2/1/1/VF/11	Mother	5746-5755	1 Calf	Resting		3:19

3:16	4-11/2/1/1/VF/12	Calf	5746-5755	1 Mother	Resting		3:19
3:27	4-11/2/1/1/VF/13	Mother	5756-5778	1 Calf [A]	Travelling		3:30
3:27	4-11/2/1/1/VF/14	Calf	5756-5778	1 Mother	Travelling		3:30

Date: 24/06/2011 **Survey Number:** 5-11

Location: Great Australia Bight **GPS:** 31o 48’ S, 131o 11’ E **Base No.:** 2

Recorder(s): Krystal Jay **Survey Hours:** 5

Camera: Pentax SLR K100 D Super with 300mm f4-5.8 telephoto lens

Weather: Clear skies, slight offshore breeze, slight swell

ST	Serial Number	Age	Photo Number	NSIS	Behavior	Comment	ET
11:07	5-11/2/1/1/KJ/1	Adult	3538-3543, 3546-3551	1 Juvenile	Travelling, Interaction [H]	Stay together	11:12
11:07	5-11/2/1/1/KJ/2	Juvenile	3538-3543, 3546-3551	1 Adult	Travelling, Interaction [H]	Stay together	11:12
11:10	5-11/2/1/1/KJ/3	Calf	3544, 3553-3571	1 Mother	Resting on Mother	Vicki’s whale	11:18
11:10	5-11/2/1/1/KJ/4	Mother	3553-3571	1 Calf	Resting	Vicki’s Whale	11:18
11:25	5-11/2/1/1/KJ/5	?	3572-3574		Sailing	Too distant	11:25
11:35	5-11/2/1/1/KJ/6	Mother	3578-3594	1 Calf	Travelling	Fred’s whale 11:40	11:44
11:35	5-11/2/1/1/KJ/7	Calf	3578-3594	1 Mother	Travelling	Fred’s whale 11:40	11:44
11:49	5-11/2/1/1/KJ/8	Mother	3595-3597	1 Calf	Travelling		11:59
11:49	5-11/2/1/1/KJ/9	Calf	3595-3597	1 Mother	Travelling		11:59
12:18	5-11/2/1/1/KJ/10	?	3615-3635		Breeching	Far offshore	12:19
1:23	5-11/2/1/1/KJ/11	Mother	3644-3660	1 Calf	Resting		1:25

1:23	5-11/2/1/1/KJ/12	Calf	3644-3660	1 Mother	Resting		1:25
1:27	5-11/2/1/1/KJ/13	Mother	3662-3668	1 Calf			1:27
1:28	5-11/2/1/1/KJ/14	Mother	3670-3810	1 Calf	Resting, Breeching, Fluke/Fin Slapping, Sunbaking		2:01
1:28	5-11/2/1/1/KJ/15	Calf	3670-3688, 3794-33810	1 Mother	Resting		2:01
2:05	5-11/2/2/1/KJ/1	Dolphins	3811-3982	1 Dolphin	Feeding	2 Dolphins	2:19
2:05	5-11/2/2/1/KJ/2	Dolphin	3811-3982	1 Dolphin	Feeding	2 Dolphins	2:19
2:24	5-11/2/1/1/KJ/16	?	3984-3991		Travelling		2:24
2:27	5-11/2/1/1/KJ/17	Mother	3992-4005	1 Calf	Travelling, puts head out water	Fred Whale	2:29
2:27	5-11/2/1/1/KJ/18	1 Calf	3992-4005	1 Mother	Resting		2:29
2:36	5-11/2/1/1/KJ/19	1 Mother	4007-4013	1 Calf	Travelling		2:36
2:36	5-11/2/1/1/KJ/20	1 Calf	4007-4013	1 Mother	Travelling		2:36
2:50	5-11/2/1/1/KJ/21	1 Mother	4017-4159	1 Calf [A]	Travelling		3:09
2:50	5-11/2/1/1/KJ/22	1 Calf [A]	4017-4159	1 Mother	Travelling		3:09
3:21	5-11/2/1/1/KJ/23	Juvenile	4161-4174				3:24
3:39	5-11/2/1/1/KJ/24	Mother	-4185	1 Calf			3:40
3:43	5-11/2/1/1/KJ/25	Mother	4186-4195	1 Calf [A]			3:44
3:45	5-11/2/1/1/KJ/26	Mother	4197-4219	1 Calf	Travelling		3:46
3:45	5-11/2/1/1/KJ/27	Calf	4197-4219	1 Mother	Travelling		3:46
3:56	5-11/2/1/1/KJ/28	Juvenile	4225-4235		Slow Travelling		3:56

Date: 24/06/2011 **Survey Number:** 5-11

Location: Great Australia Bight **GPS:** 31o 48' S, 131o 11' E **Base No.:** 2

Recorder(s): Victoria Ferguson **Survey Hours:** 5

Camera: Canon EOS 40D 15-200mm Zoom SIGMA lens

Weather: Clear skies, slight offshore breeze, slight swell

ST	Serial Number	Age	Photo Number	NSIS	Behavior	Comment	ET
2:03	5-11/2/1/1/VF/1	Mother	5819-5833	1 Calf	Resting		2:09
2:03	5-11/2/1/1/VF/2	Calf	5819-5833	1 Mother	Resting		2:09
2:57	5-11/2/1/1/VF/3	Mother	6116-6149	1 Calf [A]	Travelling		3:11
2:57	5-11/2/1/1/VF/4	Calf [A]	6116-6149	1 Mother	Travelling		3:11

Date: 25/06/2011 **Survey Number:** 5-11

Location: Great Australia Bight **GPS:** 31o 48' S, 131o 11' E **Base No.:** 1

Recorder(s): Krystal Jay **Survey Hours:** 5

Camera: Pentax SLR K100 D Super with 300mm f4-5.8 telephoto lens

Weather: windy, clear, white caps [far off shore], offshore winds

ST	Serial Number	Age	Photo Number	NSIS	Behavior	Comment	ET
10:41	6-11/1/1/1/KJ/1	Mother	4237-4261	1 Calf			10:54
10:41	6-11/1/1/1/KJ/2	Calf	4237-4261	1 Mother	Extremely playful		10:54
11:00	6-11/1/1/1/KJ/3	Mother	4263-4272	1 Calf	Travelling	Vicki's whales	11:00

11:00	6-11/1/1/1/KJ/4	Calf	4263-4272	1 Mother	Travelling	Vicki's whales	11:00
11:02	6-11/1/1/1/KJ/5	Mother	4274-4282	1 Calf		Freds whales	11:03
11:02	6-11/1/1/1/KJ/6	Calf	4274-4282	1 Mother		Freds whales	11:03
11:10	6-11/1/1/1/KJ/7	Mother	4310-4329	1 Calf	Resting		11:27
11:10	6-11/1/1/1/KJ/8	Calf	4310-4329	1 Mother	Exploring		11:27
11:30	6-11/1/1/1/KJ/9	Mother	4331-4337	1 Calf [A]	Travelling	Far offshore	11:34
11:30	6-11/1/1/1/KJ/10	Calf [A]	4331-4337	1 Mother	Travelling	Far offshore	11:34
11:42	6-11/1/1/1/KJ/11	Mother	4340-4396	1 Calf	Travelling [s]		11:52
11:42	6-11/1/1/1/KJ/12	Calf	4340-4396	1 Mother	Travelling [s]	'Flash Gordon'	11:52
11:57	6-11/1/1/1/KJ/13	Mother	4400-4402	1 Calf	Travelling [f], highly agitated		11:57
11:57	6-11/1/1/1/KJ/14	Calf	4400-4402	1 Mother	Travelling [f], following mum		11:57
12:24	6-11/1/1/1/KJ/15	Mother	4404-4427	1 Calf	Resting, Travelling [f]	Agitated and left	12:25
12:24	6-11/1/1/1/KJ/16	Calf	4404-4427	1 Mother	Resting, travelling [f]	Agitated and left	12:25
1:57	6-11/1/1/1/KJ/1	Turtle	4429-4436			Leatherback	1:59
2:08	6-11/1/1/1/KJ/17	Juvenile	4448-4451		Resting behaviour		2:09
2:19	6-11/1/1/1/KJ/18	Mother	4494-4496	1 calf	Travelling [s]	Barely moving	2:38
2:19	6-11/1/1/1/KJ/19	Calf	4494-4496, 4506-4533	1 mother	Travelling [s]	Barely moving	2:38
2:22	6-11/1/1/1/KJ/20	Juvenile	4499-4504				2:22
2:49	6-11/1/1/1/KJ/21	Amalg	4540-4547				2:49

1-11/1/SRW/1/KJ/1—BACK

1-11/1/SRW/1/KJ/1—FRONT

1-11/1/SRW/1/KJ/1—LEFT

1-11/1/SRW/1/KJ/1—FLIPleft

1-11/1/SRW/1/KJ/1—RIGHT

1-11/1/SRW/1/KJ/2—RIGHT

1-11/1/SRW/1/KJ/2—FLIPrightinner

1-11/1/SRW/1/KJ/3—BACK

1-11/1/SRW/1/KJ/5—FLIP1left

1-11/1/SRW/1/KJ/5—FLIP2left

1-11/1/SRW/1/KJ/6—RIGHT

1-11/1/SRW/1/KJ/8—RIGHT

1-11/1/SRW/1/KJ/10—LEFT

1-11/1/SRW/1/KJ/11—RIGHT

1-11/1/SRW/1/KJ/11—TOP

1-11/1/SRW/1/KJ/12—BACK

1-11/1/SRW/1/KJ/12—FRONT

1-11/1/SRW/1/KJ/12—LEFT

1-11/1/SRW/1/KJ/14—RIGHT

1-11/1/SRW/1/KJ/15—RIGHT

1-11/1/SRW/1/KJ/16—FLUKE

1-11/1/SRW/1/KJ/17—RIGHT

1-11/1/SRW/1/KJ/18—RIGHT

1-11/1/SRW/1/KJ/19—RIGHT

1-11/1/SRW/1/KJ/20—Front

1-11/1/SRW/1/KJ/22—Right

1-11/1/SRW/1/KJ/23—RIGHT

1-11/1/SRW/1/KJ/24—RIGHT

1-11/1/SRW/1/KJ/25—RIGHT

1-11/1/SRW/1/VF/1—LEFT

1-11/1/SRW/1/VF/1—BACK

1-11/1/SRW/1/VF/1—FLUKE

1-11/1/SRW/1/VF/1—FRONT

1-11/1/SRW/1/VF/1—RIGHT

1-11/1/SRW/1/VF/3—FLUKE

1-11/1/SRW/1/VF/5— RIGHT

1-11/1/SRW/1/VF/5— LEFT

1-11/1/SRW/1/VF/5— FLUKE

2-11/2/SRW/1-2/KJ/1—LEFT

2-11/2/SRW/1-2/KJ/1—RIGHT

2-11/2/SRW/1-2/KJ/1—RIGHT BACK

2-11/2/SRW/1-2/KJ/2—RIGHT

2-11/2/SRW/1-2/KJ/2—RIGHT BACK

2-11/2/SRW/1-2/KJ/3—LEFT

2-11/2/SRW/1-2/KJ/3—FLUKE

2-11/2/SRW/1-2/KJ/3—LEFT BACK

2-11/2/SRW/1-2/KJ/3—BACK

2-11/2/SRW/1-2/KJ/3—RIGHT

2-11/2/SRW/1-2/KJ/4—RIGHT

2-11/2/SRW/1-2/KJ/5—FRONT

2-11/2/SRW/1-2/KJ/5—RIGHT

2-11/2/SRW/1-2/KJ/5—TOP

2-11/2/SRW/1-2/KJ/6—RIGHT

2-11/2/SRW/1-2/KJ/6—FRONT

2-11/2/SRW/1-2/KJ/6—TOP

2-11/2/SRW/1-2/KJ/7—RIGHT

2-11/2/SRW/1-2/KJ/10—LEFT

2-11/2/SRW/1-2/KJ/10—FRONT

2-11/2/SRW/1-2/KJ/10—RIGHT

2-11/2/SRW/1-2/KJ/11—LEFT

2-11/2/SRW/1-2/KJ/12—RIGHT

2-11/2/SRW/1-2/KJ/13—RIGHT

2-11/2/SRW/1-2/VF/1—LEFT FIN

2-11/2/SRW/1-2/VF/5—FLUKE

2-11/2/SRW/1-2/VF/7—FRONT

3-11/1/SRW/1/KJ/1—RIGHT

3-11/1/SRW/1/KJ/1—LEFT

3-11/1/SRW/1/KJ/2—RIGHT

3-11/1/SRW/1/KJ/2—LEFT

3-11/1/SRW/1/KJ/3—RIGHT

3-11/1/SRW/1/KJ/4—RIGHT

3-11/1/SRW/1/KJ/6—FRONT

3-11/1/SRW/1/KJ/6—RIGHT

3-11/1/SRW/1/KJ/7—RIGHT

3-11/1/SRW/1/KJ/11—RIGHT

3-11/1/SRW/1/KJ/11—RIGHT BACK

3-11/1/SRW/1/KJ/12—RIGHT

3-11/1/SRW/1/KJ/13—RIGHT

3-11/1/SRW/1/KJ/14—RIGHT

3-11/1/SRW/1/KJ/15—BACK

3-11/1/SRW/1/KJ/15—RIGHT

3-11/1/SRW/1/KJ/18—LEFT

3-11/1/SRW/1/KJ/19—LEFT

3-11/1/SRW/1/KJ/20—LEFT

3-11/1/SRW/1/KJ/21—LEFT

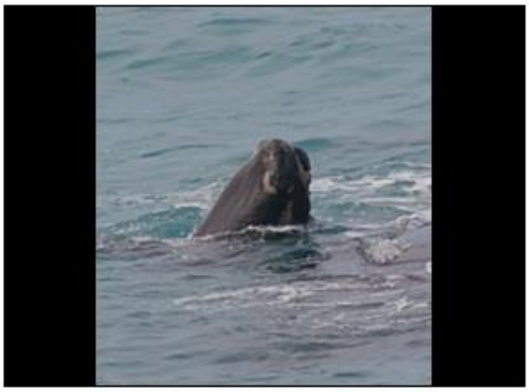
3-11/1/SRW/1/KJ/23—LEFT

3-11/1/SRW/1/KJ/25—LEFT

3-11/1/SRW/1/KJ/25—FRONT

3-11/1/SRW/1/KJ/26—RIGHT

3-11/1/SRW/1/KJ/28—FRONT



3-11/1/SRW/1/KJ/29—BOTTOM

3-11/1/SRW/1/KJ/29—RIGHT

3-11/1/SRW/1/KJ/29—LEFT

3-11/1/SRW/1/KJ/29—TOP

3-11/1/SRW/1/KJ/30—RIGHT

3-11/1/SRW/1/KJ/31—FLUKE

3-11/1/SRW/1/KJ/32—FLUKE partial

3-11/1/SRW/1/KJ/32—RIGHT

3-11/1/SRW/1/KJ/33—LEFT

3-11/1/SRW/1/KJ/33—RIGHT

3-11/1/SRW/1/KJ/34—FLUKE partial

3-11/1/SRW/1/KJ/35—BACK

3-11/1/SRW/1/KJ/35—RIGHT

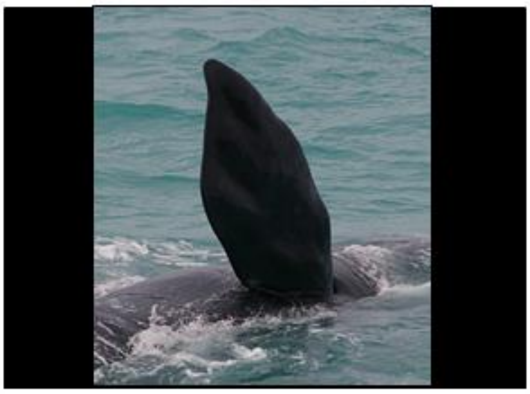
3-11/1/SRW/1/KJ/36—FRONT

3-11/1/SRW/1/KJ/36—RIGHT

3-11/1/SRW/1/KJ/37—RIGHT

3-11/1/SRW/1/VF/3—RIGHT

3-11/1/SRW/1/VF/5—RIGHT



4-11/1/SRW/1/KJ/1—FIN right bottom

4-11/1/SRW/1/KJ/1—FLANKright

4-11/1/SRW/1/KJ/1—LEFT

4-11/1/SRW/1/KJ/2—RIGHT

4-11/1/SRW/1/KJ/2—FINleft

4-11/1/SRW/1/KJ/3—FLUKE

4-11/1/SRW/1/KJ/3—RIGHT

4-11/1/SRW/1/KJ/3—LEFT

4-11/1/SRW/1/KJ/4—FLUKEpartial

4-11/1/SRW/1/KJ/4—LEFT

4-11/1/SRW/1/KJ/7—LEFT

4-11/1/SRW/1/KJ/9—LEFT

4-11/1/SRW/1/KJ/14—LEFT

4-11/1/SRW/1/KJ/16—LEFT

4-11/1/SRW/1/KJ/17—RIGHT

4-11/1/SRW/1/KJ/18—RIGHT

4-11/1/SRW/1/KJ/20—BELLY

4-11/1/SRW/1/KJ/20—FINright

4-11/1/SRW/1/KJ/21—RIGHT

4-11/1/SRW/1/KJ/23—BACK

4-11/1/SRW/1/KJ/25—RIGHT

4-11/1/SRW/1/KJ/25—FRONT

4-11/1/SRW/1/KJ/25—LEFT

4-11/1/SRW/1/KJ/26—RIGHT

4-11/1/SRW/1/KJ/27—RIGHT

4-11/1/SRW/1/KJ/27—TOP

4-11/1/SRW/1/KJ/36—LEFT

4-11/1/SRW/1/KJ/36—FRONT

4-11/1/SRW/1/KJ/37—RIGHT

4-11/1/SRW/1/KJ/37—FRONT

4-11/1/SRW/1/KJ/38—LEFT

4-11/1/SRW/1/KJ/39—RIGHT

4-11/2/SRW/1/VF/6—RIGHT

4-11/2/SRW/1/VF/6—BELLY

5-11/2/SRW/1/KJ/1—LEFT

5-11/2/SRW/1/KJ/2—LEFT

5-11/2/SRW/1/KJ/3—FRONTright

5-11/2/SRW/1/KJ/4—FRONTright

5-11/2/SRW/1/KJ/8—FRONTright

5-11/2/SRW/1/KJ/8—RIGHT

5-11/2/SRW/1/KJ/9—RIGHT

5-11/2/SRW/1/KJ/12—FRONT

5-11/2/SRW/1/KJ/12—BOTTOM

5-11/2/SRW/1/KJ/12—RIGHT

5-11/2/SRW/1/KJ/14—RIGHT

5-11/2/SRW/1/KJ/14—TOP

5-11/2/SRW/1/KJ/14—FRONT

5-11/2/SRW/1/KJ/14—FLUKEunderneath

5-11/2/SRW/1/KJ/14—BELLY

5-11/2/SRW/1/KJ/14—FLUKEtop

5-11/2/SRW/1/KJ/14—LEFT

5-11/2/SRW/1/KJ/15—FRONT

5-11/2/SRW/1/KJ/15—BACK

5-11/2/SRW/1/KJ/15—RIGHT

5-11/2/SRW/1/KJ/15—LEFT

5-11/2/SRW/1/KJ/17—LEFT

5-11/2/SRW/1/KJ/18—LEFT

5-11/2/SRW/1/KJ/21—LEFT

5-11/2/SRW/1/KJ/22—FRONT

5-11/2/SRW/1/KJ/22—FLUKE

5-11/2/SRW/1/KJ/22—LEFT

5-11/2/SRW/1/KJ/23—RIGHT

5-11/2/SRW/1/KJ/25—RIGHT

5-11/2/SRW/1/KJ/26—BACK

5-11/2/SRW/1/KJ/27—LEFT

5-11/2/SRW/1/VF/1—LEFT

6-11/1/SRW/1/KJ/1—RIGHT

6-11/1/SRW/1/KJ/1—FLUKE

6-11/1/SRW/1/KJ/2—LEFT

6-11/1/SRW/1/KJ/2—RIGHT

6-11/1/SRW/1/KJ/11—LEFT

6-11/1/SRW/1/KJ/12—LEFT

6-11/1/SRW/1/KJ/12—FLANKleft

6-11/1/SRW/1/KJ/12—FLUKE

6-11/1/SRW/1/KJ/12—RIGHT

6-11/1/SRW/1/KJ/12—RIGHT 2

6-11/1/SRW/1/KJ/12—FLANKright

6-11/1/SRW/1/KJ/12—BACKright

6-11/1/SRW/1/KJ/13—LEFT

6-11/1/SRW/1/KJ/15—RIGHT

6-11/1/SRW/1/KJ/16—RIGHT

6-11/1/SRW/1/KJ/18—RIGHT

6-11/1/SRW/1/KJ/18—BACK

6-11/1/SRW/1/KJ/19—RIGHT

Appendix B) Behavior

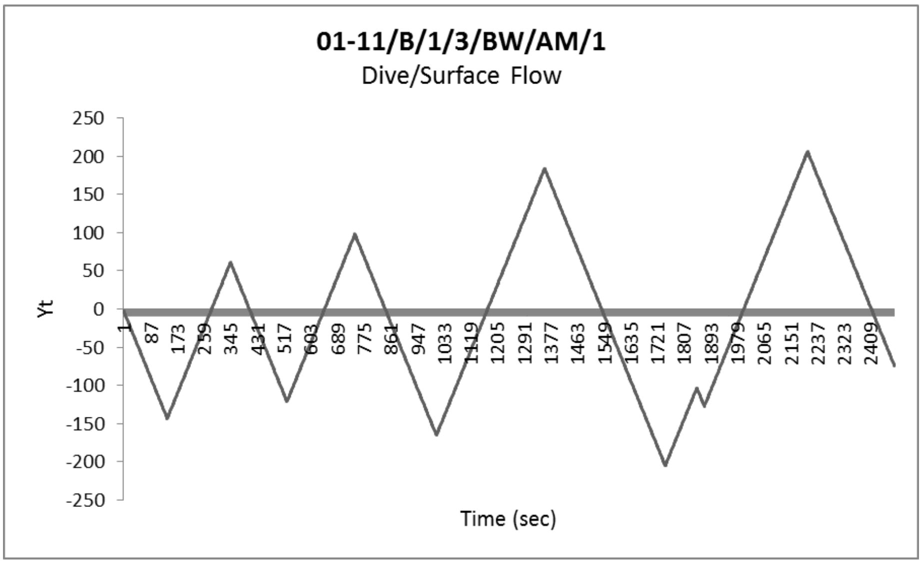
Appendix B1: Complete *Eubalaena australis* Dive/Surface Pattern data, as seen in Volume 1 – Chapter 5

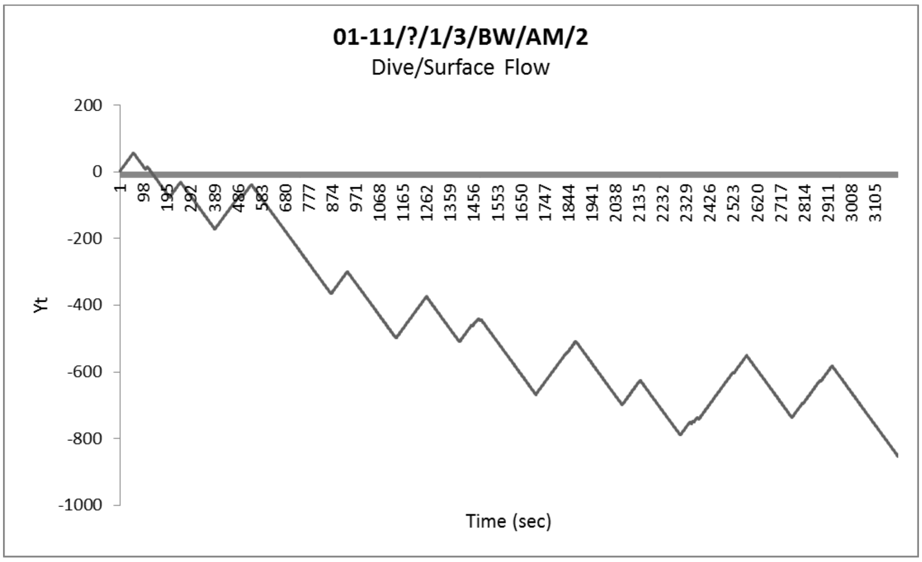
Appendix B2: *Eubalaena australis* Orbital Phase Spacing data, as seen in Volume 1 –Chapter 5

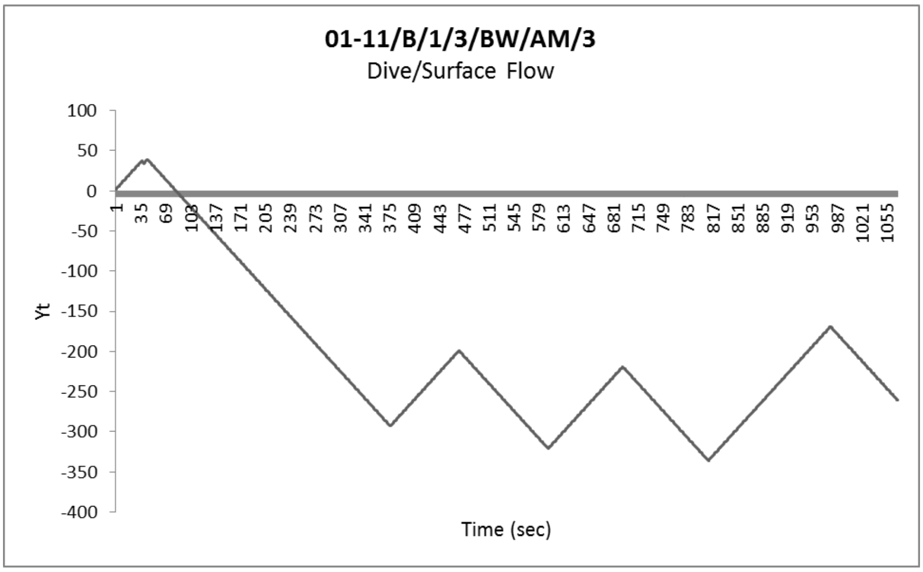
Appendix B3: Tidal Influence on Foraging Dynamics in the Pied Cormorant, *Phalacrocorax varius*

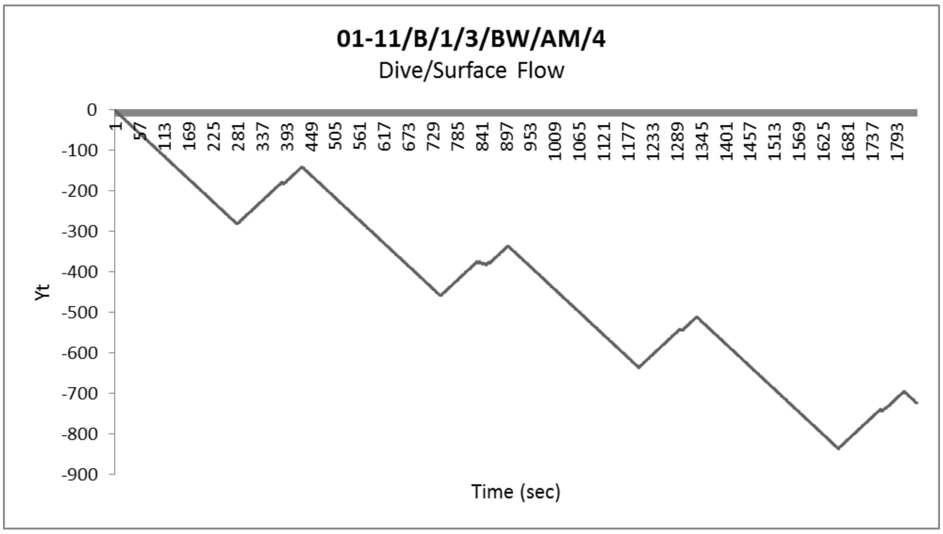
Appendix B1: Dive/Surface Pattern of E. australis

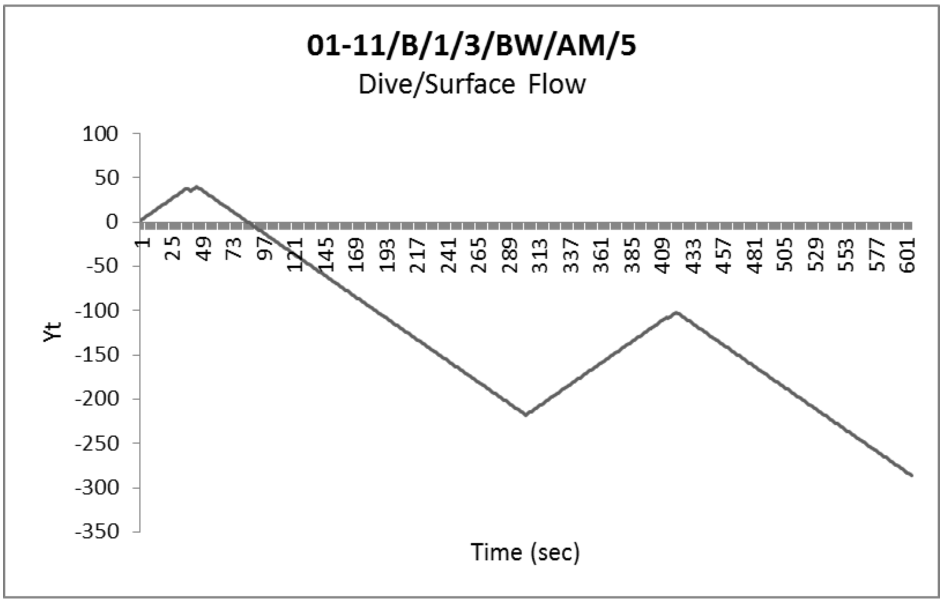
a: Accompanied Mother Dive/Surface Pattern

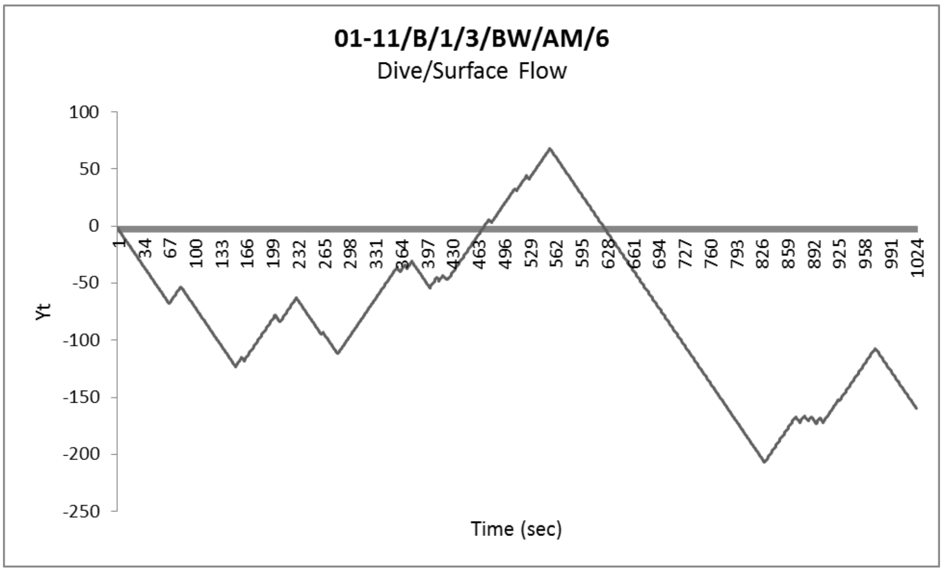


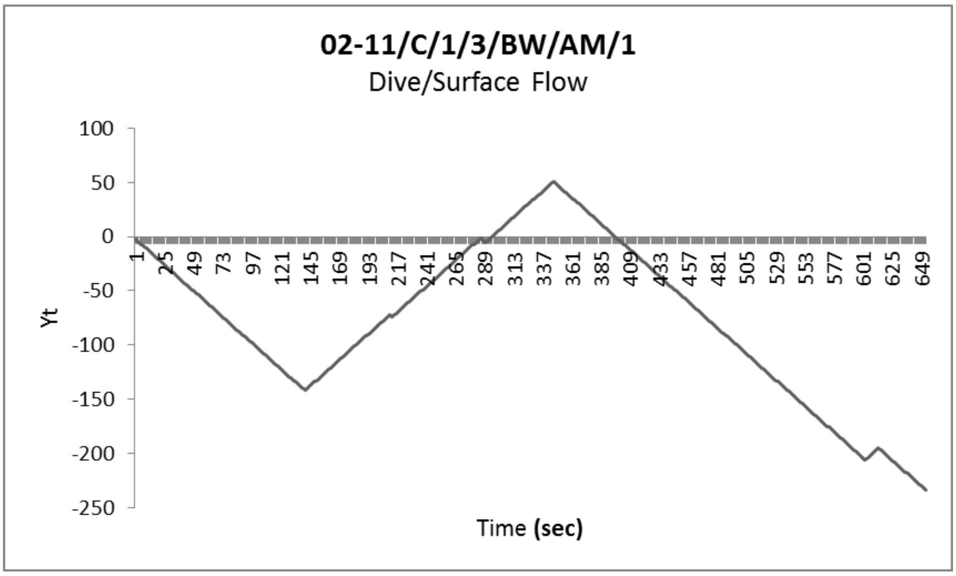


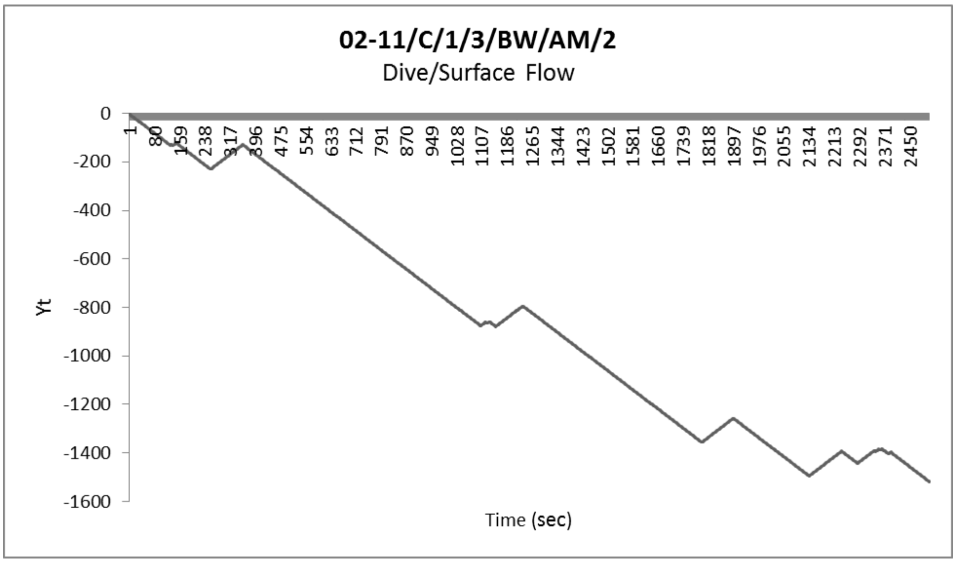


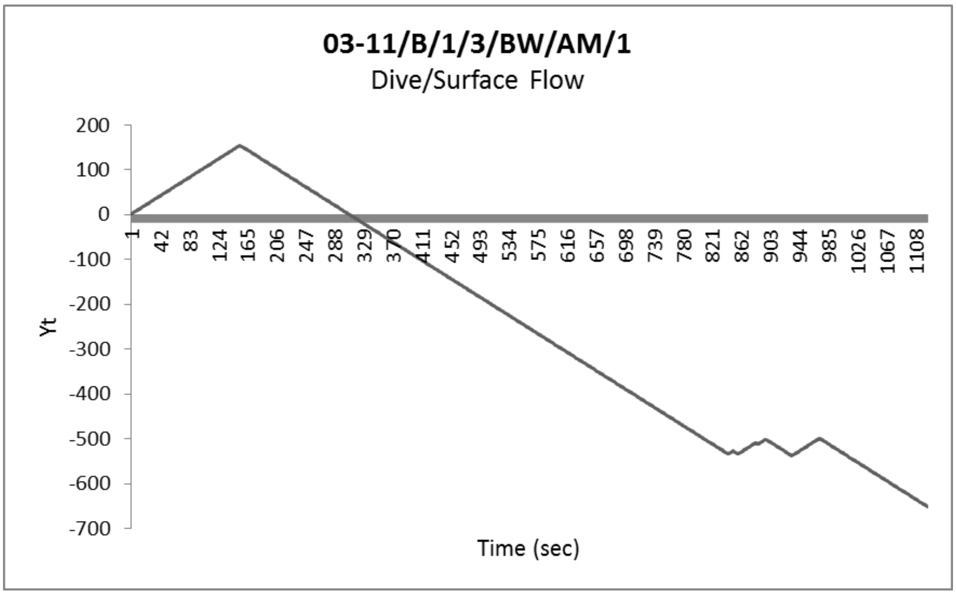

01-11/B/1/3/BW/AM/4
Dive/Surface Flow
Yt
Time (sec)

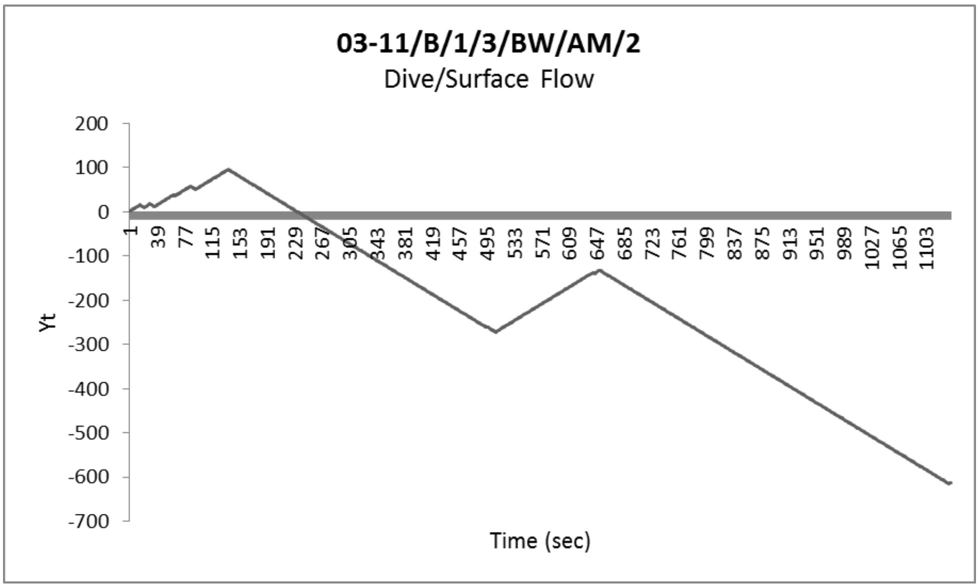

01-11/B/1/3/BW/AM/5
Dive/Surface Flow
Yt
Time (sec)

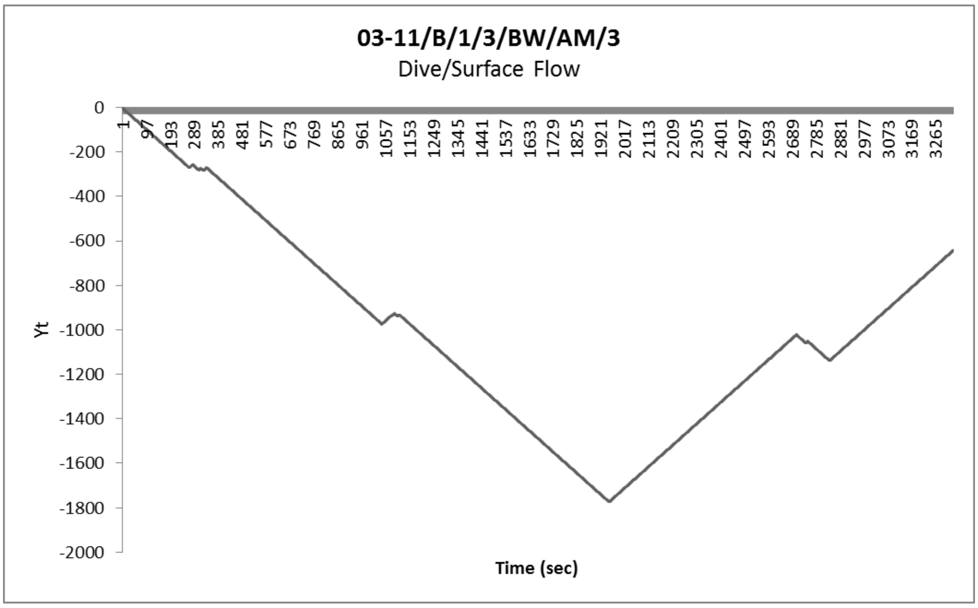

01-11/B/1/3/BW/AM/6
Dive/Surface Flow
Yt
Time (sec)

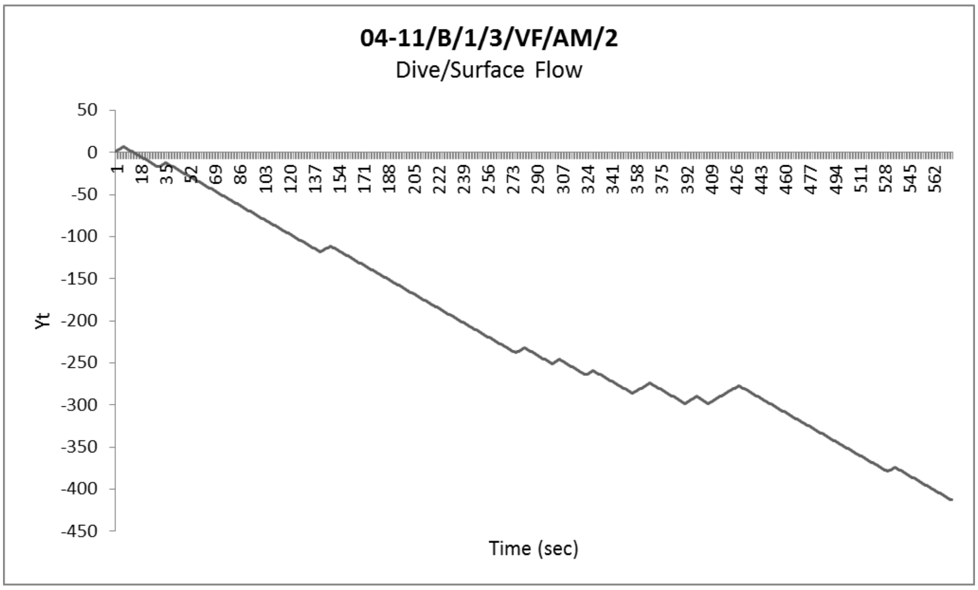

02-11/C/1/3/BW/AM/1
Dive/Surface Flow
Yt
Time (sec)

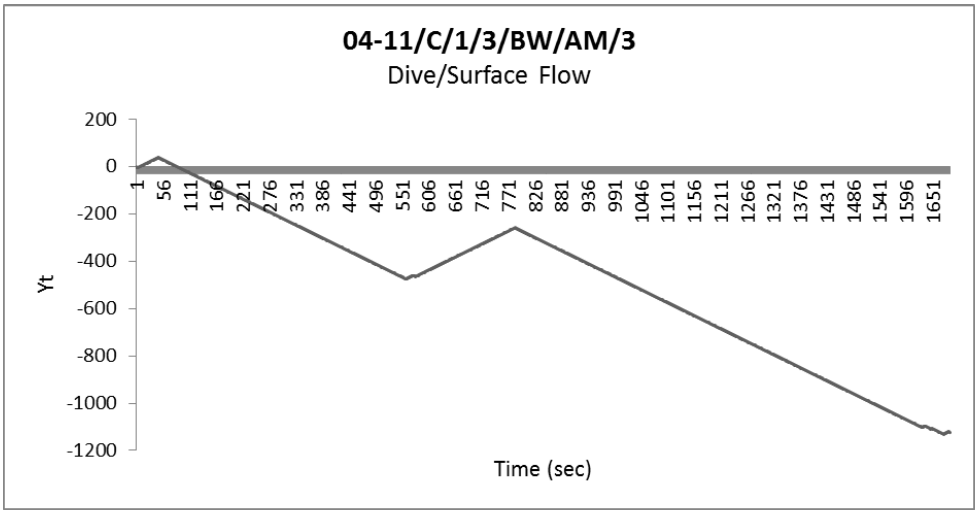

02-11/C/1/3/BW/AM/2
Dive/Surface Flow
Yt
Time (sec)

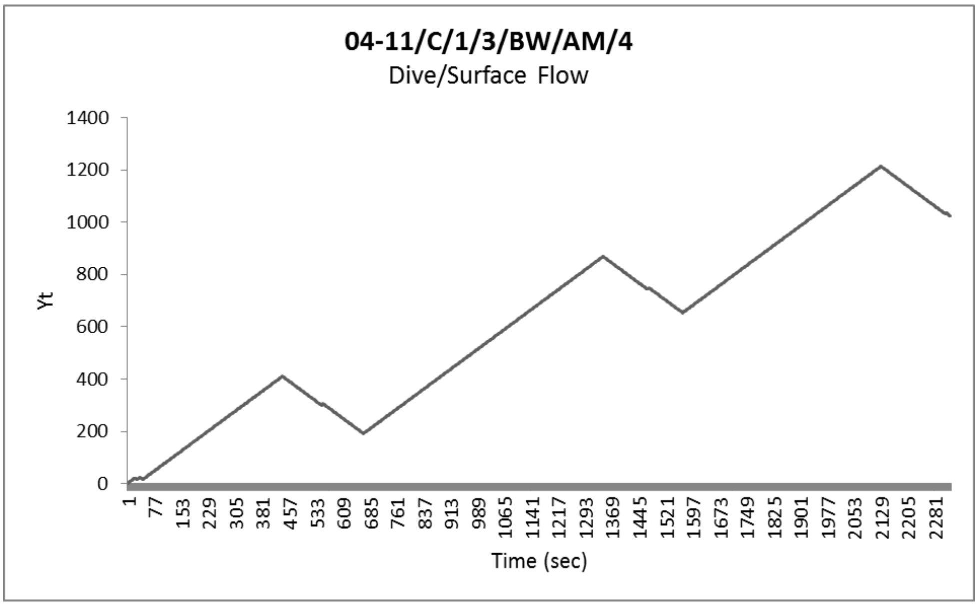

03-11/B/1/3/BW/AM/1
Dive/Surface Flow
Yt
Time (sec)

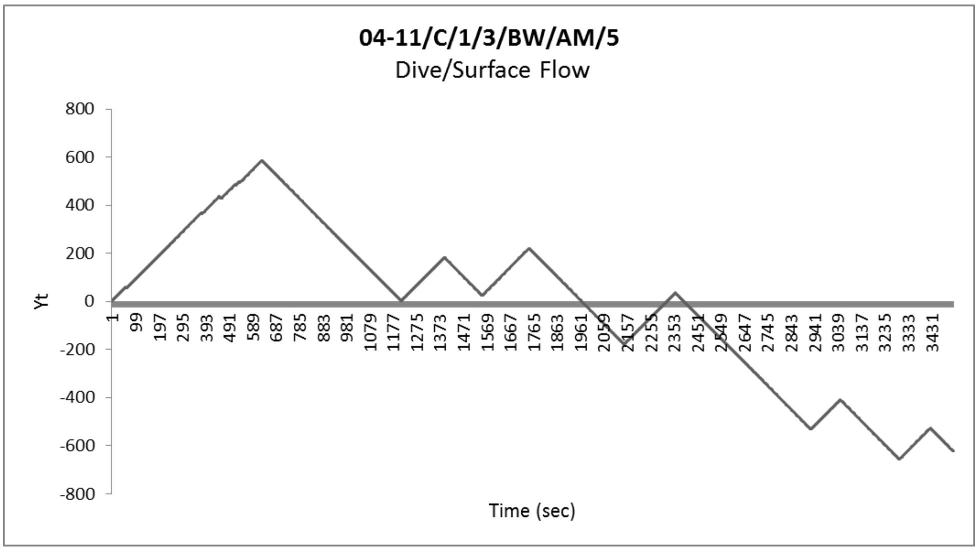

03-11/B/1/3/BW/AM/2
Dive/Surface Flow
Yt
Time (sec)

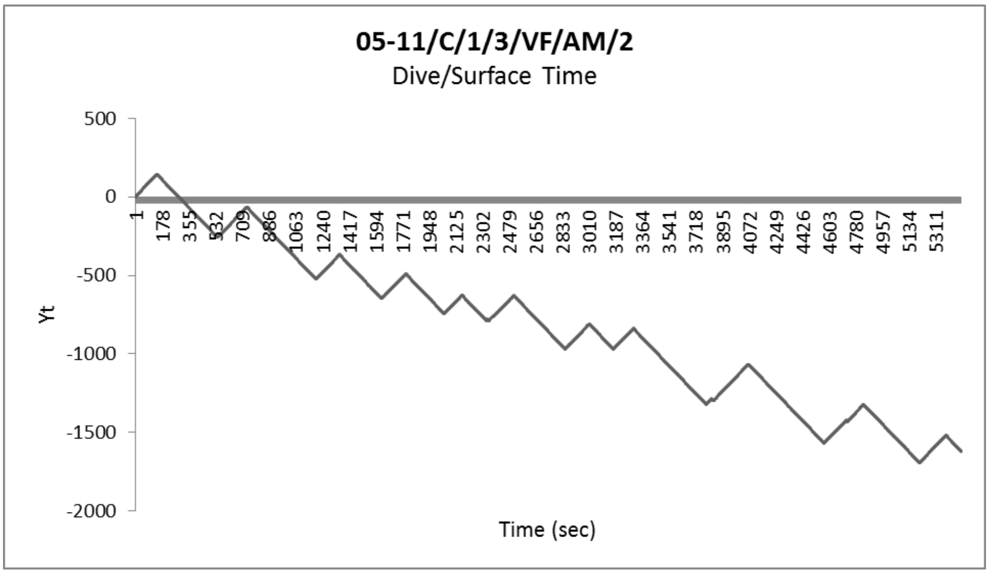

03-11/B/1/3/BW/AM/3
Dive/Surface Flow
Yt
Time (sec)

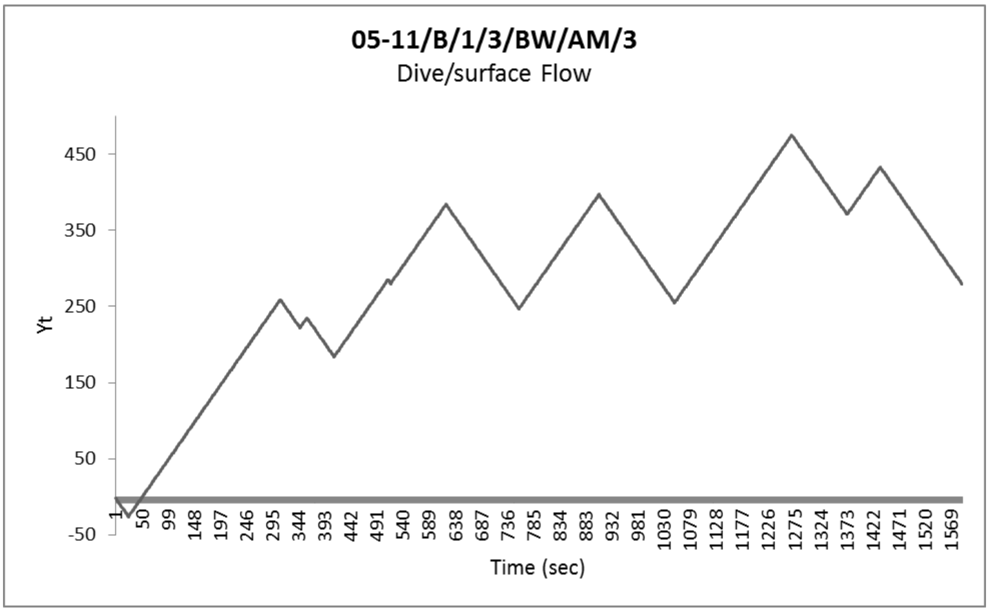

04-11/B/1/3/VF/AM/2
Dive/Surface Flow
Yt
Time (sec)

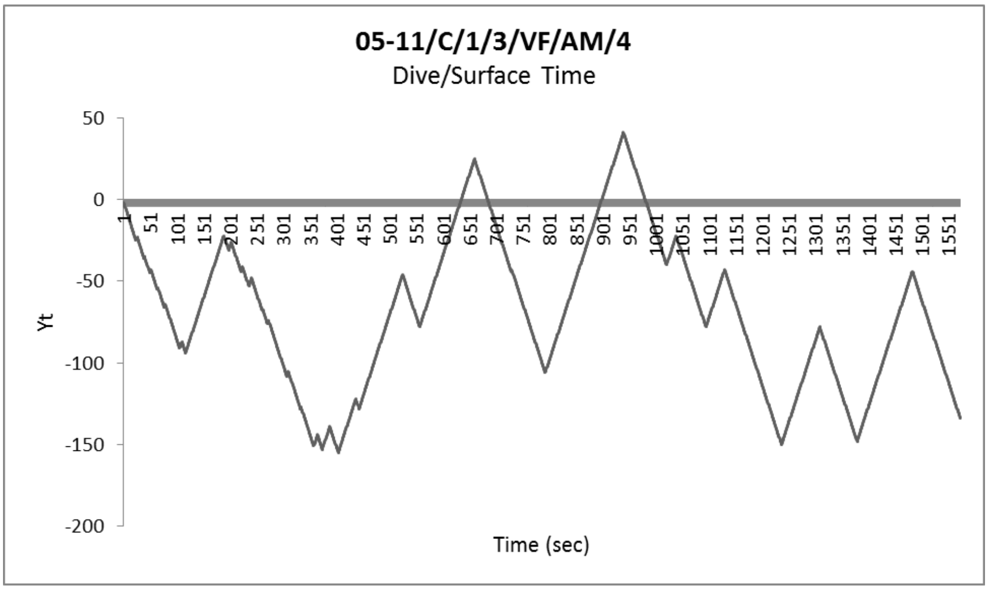

04-11/C/1/3/BW/AM/3
Dive/Surface Flow
Yt
Time (sec)

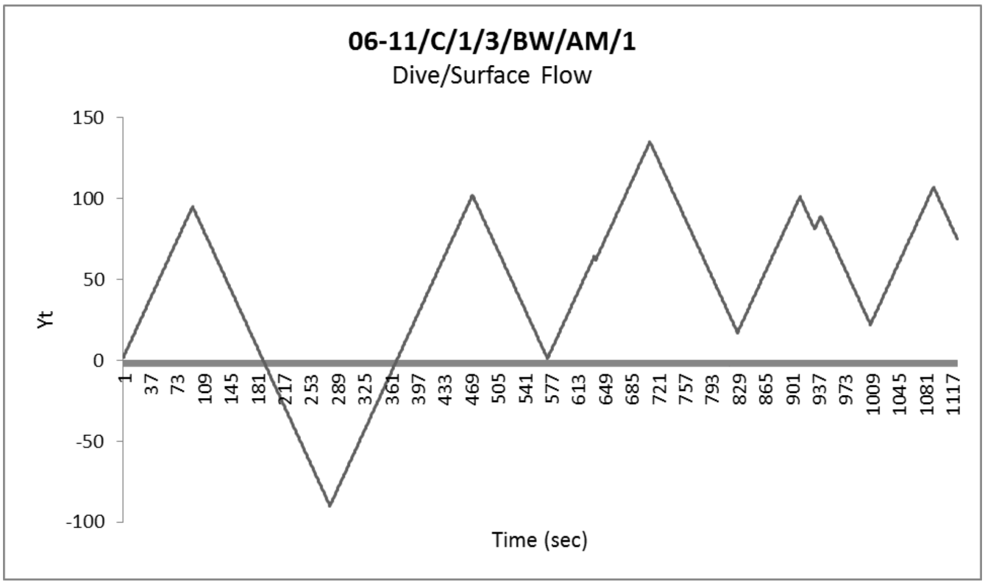

04-11/C/1/3/BW/AM/4
Dive/Surface Flow
Yt
Time (sec)

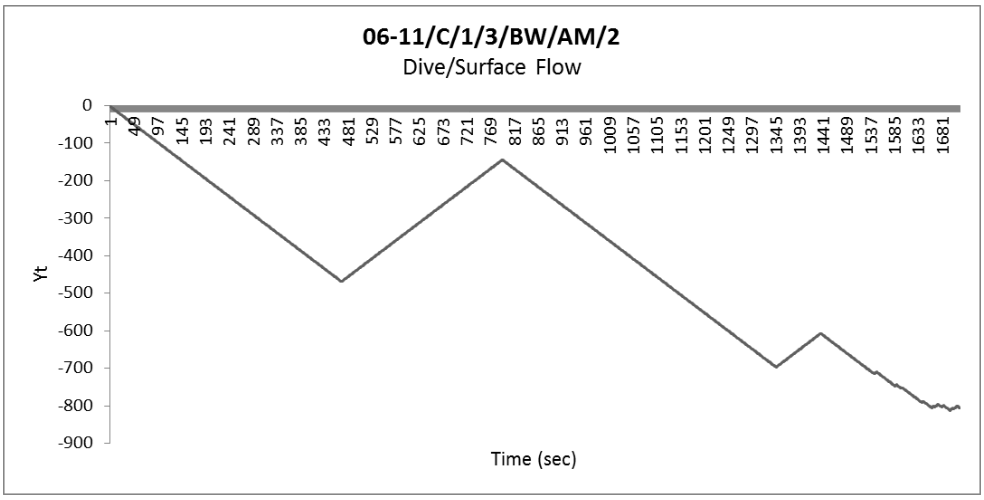

04-11/C/1/3/BW/AM/5
Dive/Surface Flow
Yt
Time (sec)


05-11/C/1/3/VF/AM/2
Dive/Surface Time
Yt
500
0
-500
-1000
-1500
-2000
1
178
355
532
709
886
1063
1240
1417
1594
1771
1948
2125
2302
2479
2656
2833
3010
3187
3364
3541
3718
3895
4072
4249
4426
4603
4780
4957
5134
5311
Time (sec)

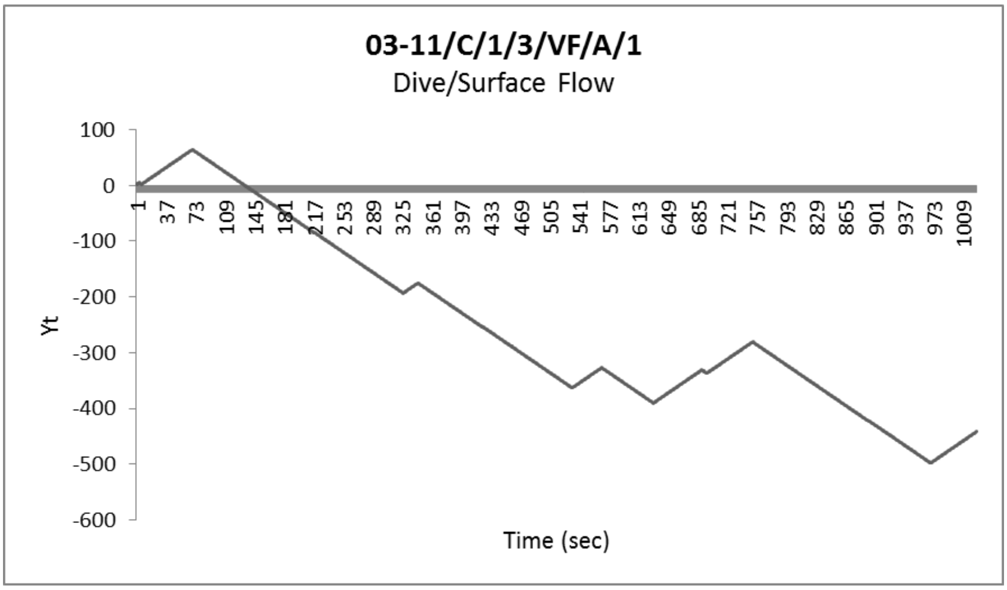

05-11/B/1/3/BW/AM/3
Dive/surface Flow
Yt
450
350
250
150
50
-50
1
50
99
148
197
246
295
344
393
442
491
540
589
638
687
736
785
834
883
932
981
1030
1079
1128
1177
1226
1275
1324
1373
1422
1471
1520
1569
Time (sec)

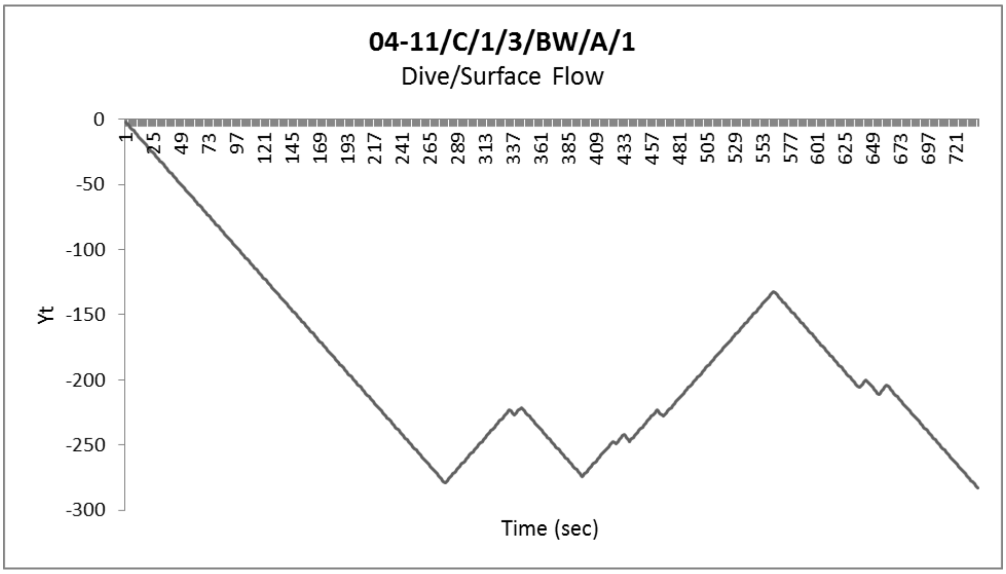

05-11/C/1/3/VF/AM/4
Dive/Surface Time
Yt
50
0
-50
-100
-150
-200
1
51
101
151
201
251
301
351
401
451
501
551
601
651
701
751
801
851
901
951
1001
1051
1101
1151
1201
1251
1301
1351
1401
1451
1501
1551
Time (sec)


06-11/C/1/3/BW/AM/1
Dive/Surface Flow
150
100
50
0
-50
-100
Yt
1
37
73
109
145
181
217
253
289
325
361
397
433
469
505
541
577
613
649
685
721
757
793
829
865
901
937
973
1009
1045
1081
1117
Time (sec)

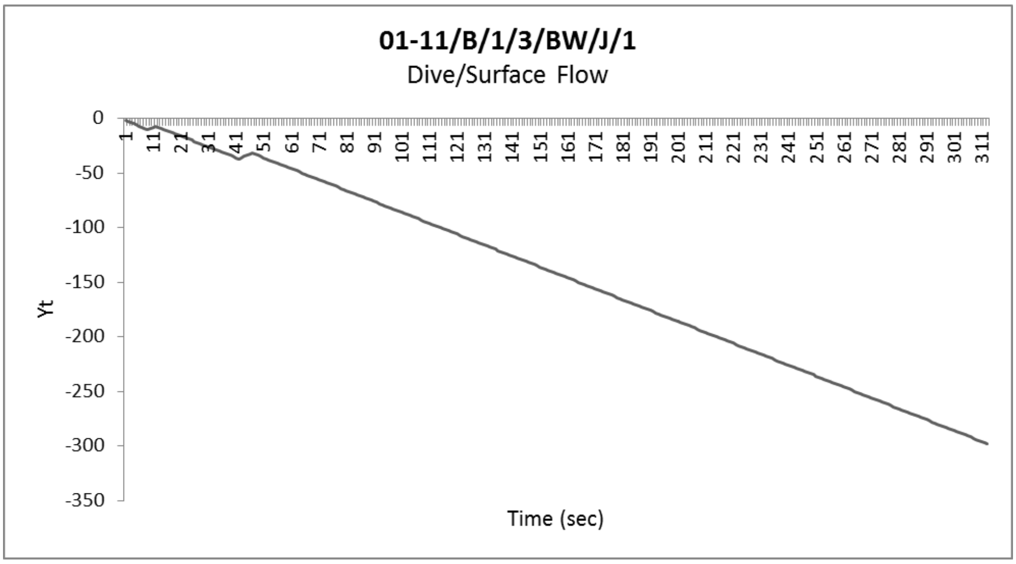

06-11/C/1/3/BW/AM/2
Dive/Surface Flow
0
-100
-200
-300
-400
-500
-600
-700
-800
-900
Yt
1
49
97
145
193
241
289
337
385
433
481
529
577
625
673
721
769
817
865
913
961
1009
1057
1105
1153
1201
1249
1297
1345
1393
1441
1489
1537
1585
1633
1681
Time (sec)

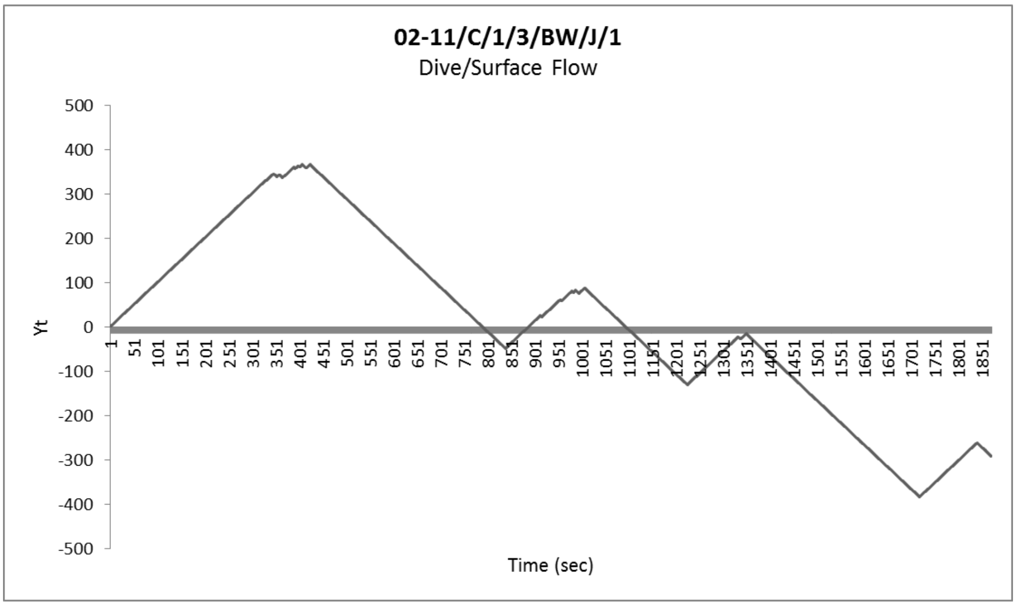
B: Adult Dive/Surface Pattern

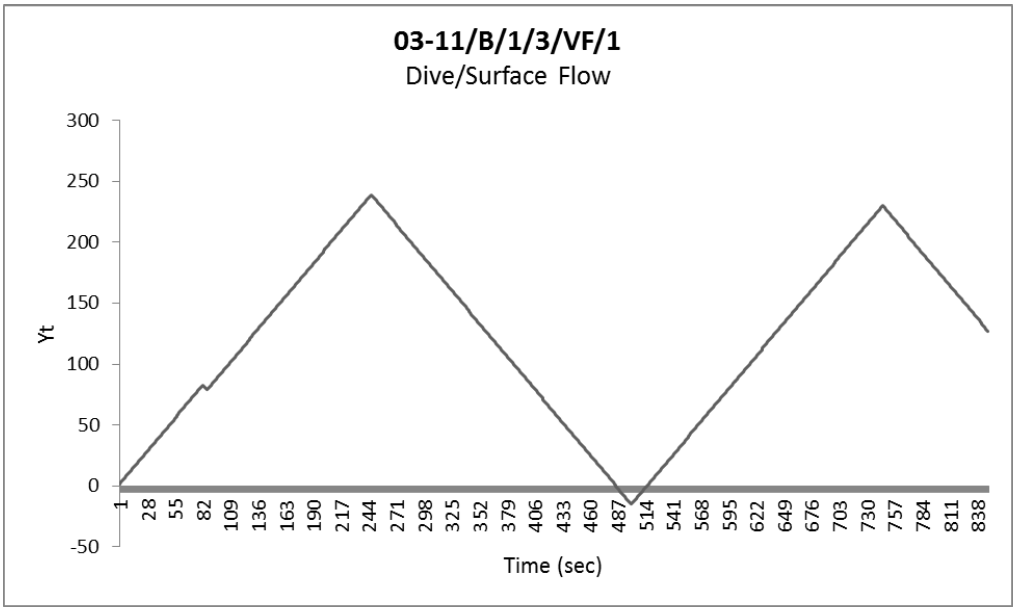


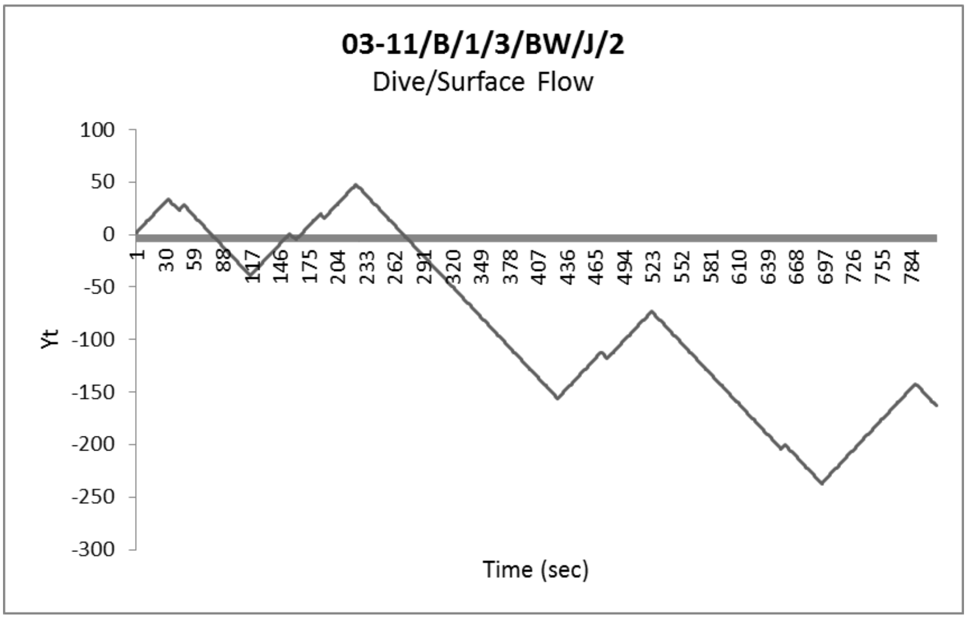


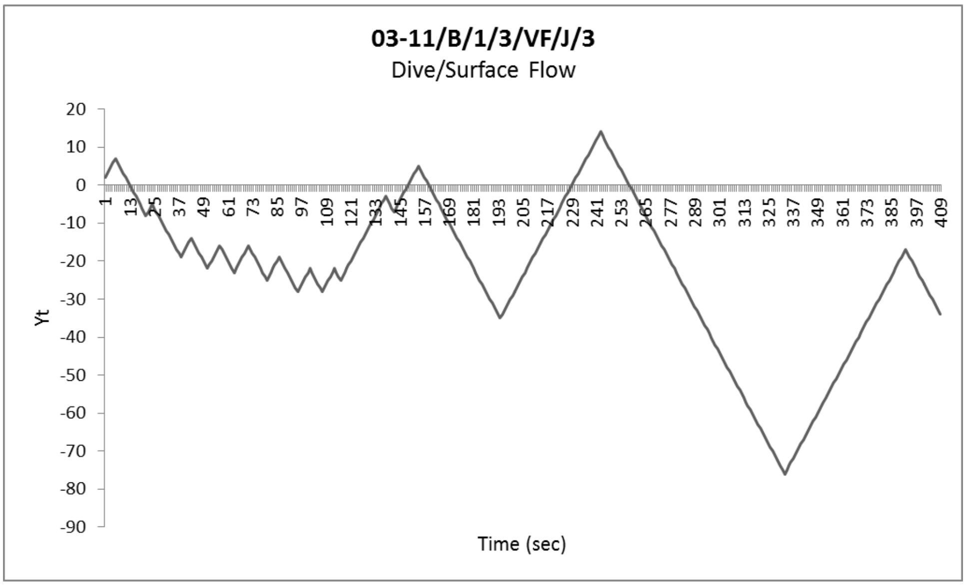
C: Juvenile Dive/Surface Pattern

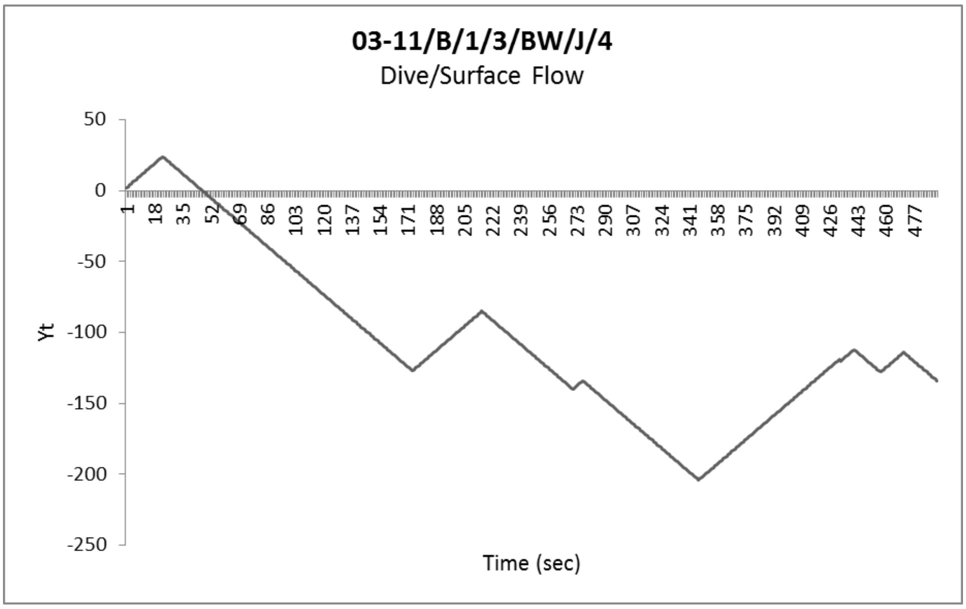


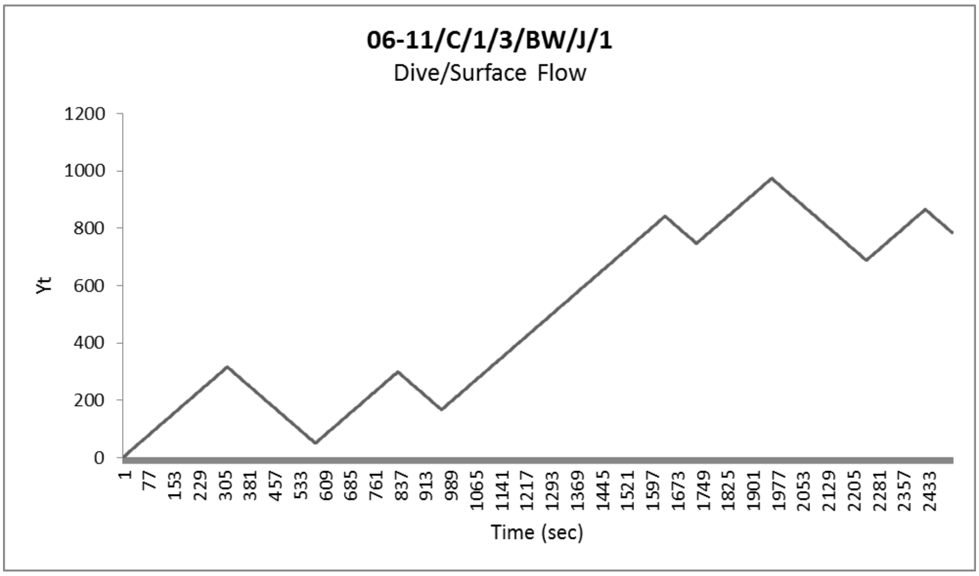




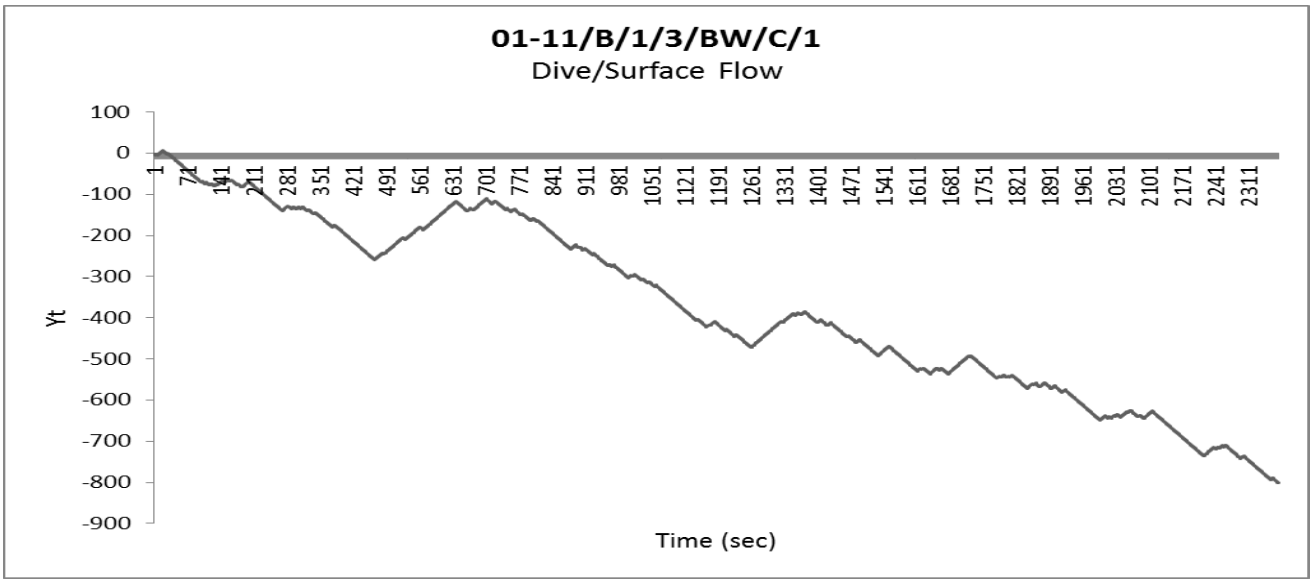

03-11/B/1/3/BW/J/2
Dive/Surface Flow
Yt
Time (sec)

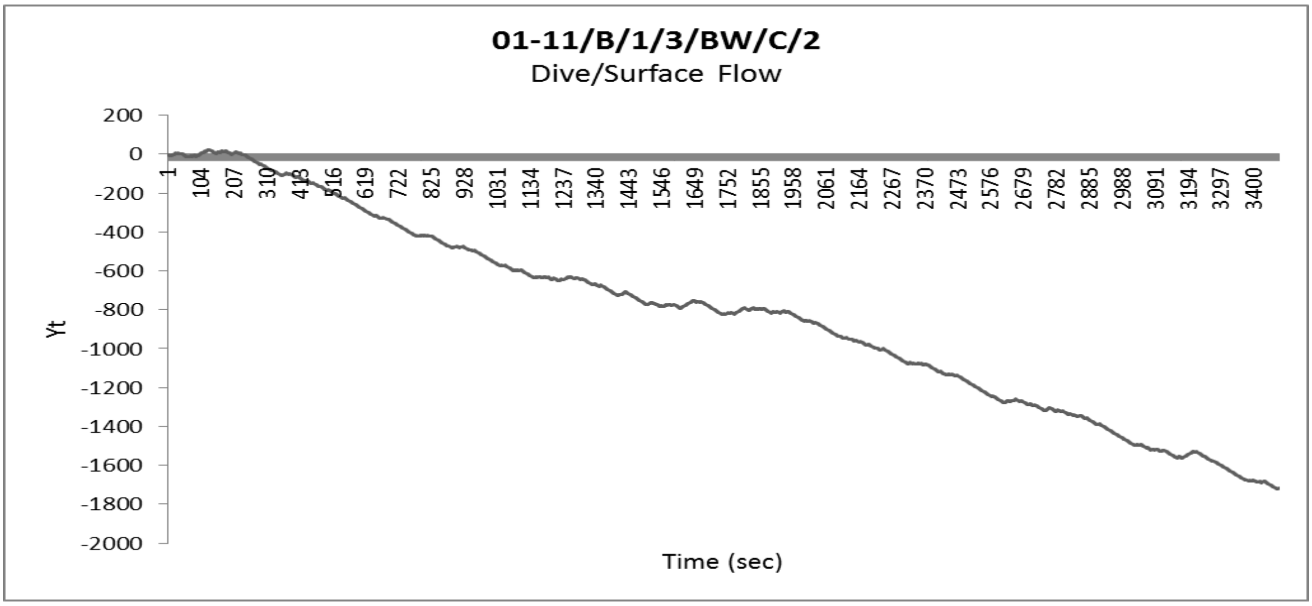

03-11/B/1/3/VF/J/3
Dive/Surface Flow
Yt
Time (sec)

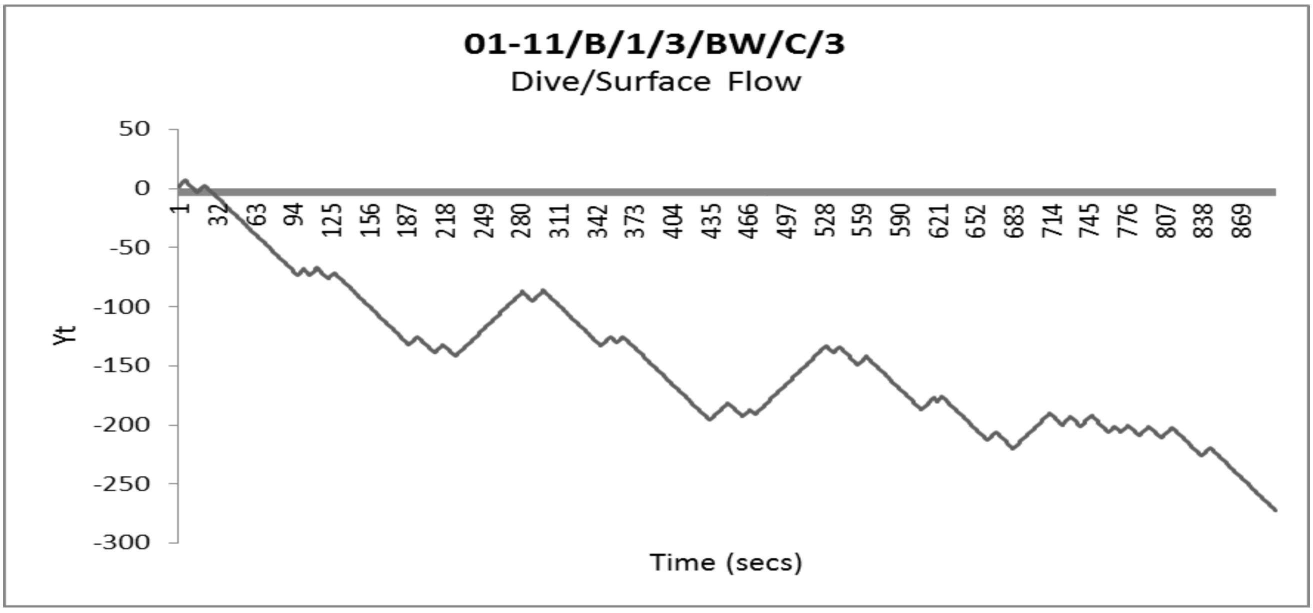

03-11/B/1/3/BW/J/4
Dive/Surface Flow
Yt
Time (sec)

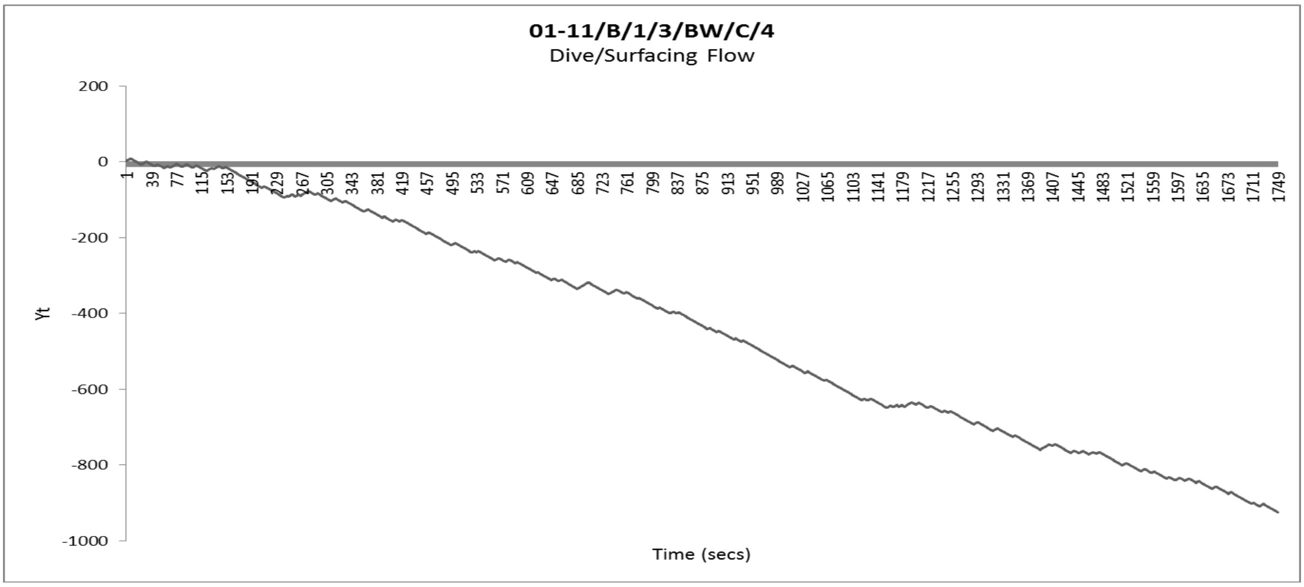

06-11/C/1/3/BW/J/1
Dive/Surface Flow
Yt
1200
1000
800
600
400
200
0
1
77
153
229
305
381
457
533
609
685
761
837
913
989
1065
1141
1217
1293
1369
1445
1521
1597
1673
1749
1825
1901
1977
2053
2129
2205
2281
2357
2433
Time (sec)

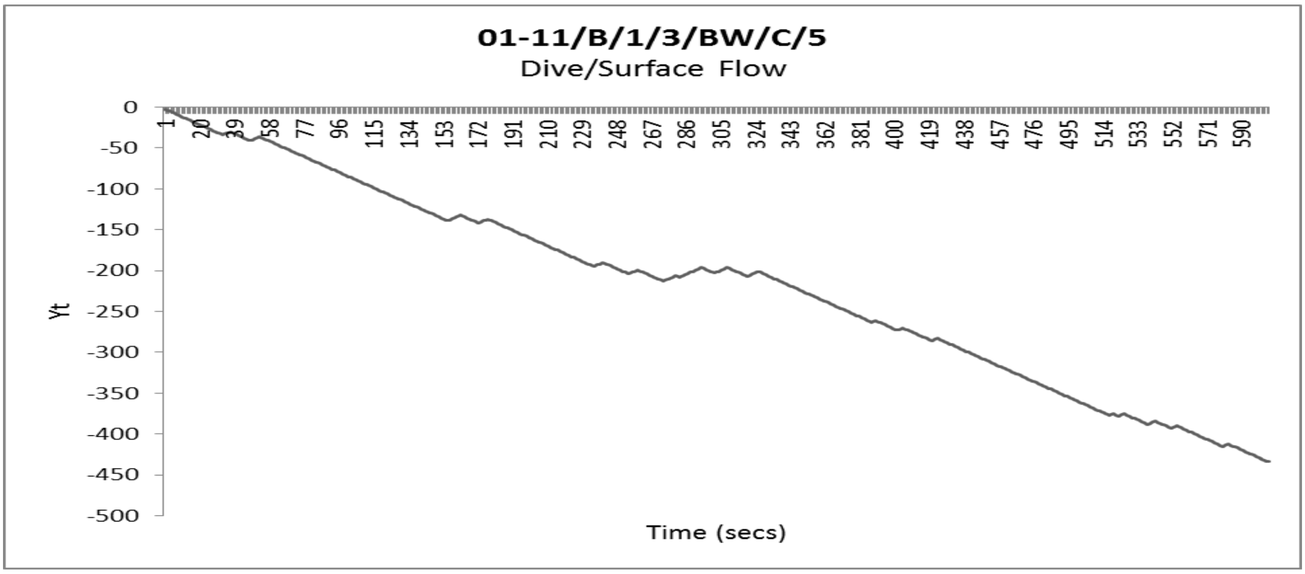
D: Calf Dive/Surface Pattern

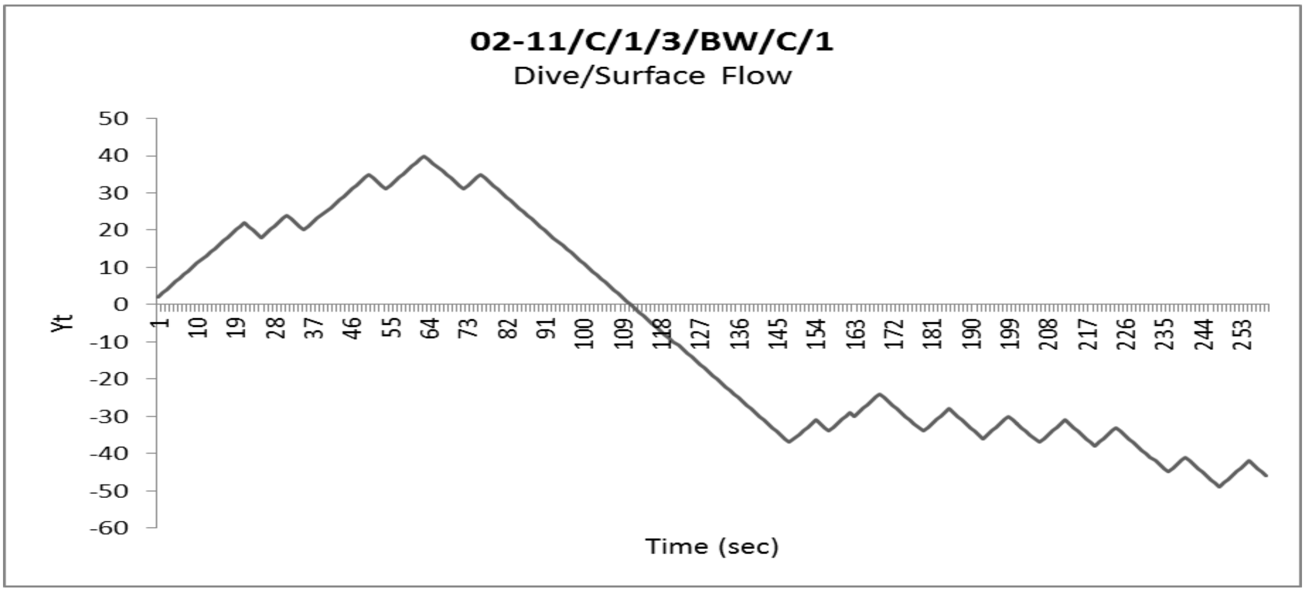


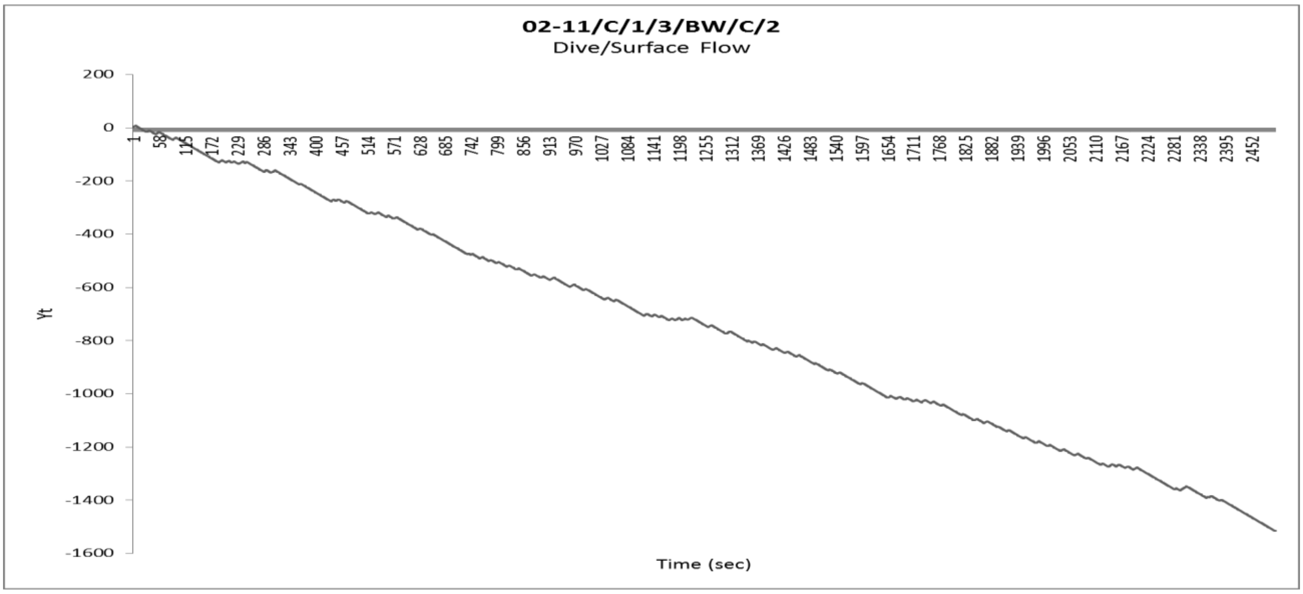


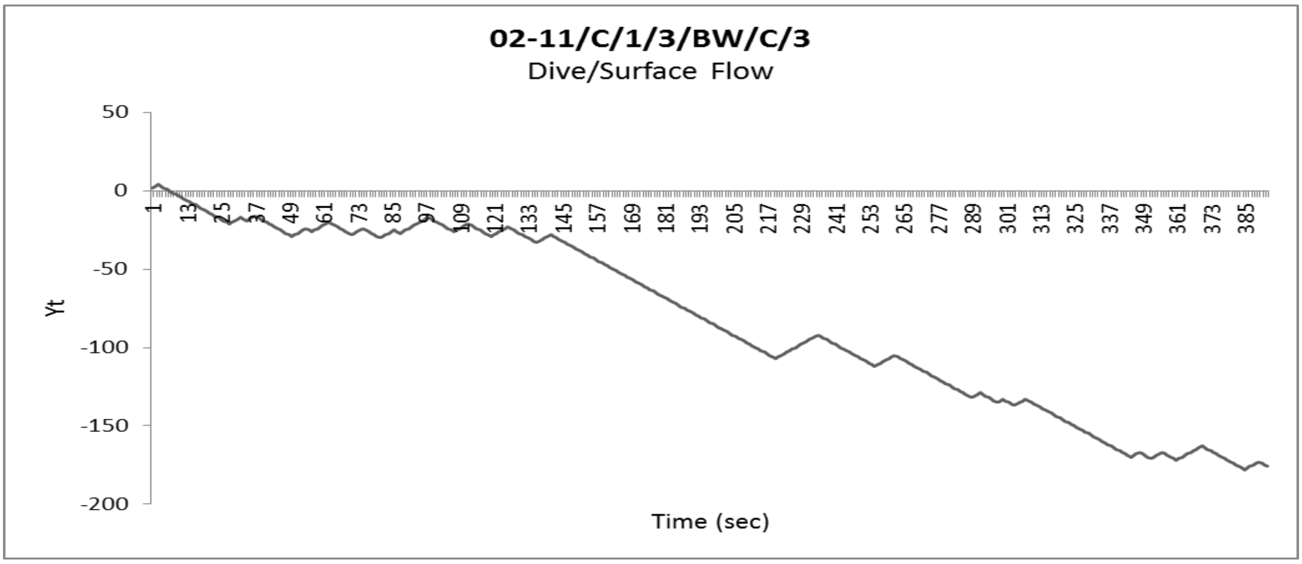


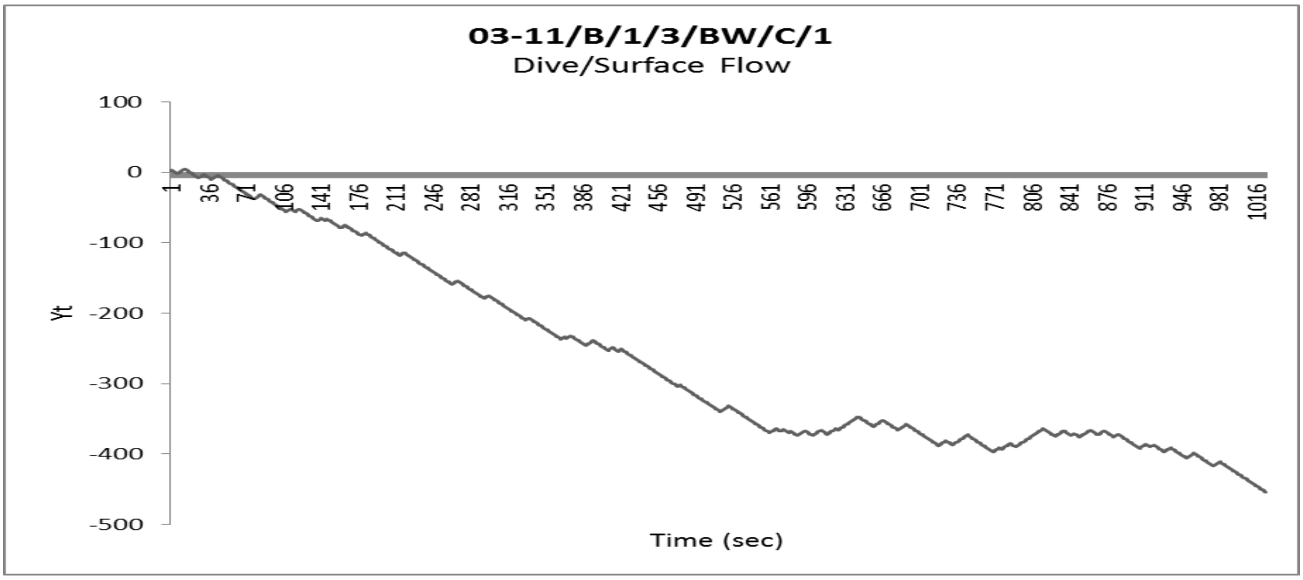

01-11/B/1/3/BW/C/4
Dive/Surfacing Flow
Yt
Time (secs)

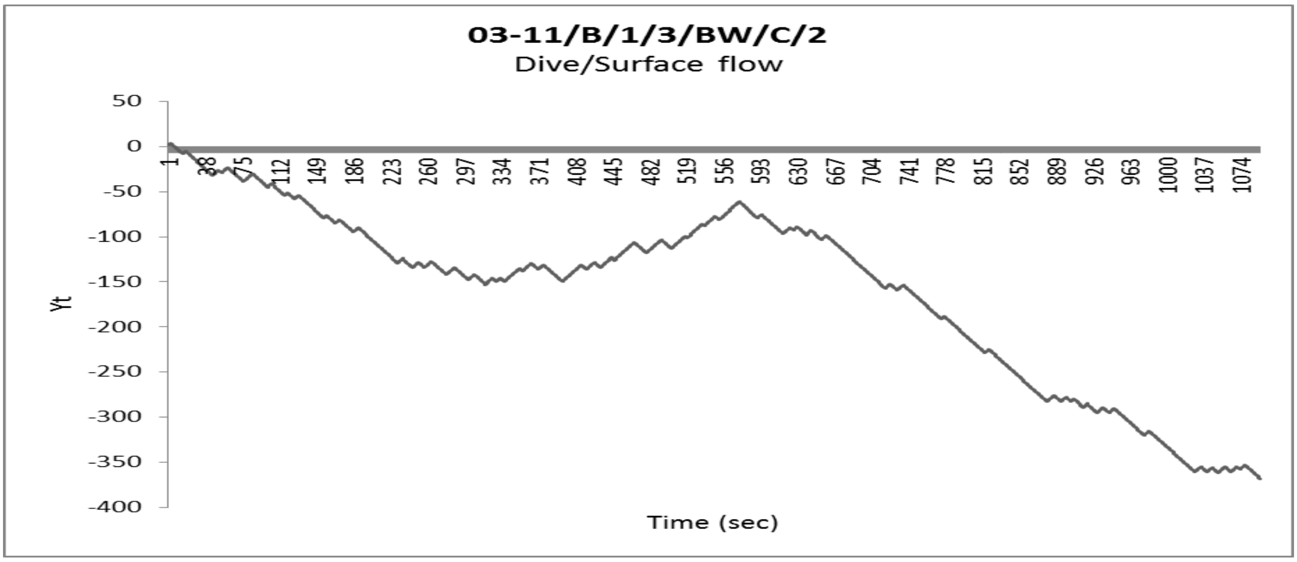

01-11/B/1/3/BW/C/5
Dive/Surface Flow
Yt
Time (secs)

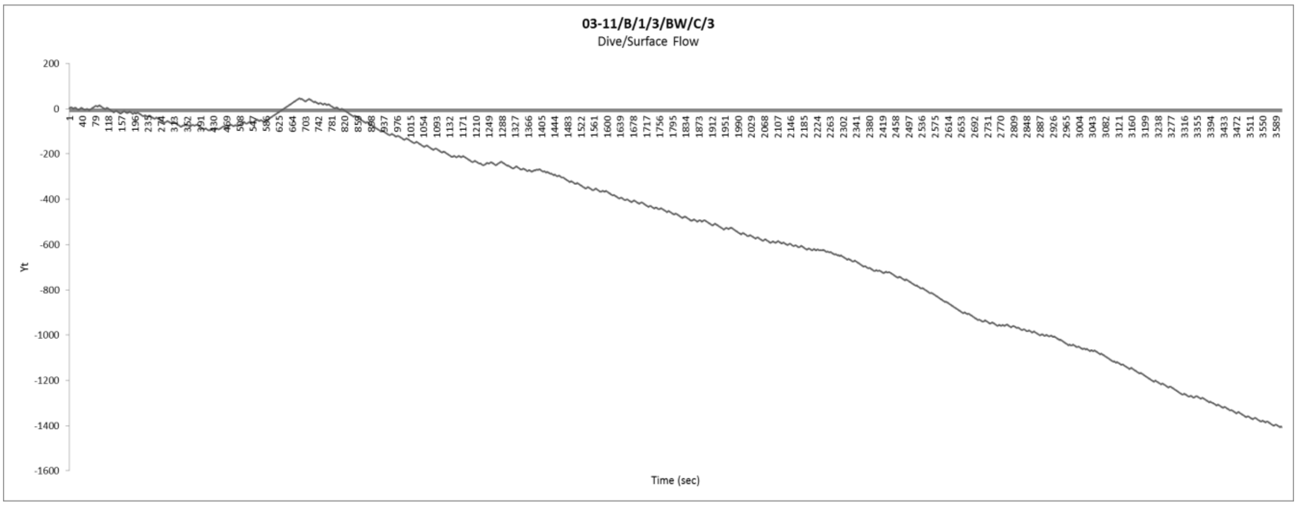

02-11/C/1/3/BW/C/1
Dive/Surface Flow
Yt
Time (sec)

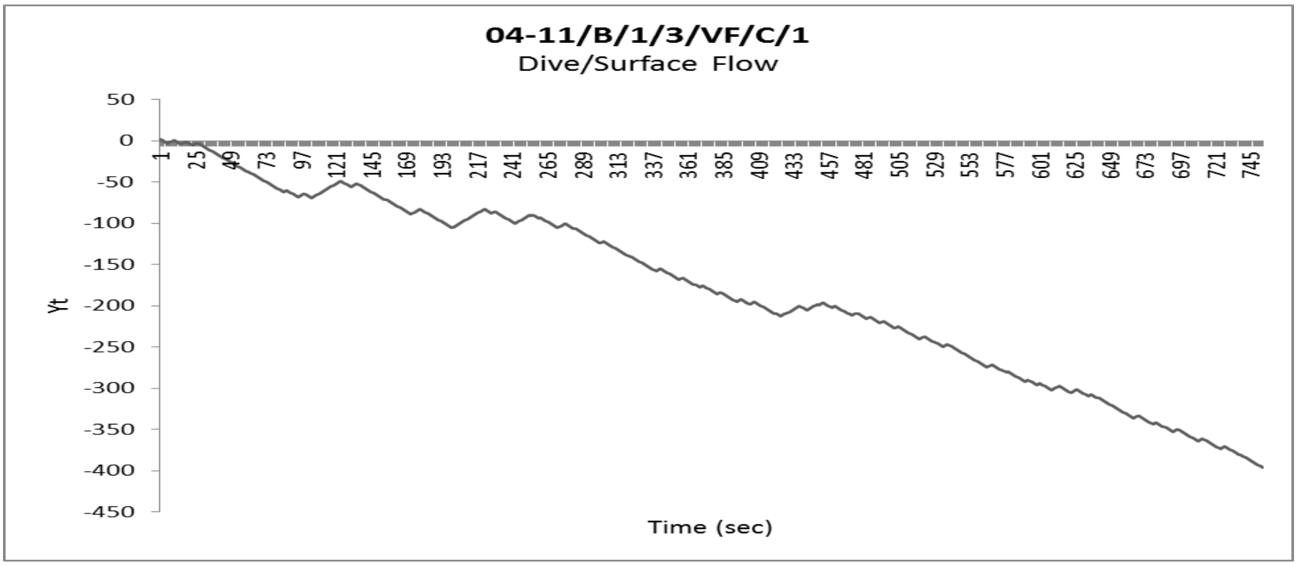

02-11/C/1/3/BW/C/2
Dive/Surface Flow
Yt
Time (sec)

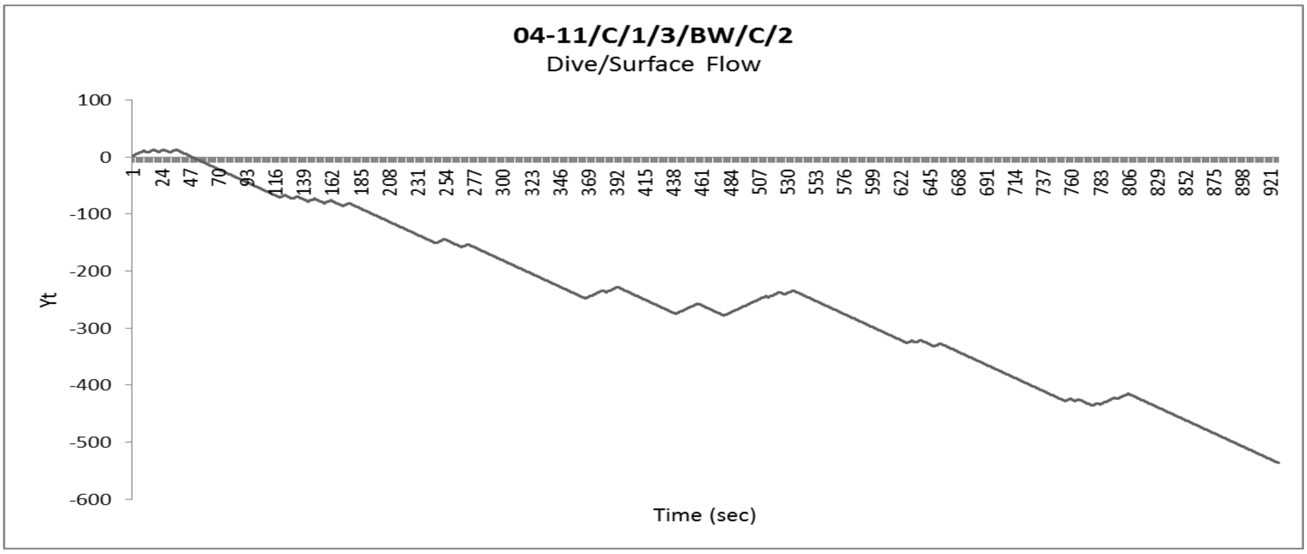

02-11/C/1/3/BW/C/3
Dive/Surface Flow
Yt
Time (sec)

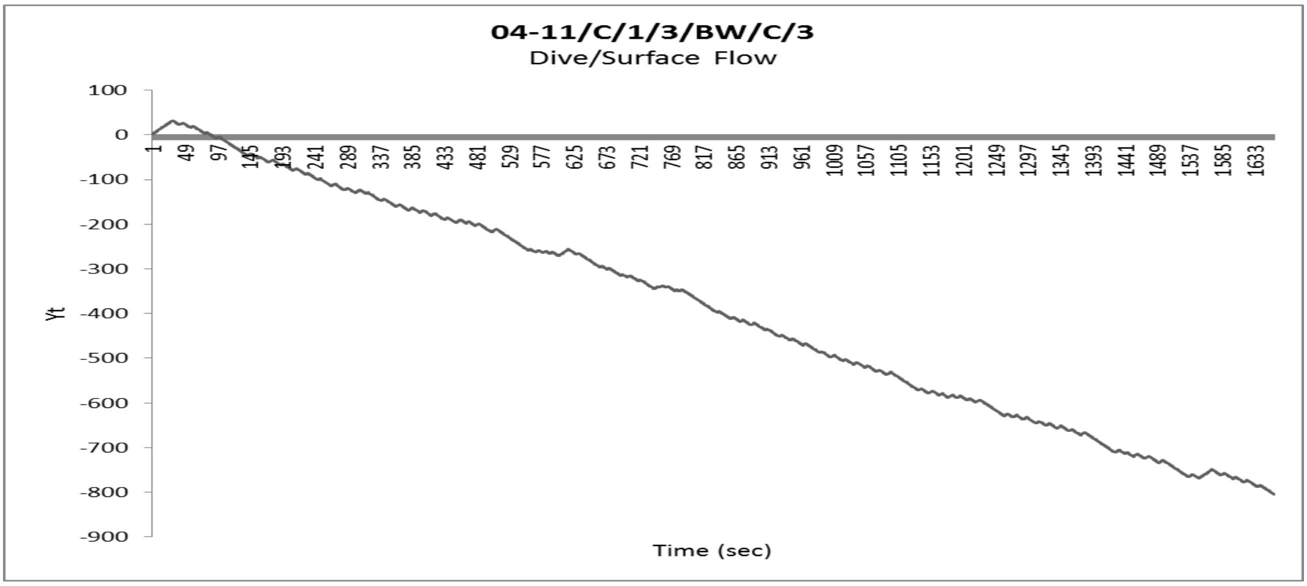

03-11/B/1/3/BW/C/1
Dive/Surface Flow
Yt
Time (sec)

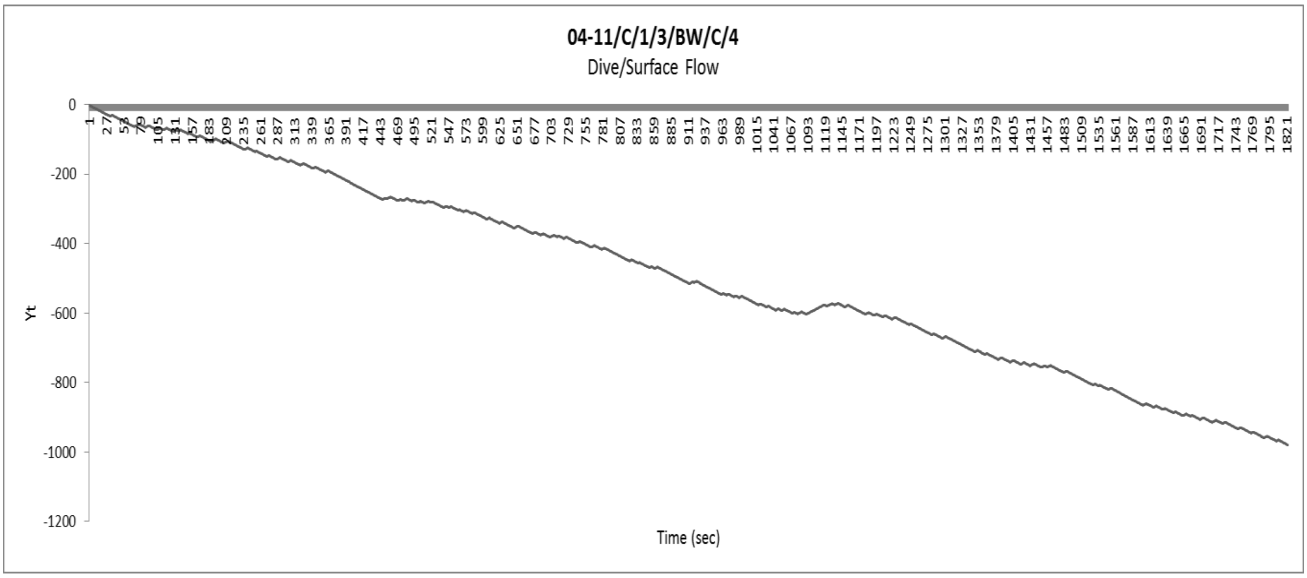

03-11/B/1/3/BW/C/2
Dive/Surface flow
Yt
Time (sec)

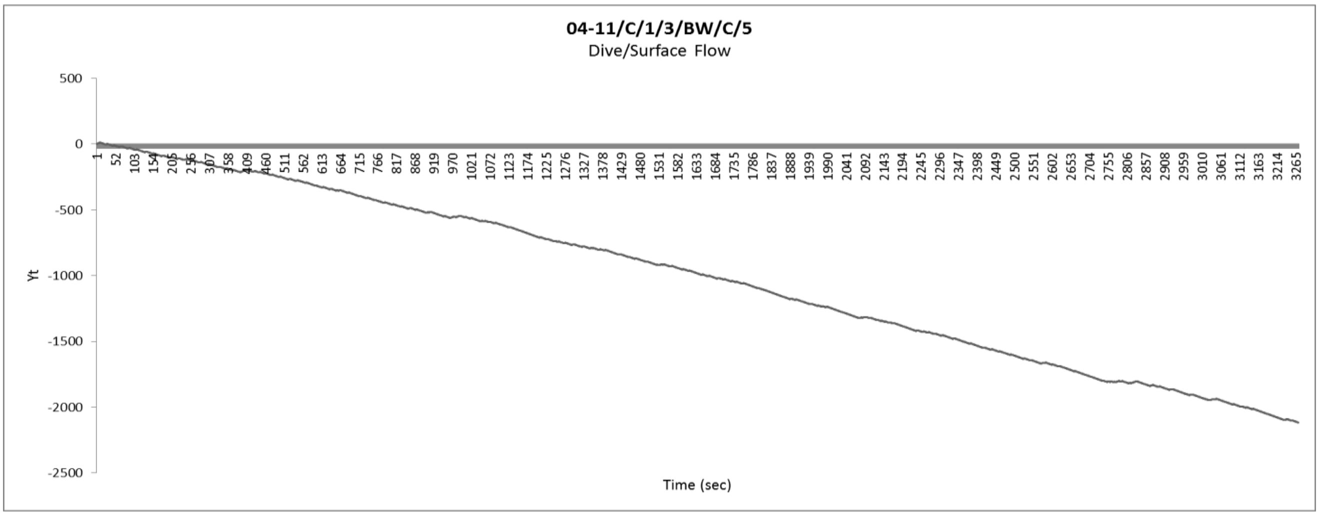

03-11/B/1/3/BW/C/3
Dive/Surface Flow
Yt
Time (sec)

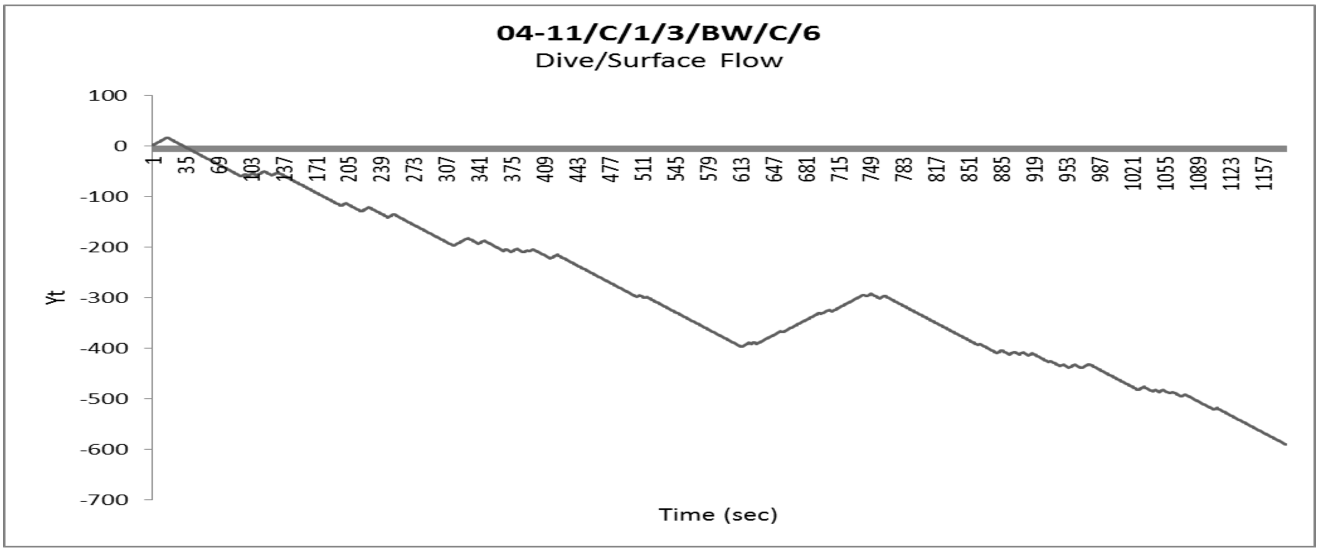

04-11/B/1/3/VF/C/1
Dive/Surface Flow
Yt
Time (sec)

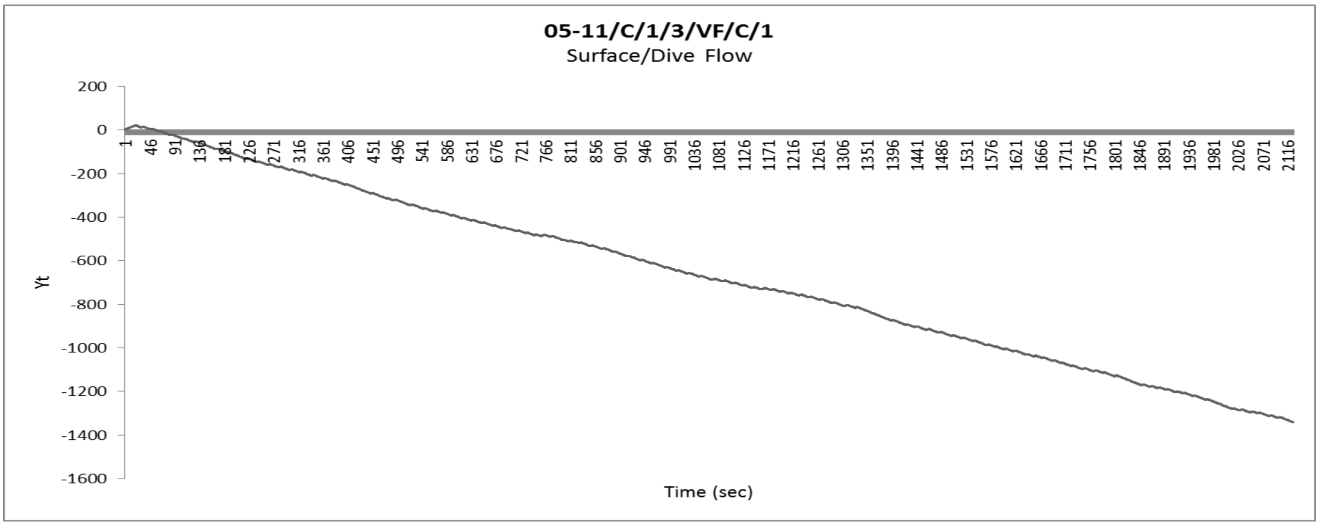

04-11/C/1/3/BW/C/2
Dive/Surface Flow
Yt
Time (sec)

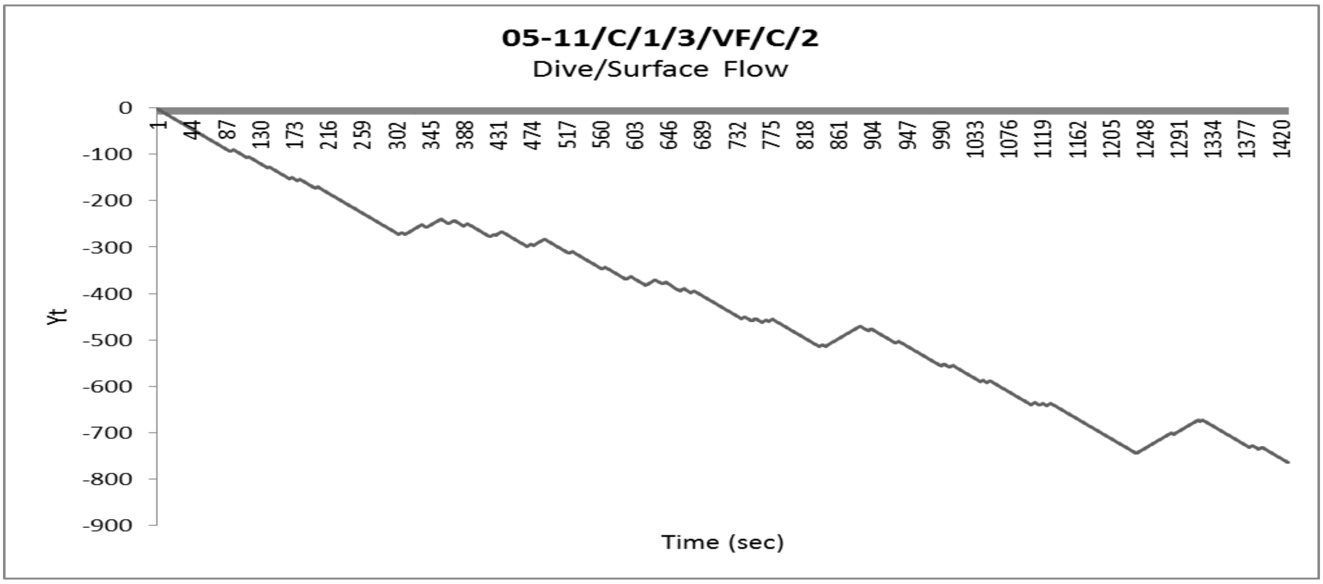

04-11/C/1/3/BW/C/3
Dive/Surface Flow
Yt
Time (sec)

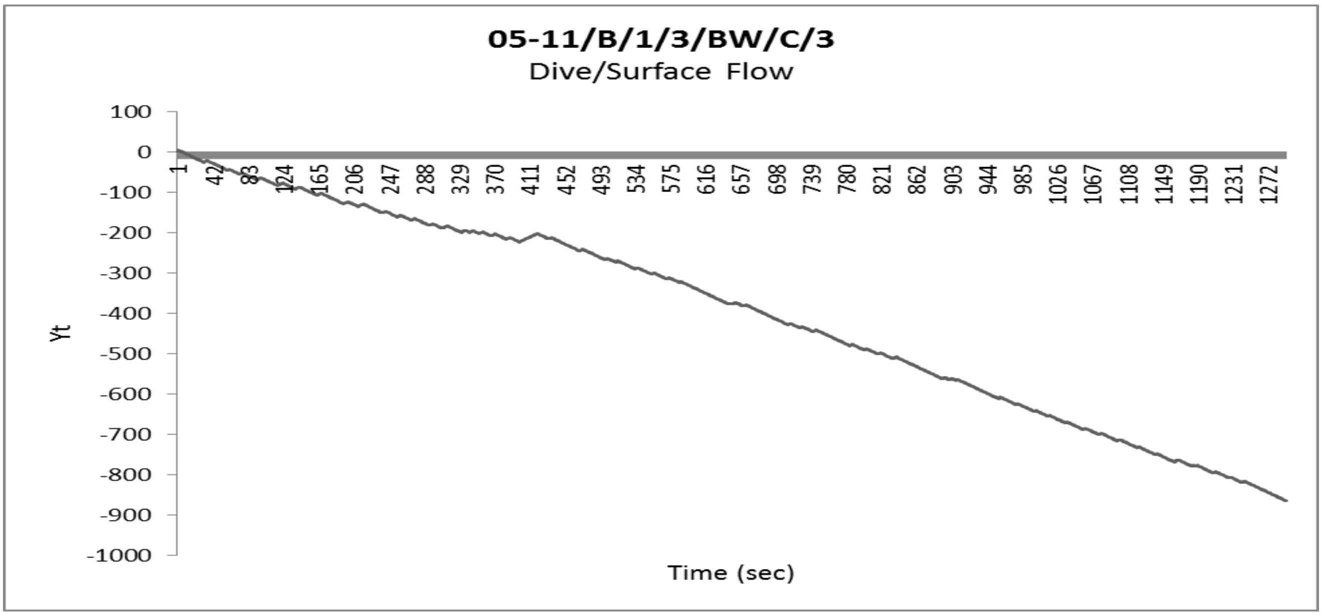

04-11/C/1/3/BW/C/4
Dive/Surface Flow
Yt
Time (sec)

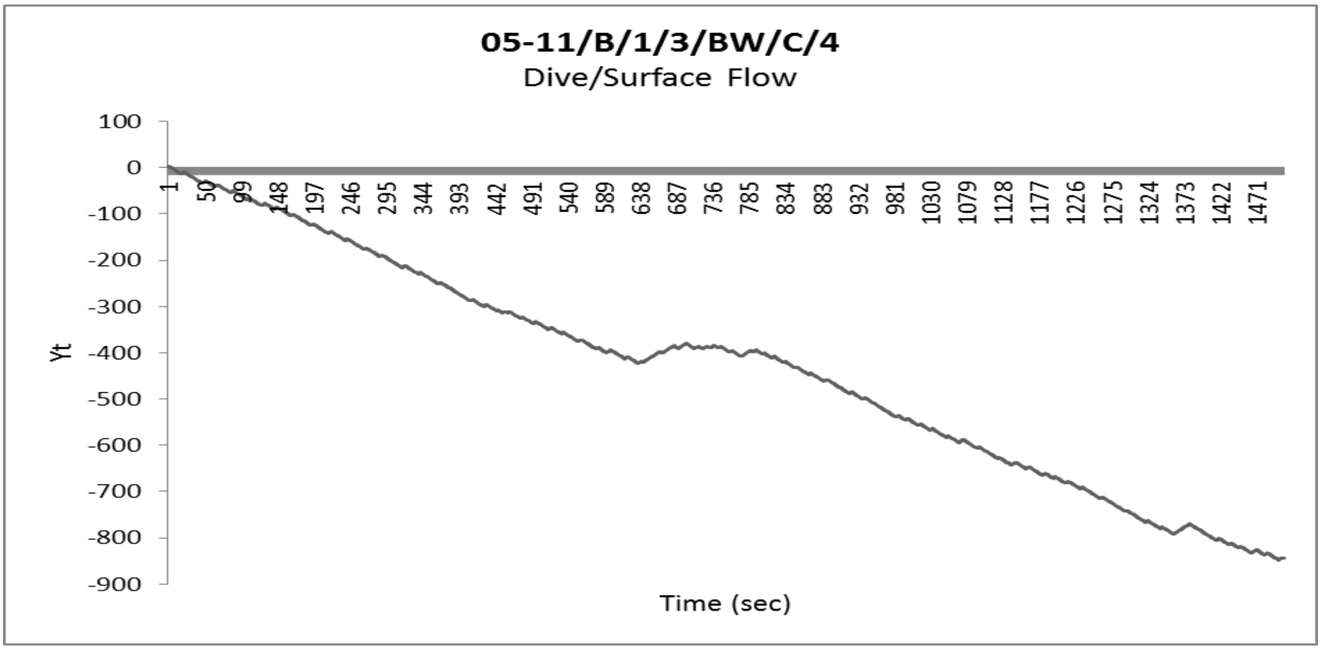

04-11/C/1/3/BW/C/5
Dive/Surface Flow
Yt
Time (sec)

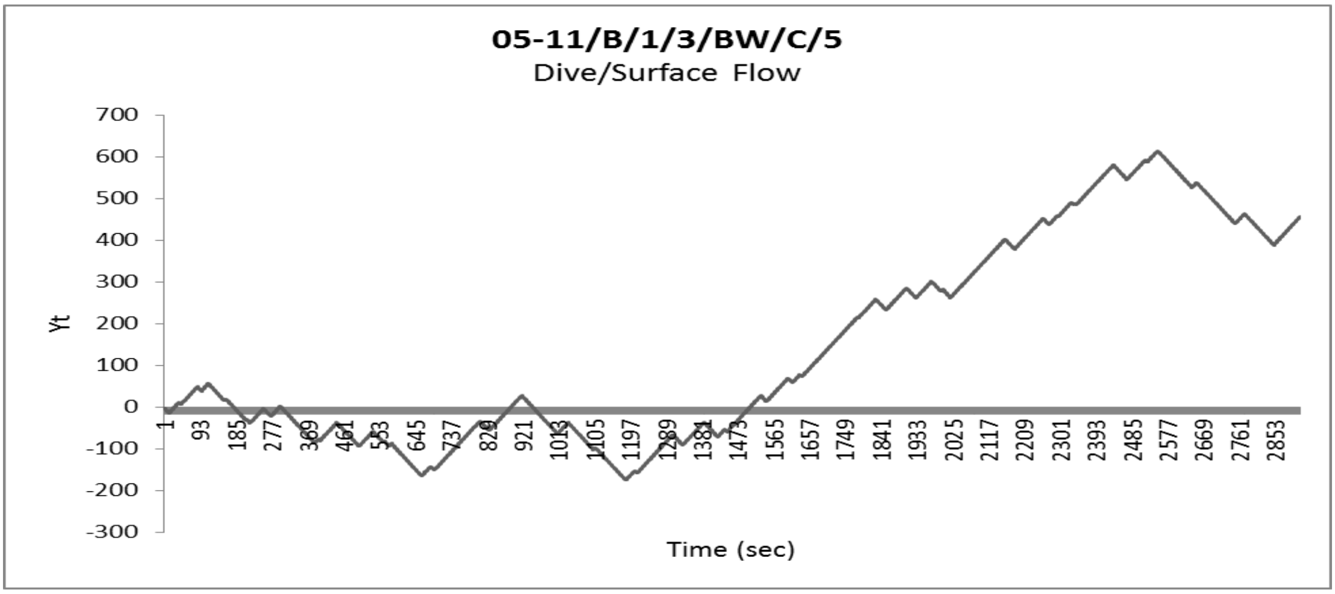

04-11/C/1/3/BW/C/6
Dive/Surface Flow
Yt
Time (sec)

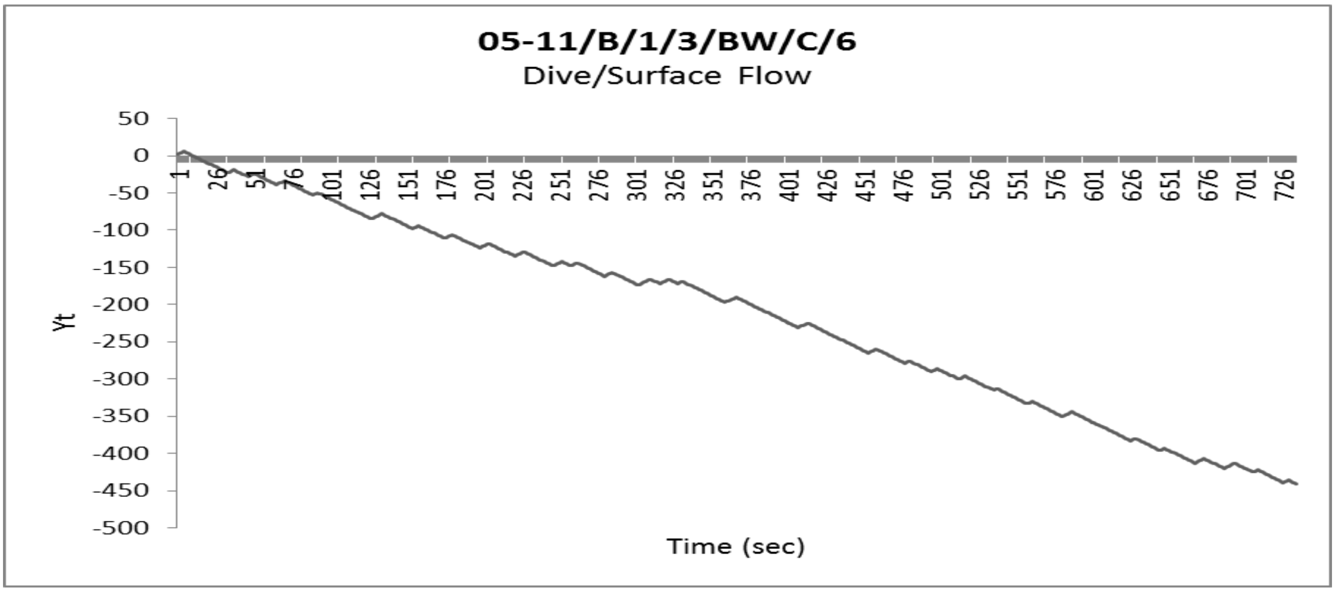

05-11/C/1/3/VF/C/1
Surface/Dive Flow
Yt
Time (sec)

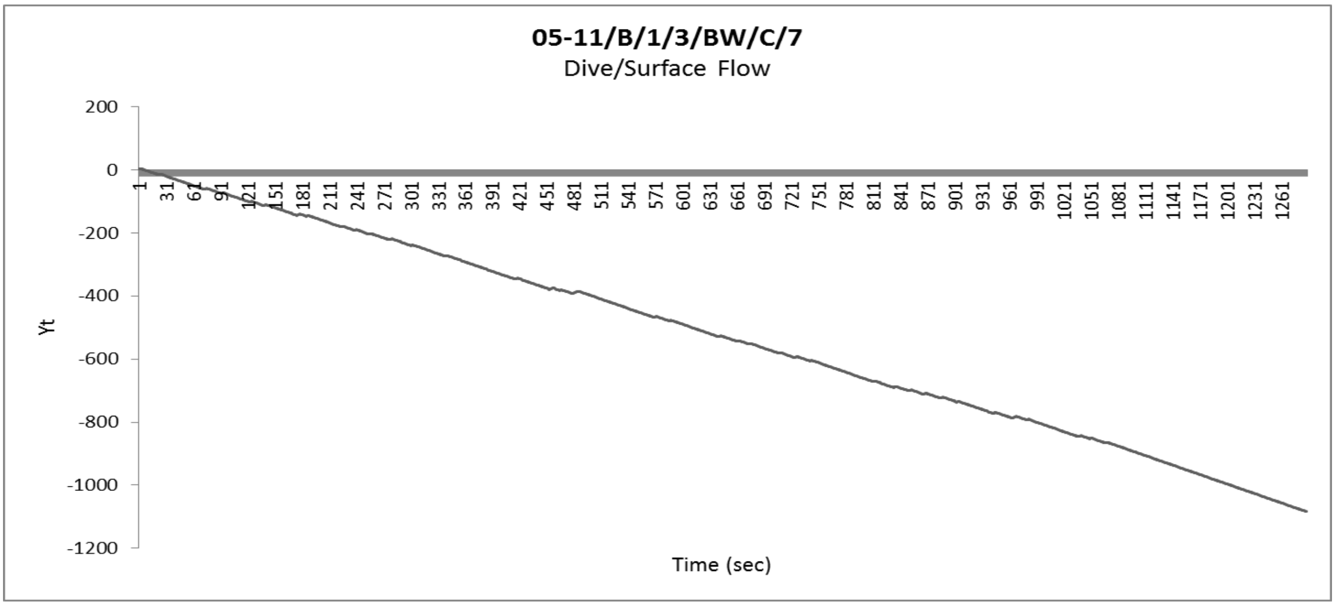

05-11/C/1/3/VF/C/2
Dive/Surface Flow
Yt
Time (sec)

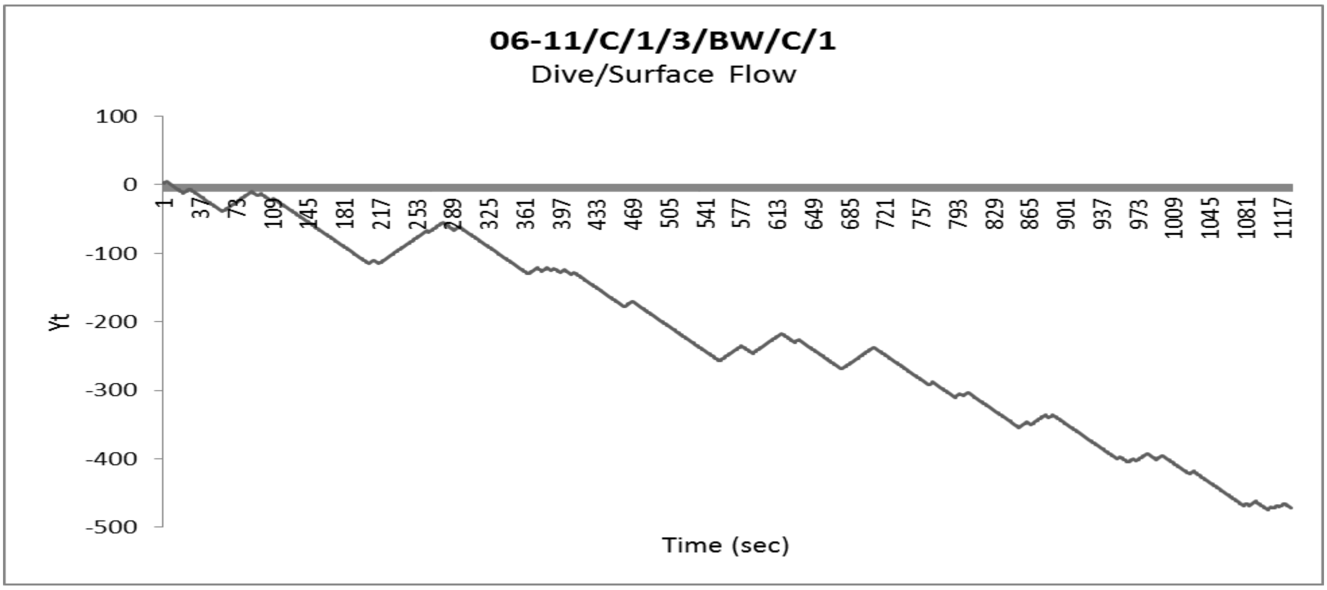

05-11/B/1/3/BW/C/3
Dive/Surface Flow
Yt
Time (sec)

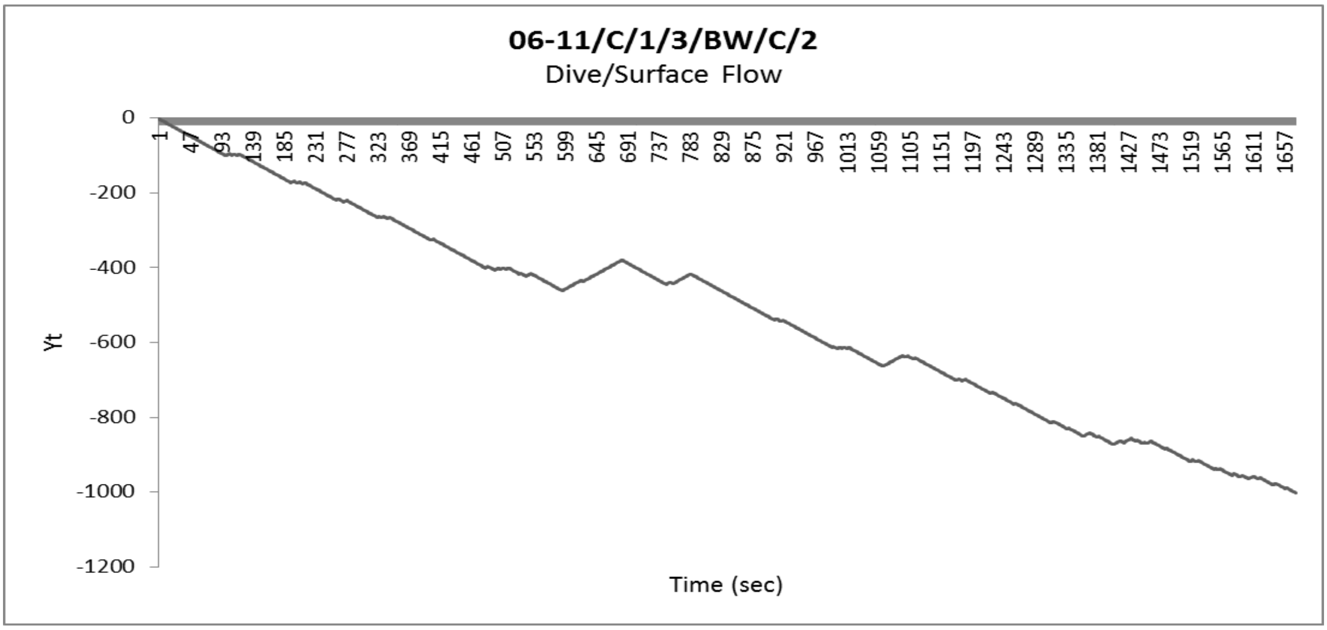

05-11/B/1/3/BW/C/4
Dive/Surface Flow
Yt
Time (sec)

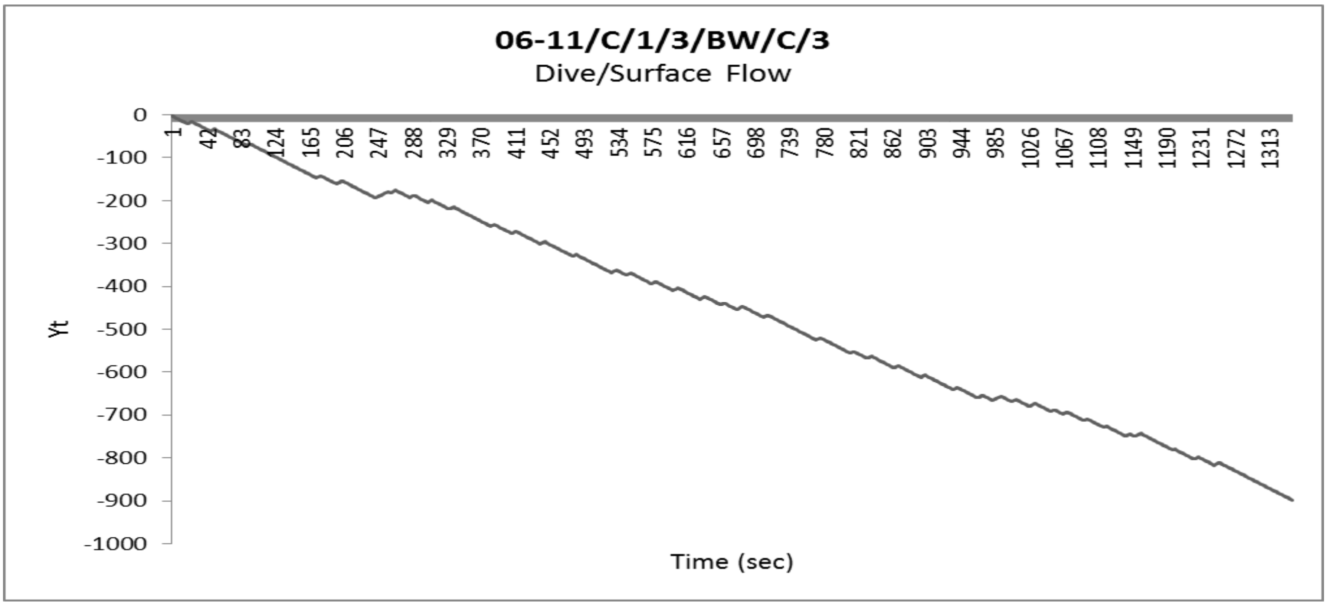

05-11/B/1/3/BW/C/5
Dive/Surface Flow
Yt
Time (sec)

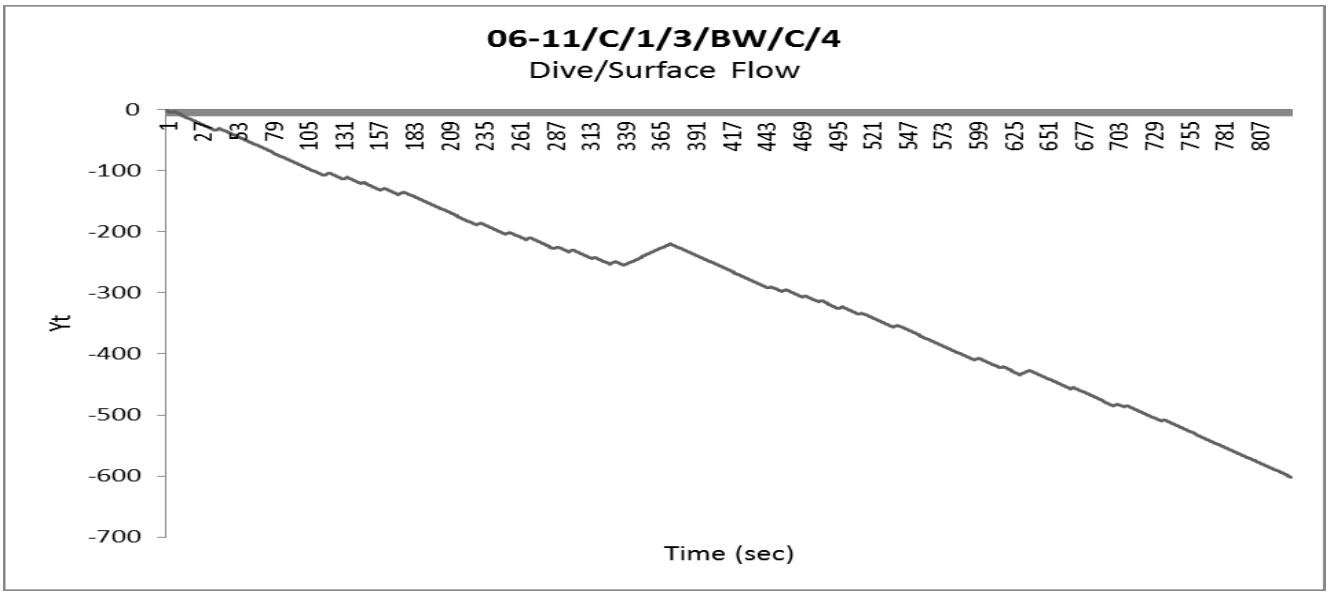

05-11/B/1/3/BW/C/6
Dive/Surface Flow
Yt
Time (sec)


05-11/B/1/3/BW/C/7
Dive/Surface Flow
Yt
Time (sec)


06-11/C/1/3/BW/C/1
Dive/Surface Flow
Yt
Time (sec)

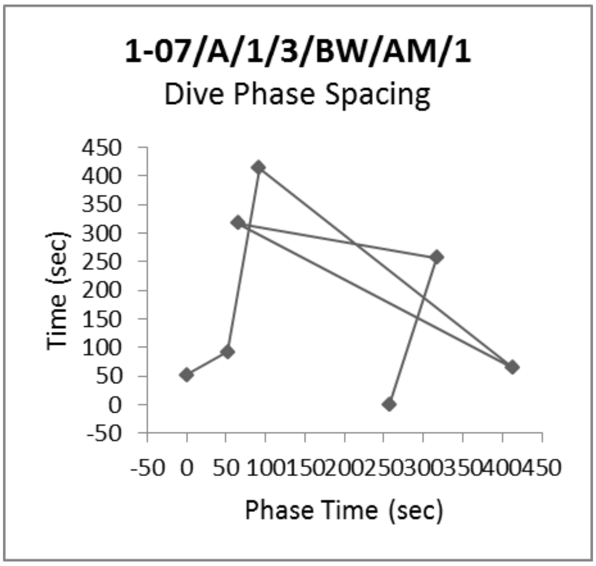

06-11/C/1/3/BW/C/2
Dive/Surface Flow
Yt
Time (sec)

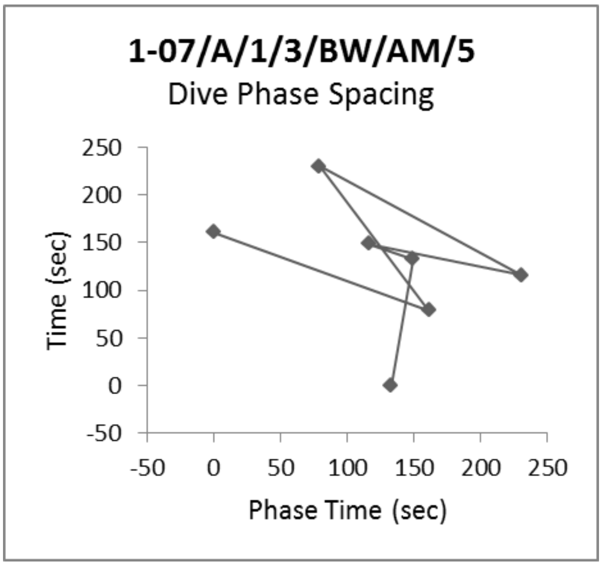

06-11/C/1/3/BW/C/3
Dive/Surface Flow
Yt
Time (sec)

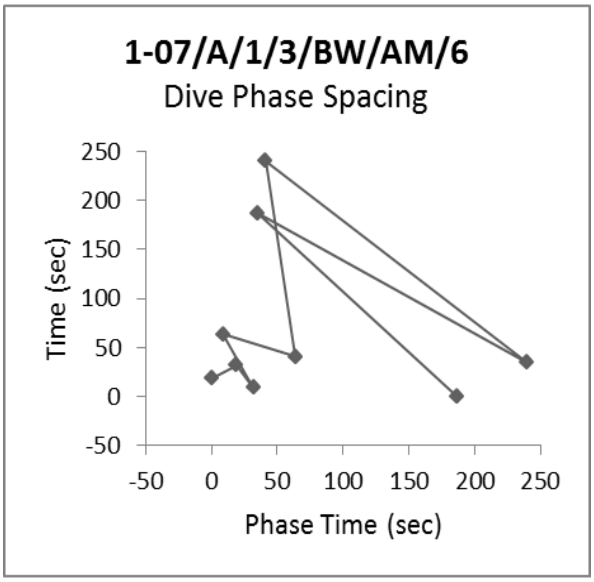

06-11/C/1/3/BW/C/4
Dive/Surface Flow
0
-100
-200
-300
-400
-500
-600
-700
Yt
1
27
53
79
105
131
157
183
209
235
261
287
313
339
365
391
417
443
469
495
521
547
573
599
625
651
677
703
729
755
781
807
Time (sec)

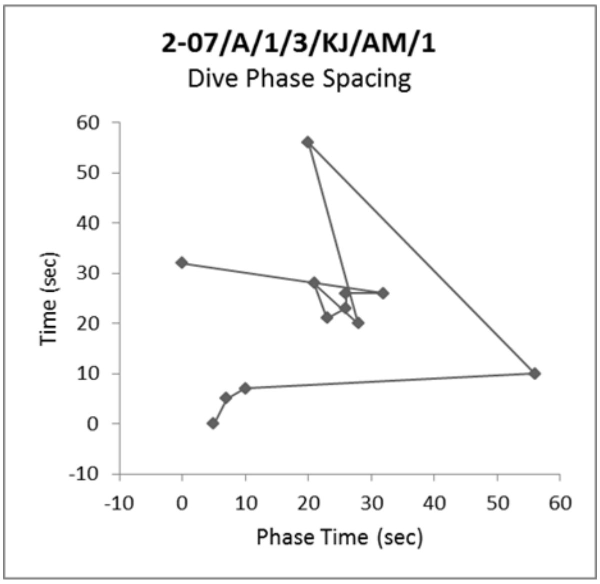
Appendix B2: Orbital Phase Spacing of *E. australis*

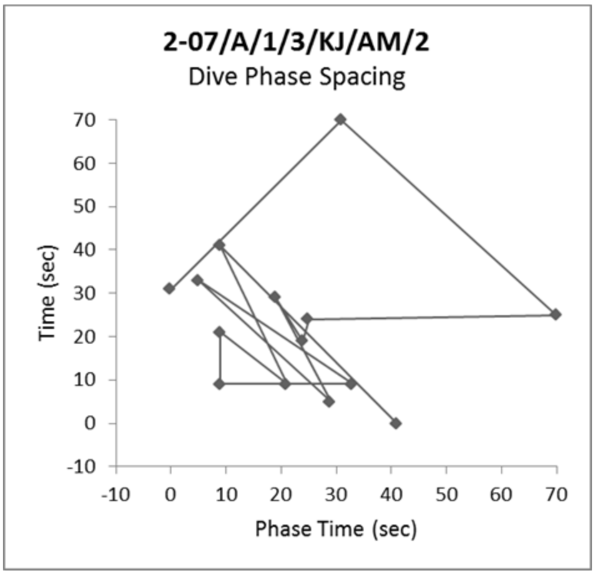
a: Dive Phase Spacing in Accompanied Mothers

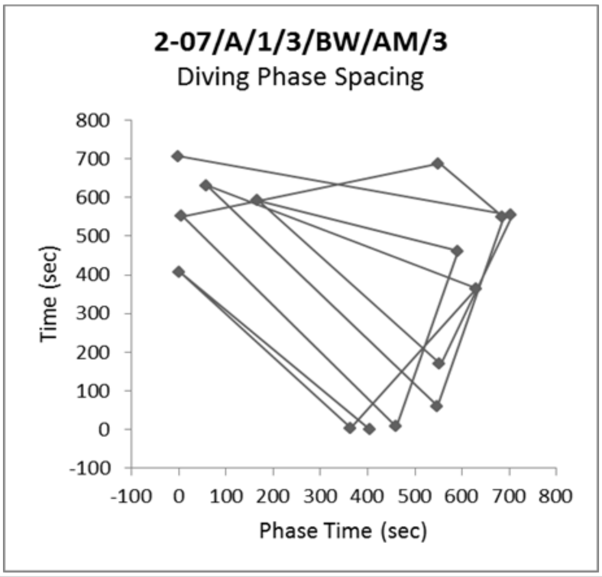


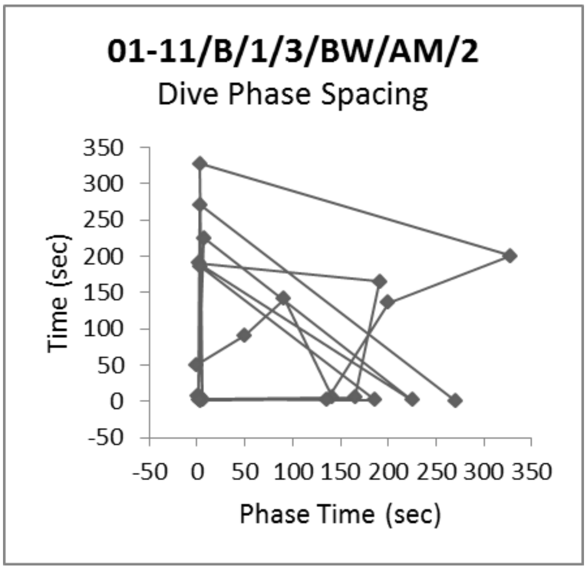


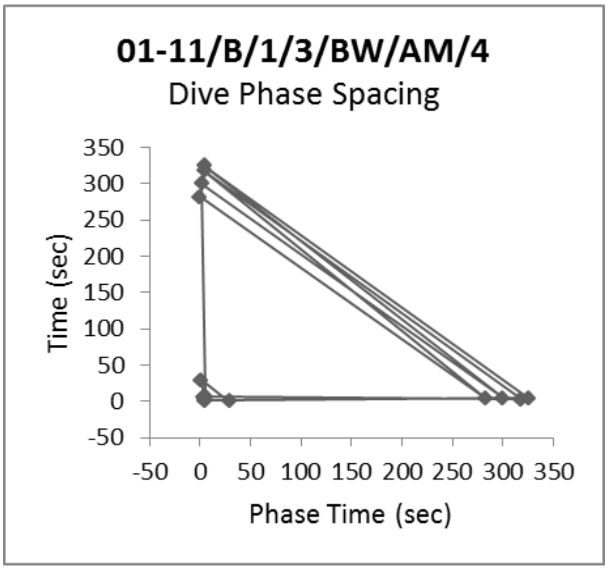


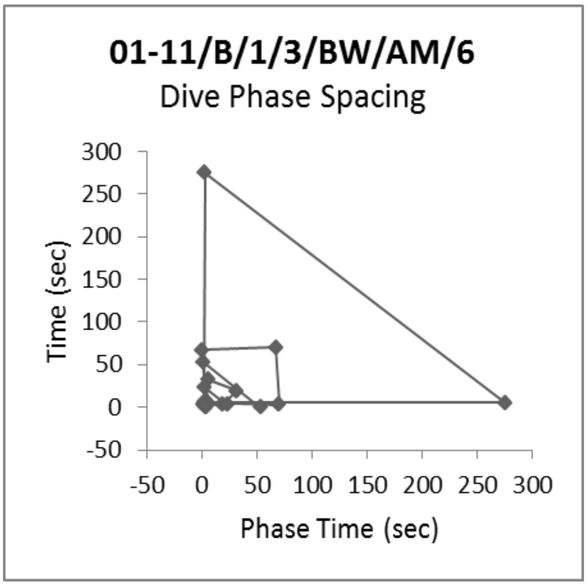


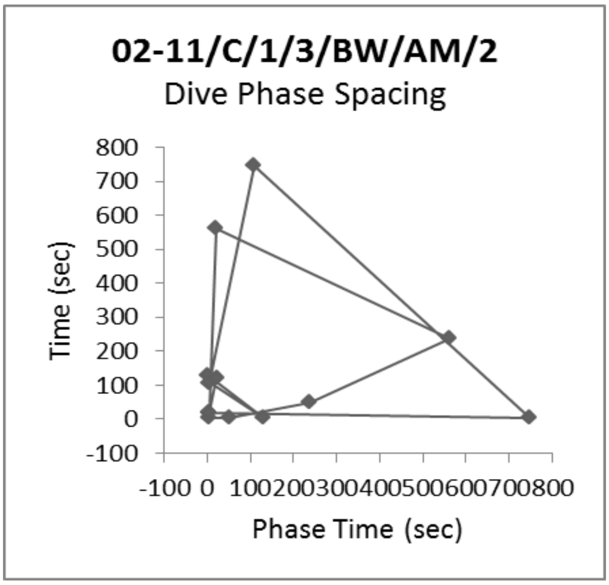


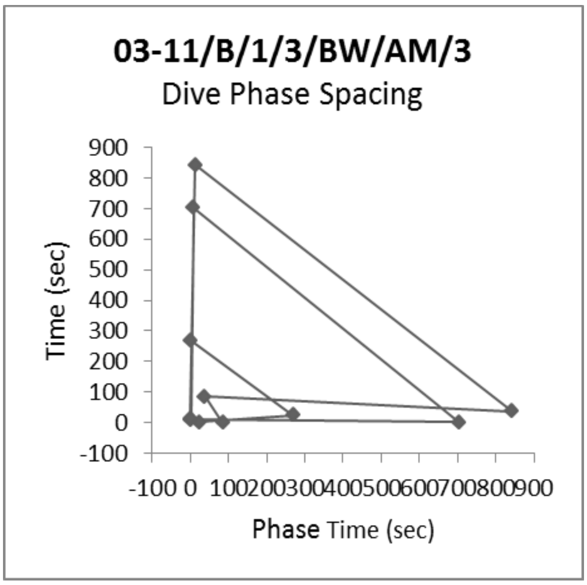


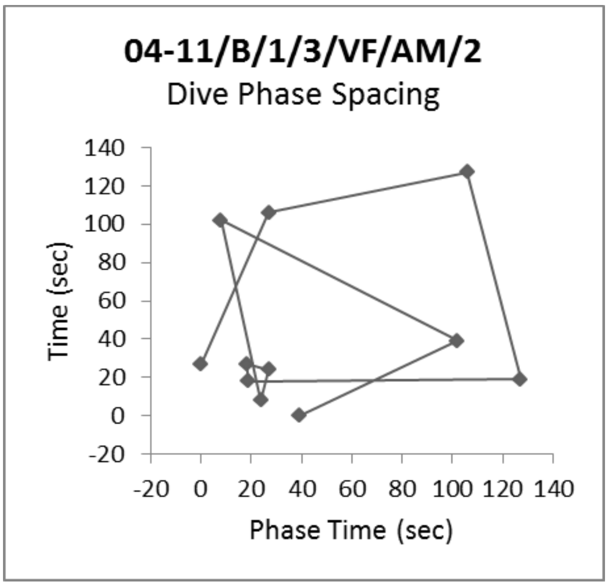

01-11/B/1/3/BW/AM/2
Dive Phase Spacing
Time (sec)
350 300 250 200 150 100 50 0 -50
-50 0 50 100 150 200 250 300 350
Phase Time (sec)

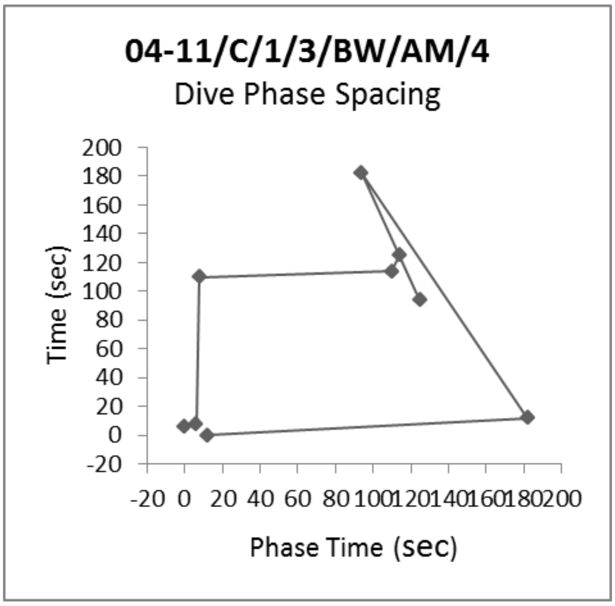

01-11/B/1/3/BW/AM/4
Dive Phase Spacing
Time (sec)
350 300 250 200 150 100 50 0 -50
-50 0 50 100 150 200 250 300 350
Phase Time (sec)

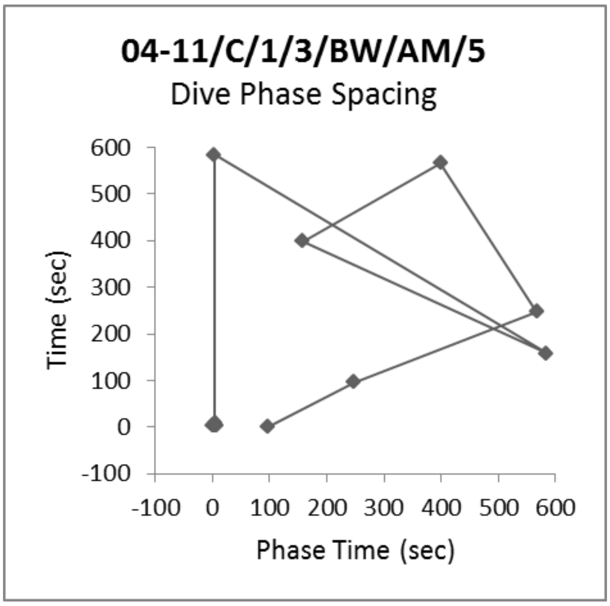

01-11/B/1/3/BW/AM/6
Dive Phase Spacing
Time (sec)
300 250 200 150 100 50 0 -50
-50 0 50 100 150 200 250 300
Phase Time (sec)

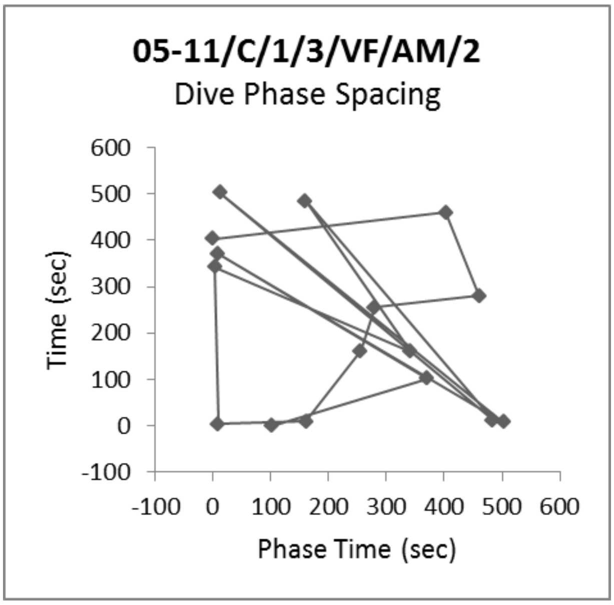

02-11/C/1/3/BW/AM/2
Dive Phase Spacing
Time (sec)
800 700 600 500 400 300 200 100 0 -100
-100 0 100200300400500600700800
Phase Time (sec)

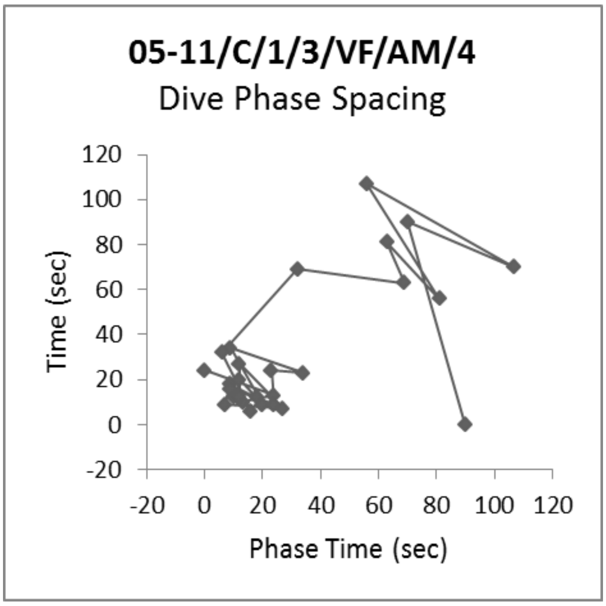

03-11/B/1/3/BW/AM/3
Dive Phase Spacing
Time (sec)
900 800 700 600 500 400 300 200 100 0 -100
-100 0 100200300400500600700800900
Phase Time (sec)

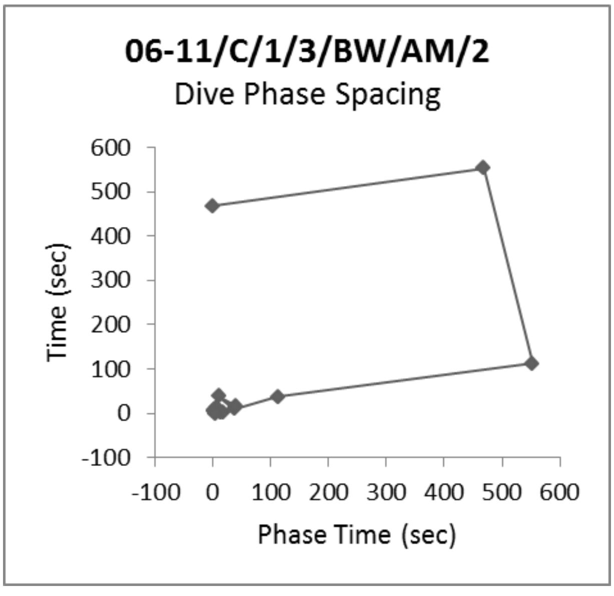

04-11/B/1/3/VF/AM/2
Dive Phase Spacing
Time (sec)
140 120 100 80 60 40 20 0 -20
-20 0 20 40 60 80 100 120 140
Phase Time (sec)


04-11/C/1/3/BW/AM/4
Dive Phase Spacing
Time (sec)
Phase Time (sec)
200
180
160
140
120
100
80
60
40
20
0
-20
-20 0 20 40 60 80 100 120 140 160 180 200

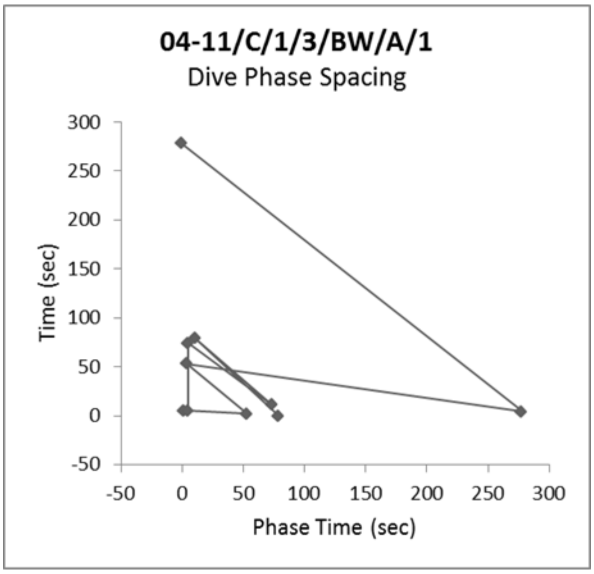

04-11/C/1/3/BW/AM/5
Dive Phase Spacing
Time (sec)
Phase Time (sec)
600
500
400
300
200
100
0
-100
-100 0 100 200 300 400 500 600


05-11/C/1/3/VF/AM/2
Dive Phase Spacing
Time (sec)
Phase Time (sec)
600
500
400
300
200
100
0
-100
-100 0 100 200 300 400 500 600

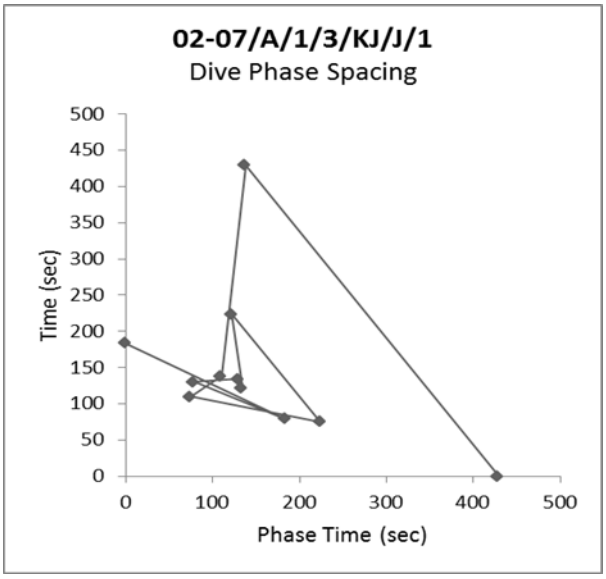

05-11/C/1/3/VF/AM/4
Dive Phase Spacing
Time (sec)
Phase Time (sec)
120
100
80
60
40
20
0
-20
-20 0 20 40 60 80 100 120

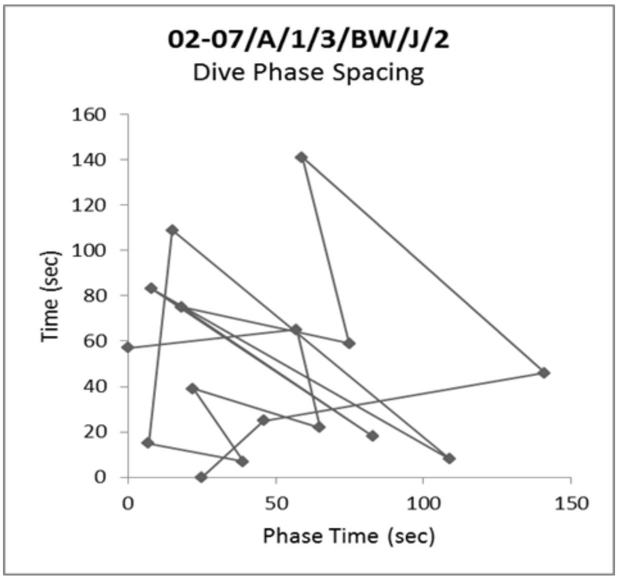

06-11/C/1/3/BW/AM/2
Dive Phase Spacing
Time (sec)
Phase Time (sec)
600
500
400
300
200
100
0
-100
-100 0 100 200 300 400 500 600

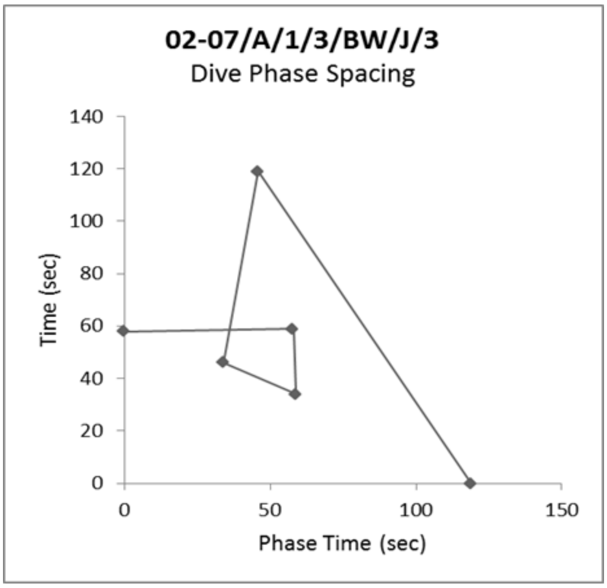
b: Dive Phase Spacing in Adults

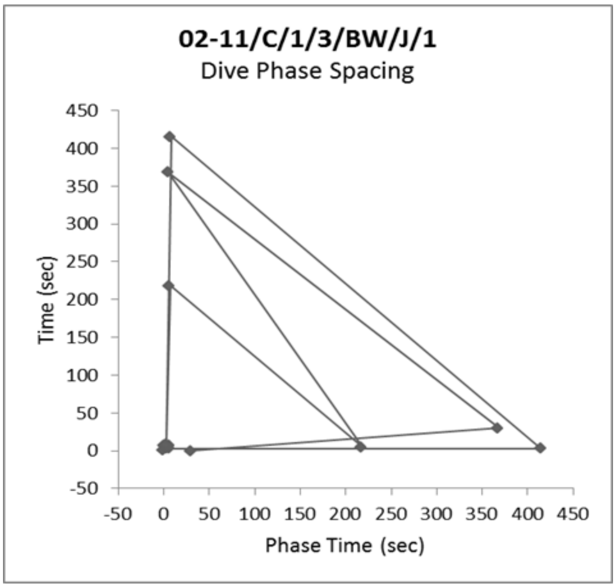


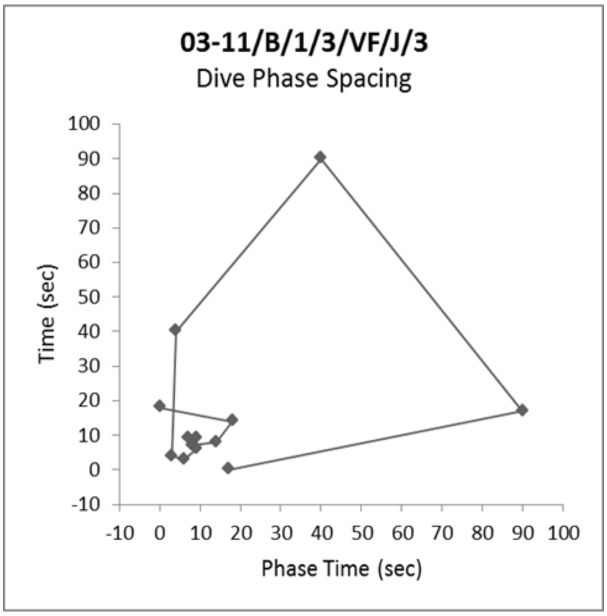
c: Dive Phase Spacing in Juveniles



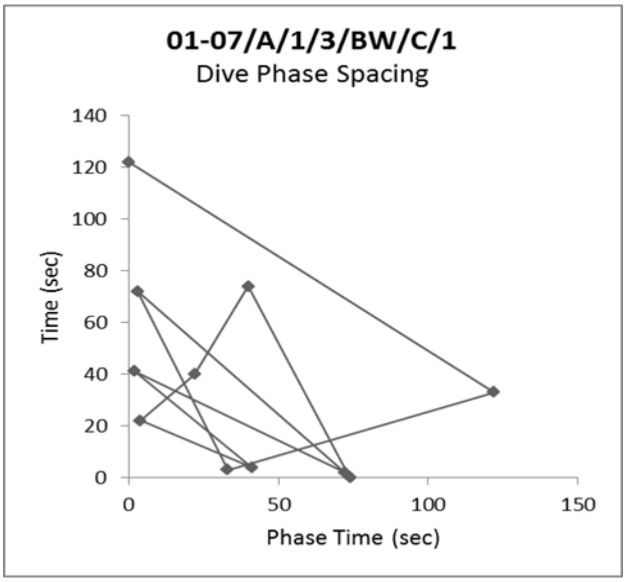


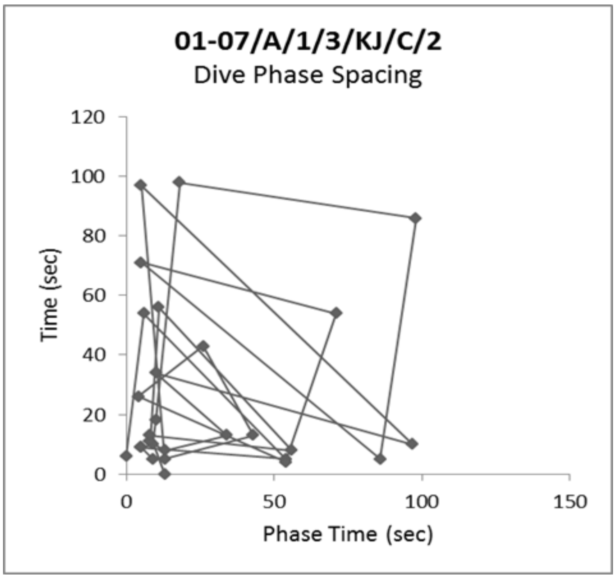


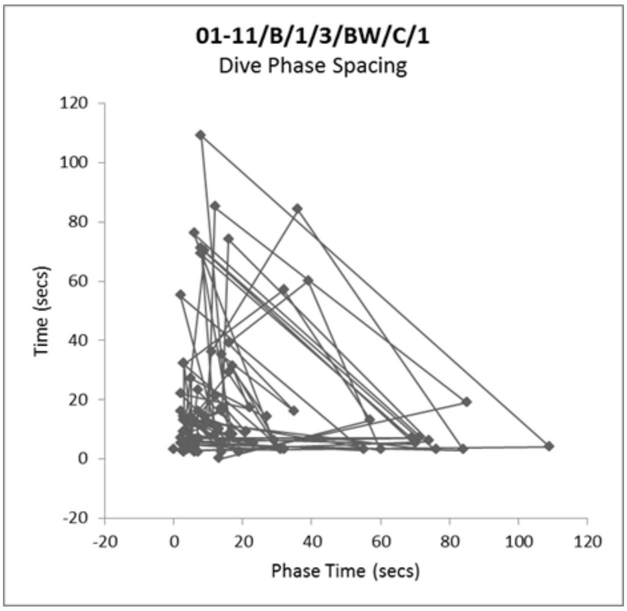


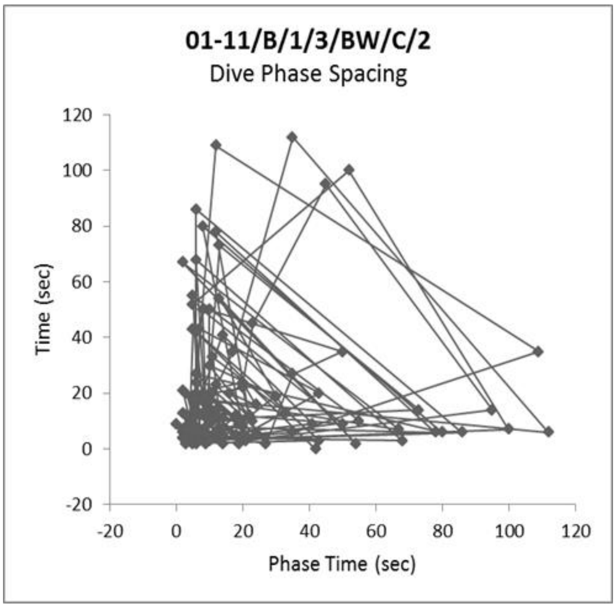


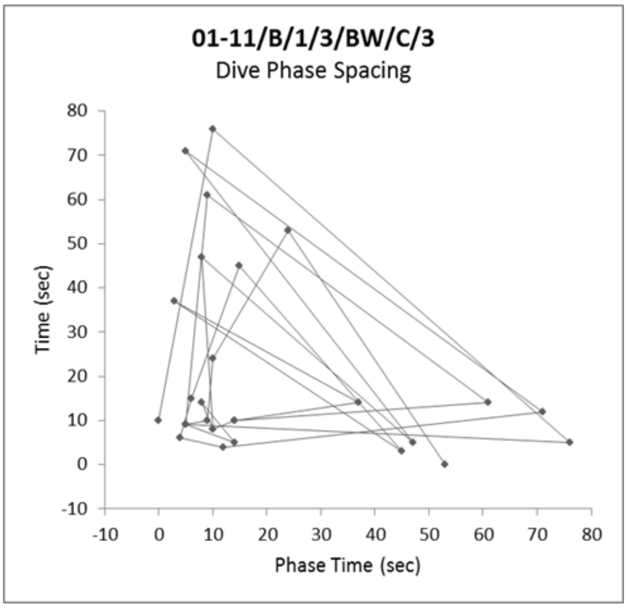
d: Dive Phase Spacing in Calves

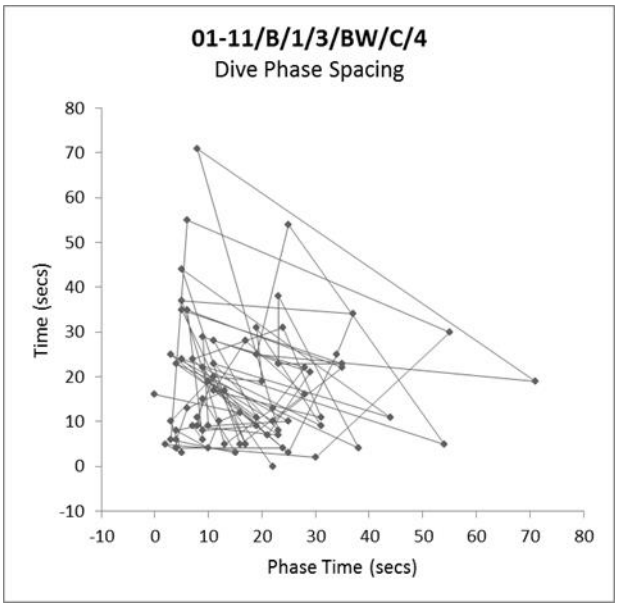


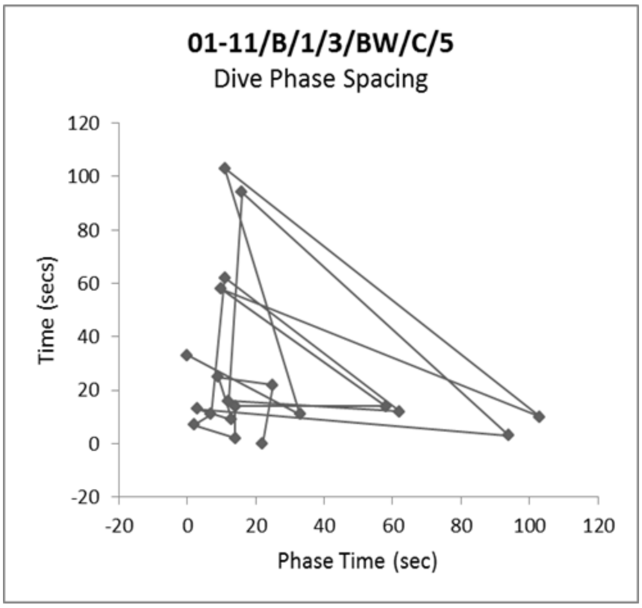


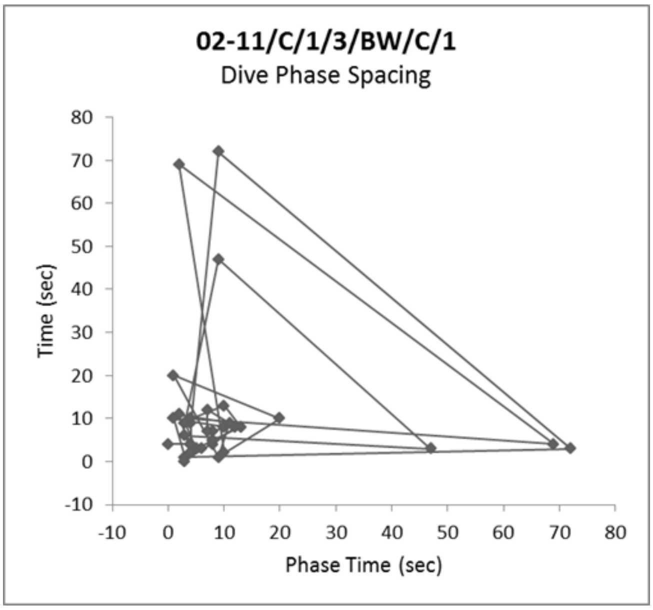


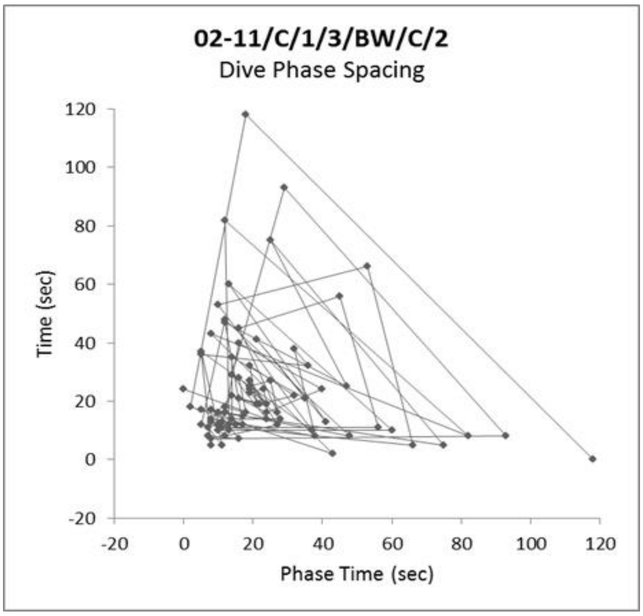


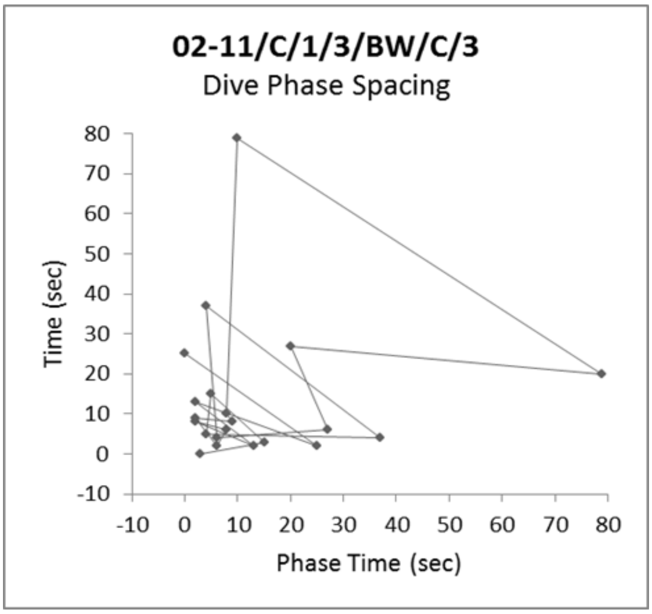


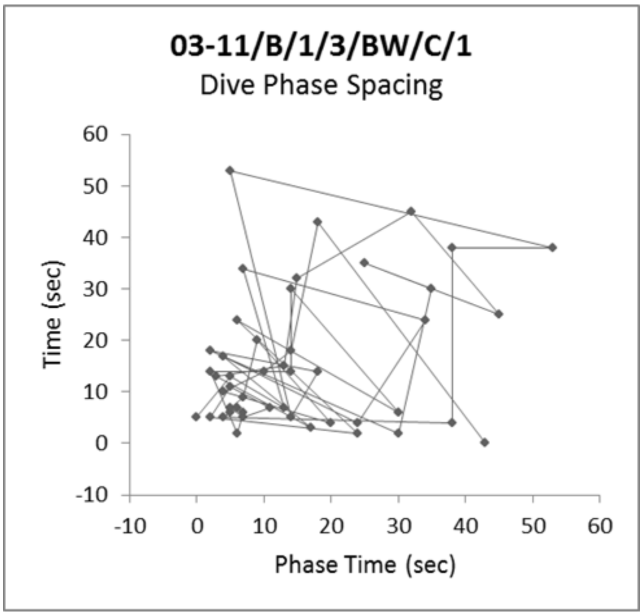


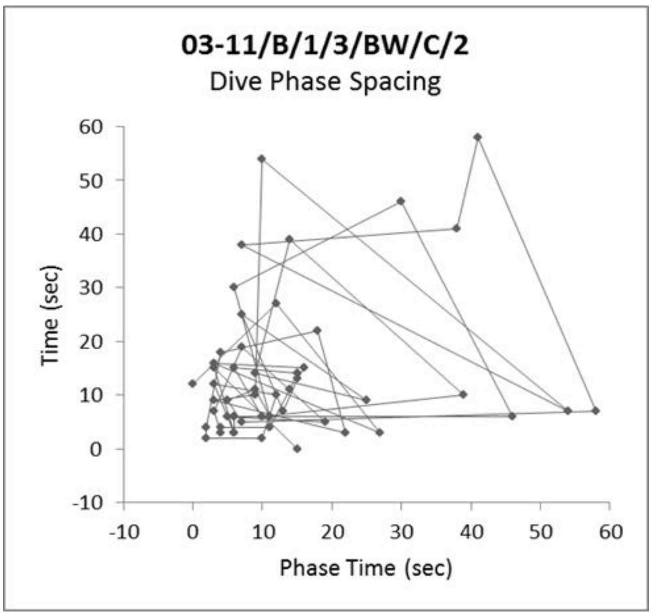

01-11/B/1/3/BW/C/5
Dive Phase Spacing
Time (secs)
Phase Time (sec)

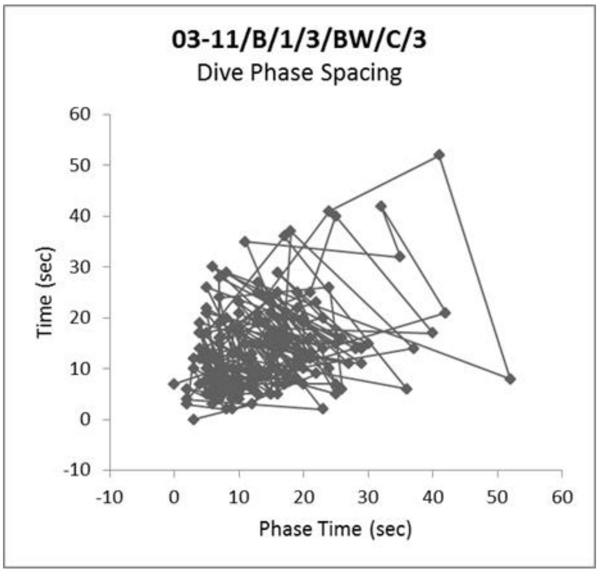

02-11/C/1/3/BW/C/1
Dive Phase Spacing
Time (sec)
Phase Time (sec)

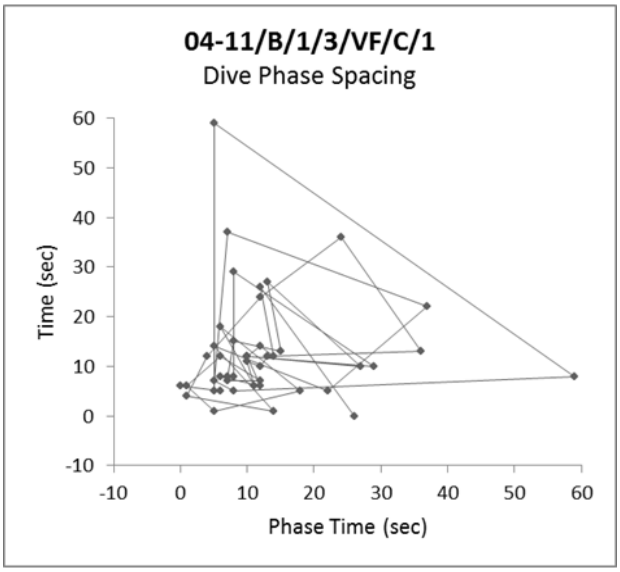

02-11/C/1/3/BW/C/2
Dive Phase Spacing
Time (sec)
Phase Time (sec)

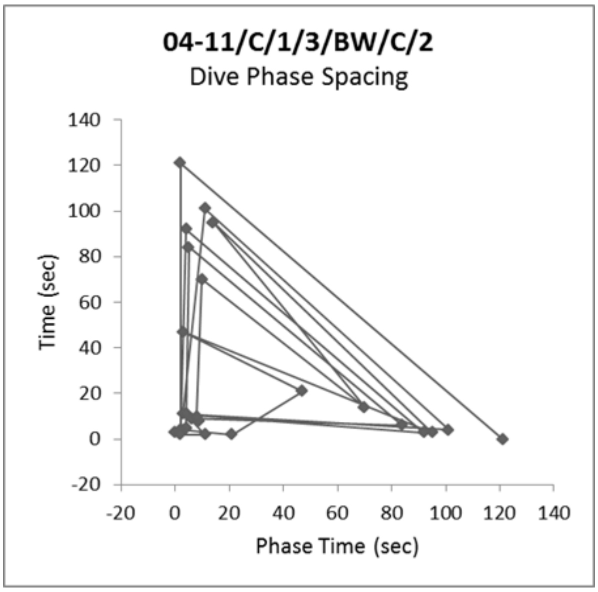

02-11/C/1/3/BW/C/3
Dive Phase Spacing
Time (sec)
Phase Time (sec)

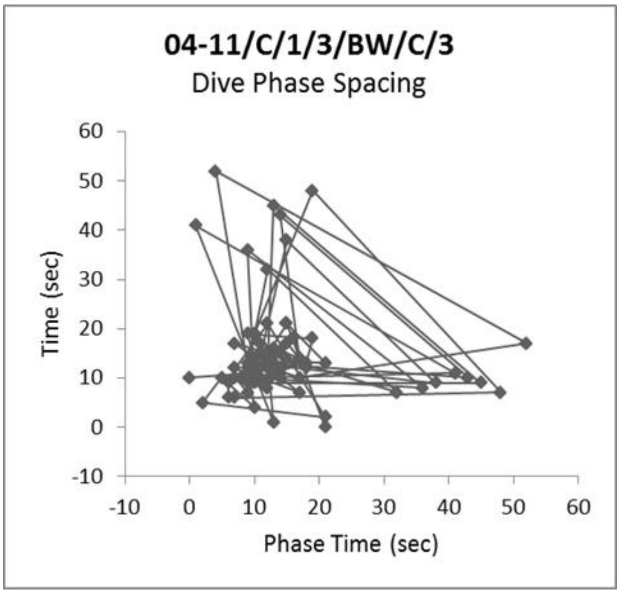

03-11/B/1/3/BW/C/1
Dive Phase Spacing
Time (sec)
Phase Time (sec)

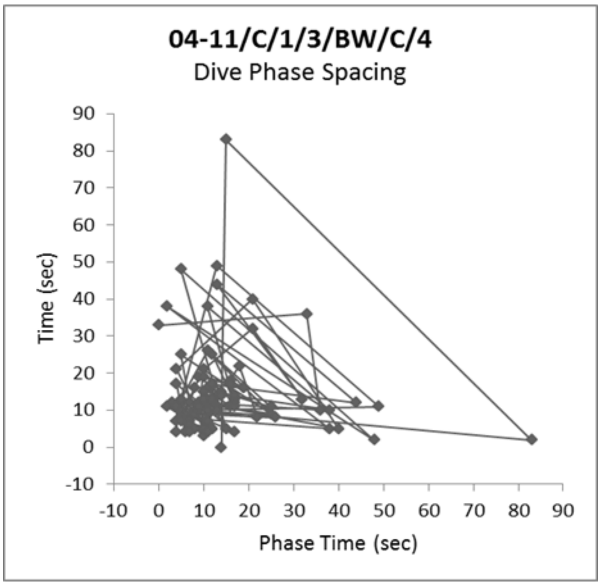

03-11/B/1/3/BW/C/2
Dive Phase Spacing
Time (sec)
Phase Time (sec)

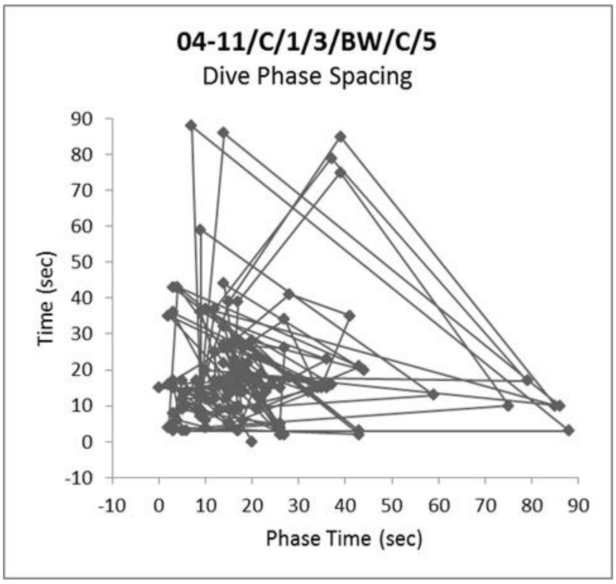

03-11/B/1/3/BW/C/3
Dive Phase Spacing
Time (sec)
Phase Time (sec)

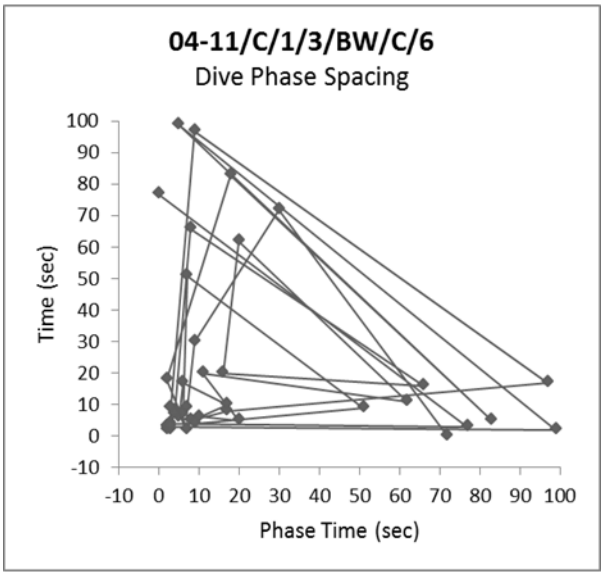

04-11/B/1/3/VF/C/1
Dive Phase Spacing
Time (sec)
Phase Time (sec)

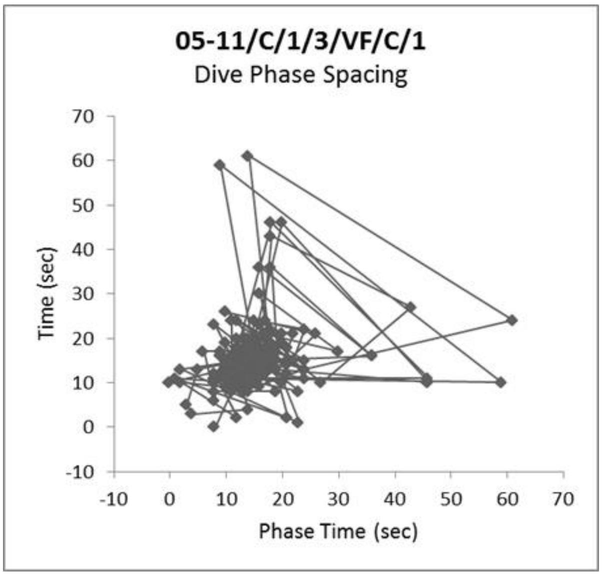

04-11/C/1/3/BW/C/2
Dive Phase Spacing
Time (sec)
Phase Time (sec)

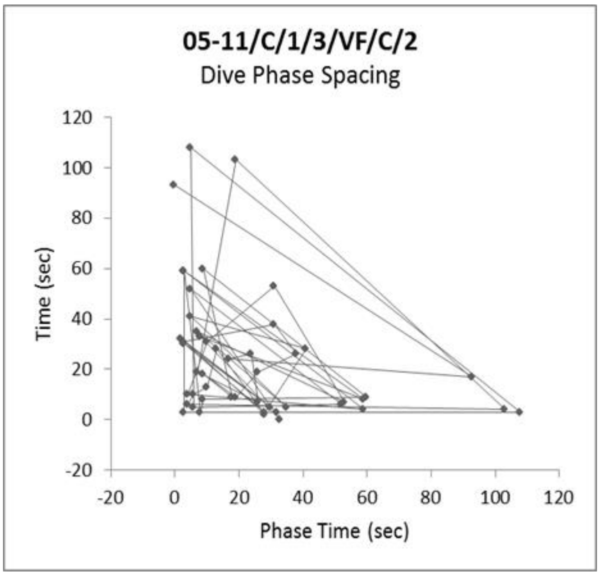

04-11/C/1/3/BW/C/3
Dive Phase Spacing
Time (sec)
Phase Time (sec)

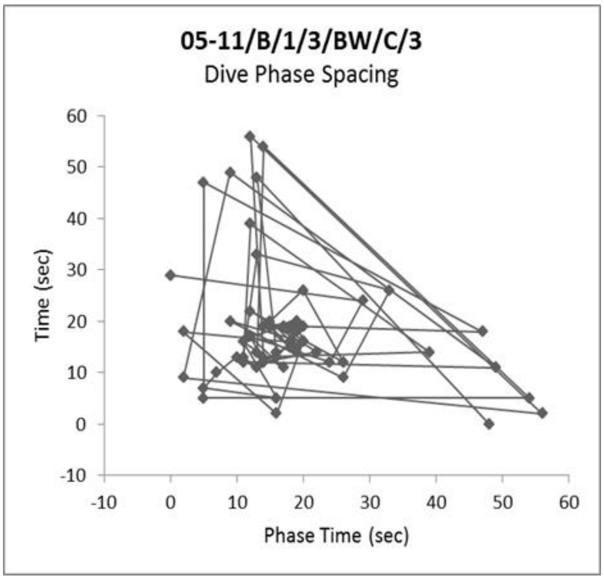

04-11/C/1/3/BW/C/4
Dive Phase Spacing
Time (sec)
Phase Time (sec)

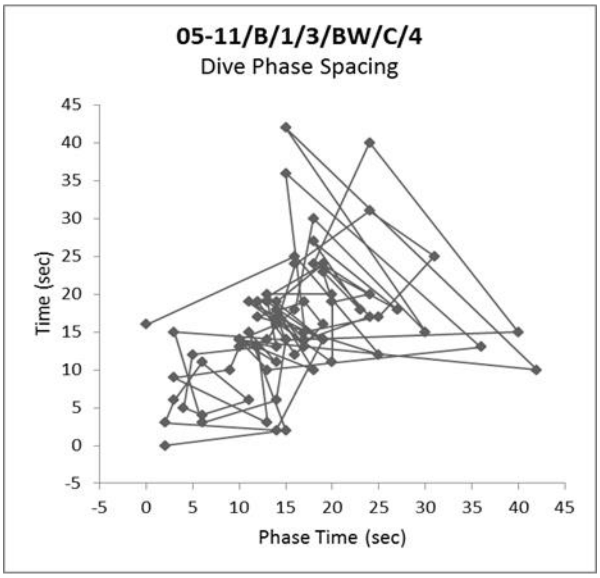

04-11/C/1/3/BW/C/5
Dive Phase Spacing
Time (sec)
Phase Time (sec)

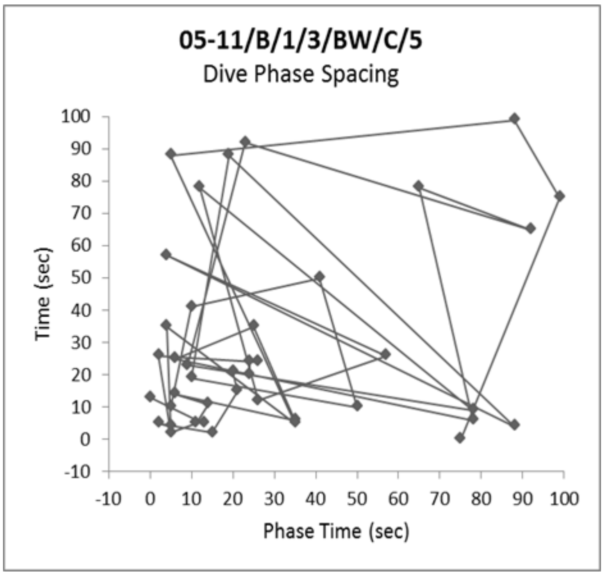

04-11/C/1/3/BW/C/6
Dive Phase Spacing
Time (sec)
Phase Time (sec)

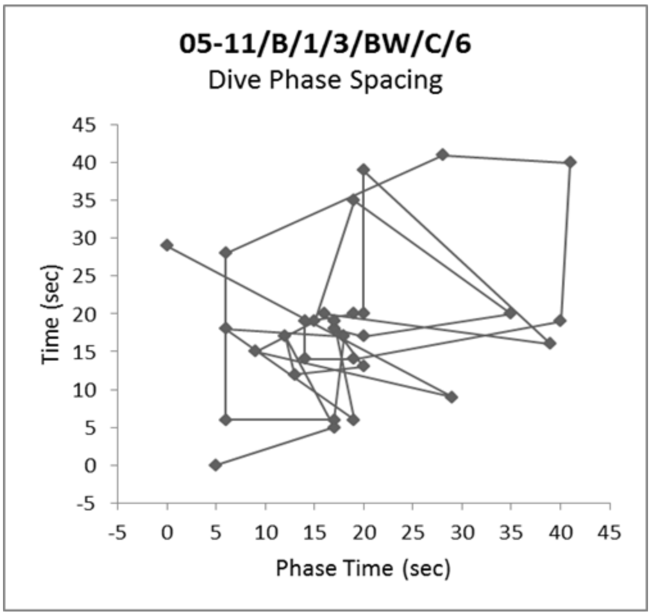

05-11/C/1/3/VF/C/1
Dive Phase Spacing
Time (sec)
Phase Time (sec)

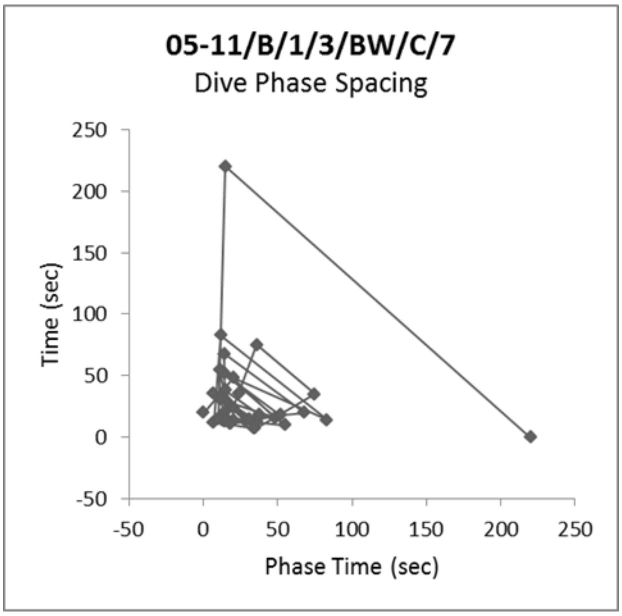

05-11/C/1/3/VF/C/2
Dive Phase Spacing
Time (sec)
Phase Time (sec)

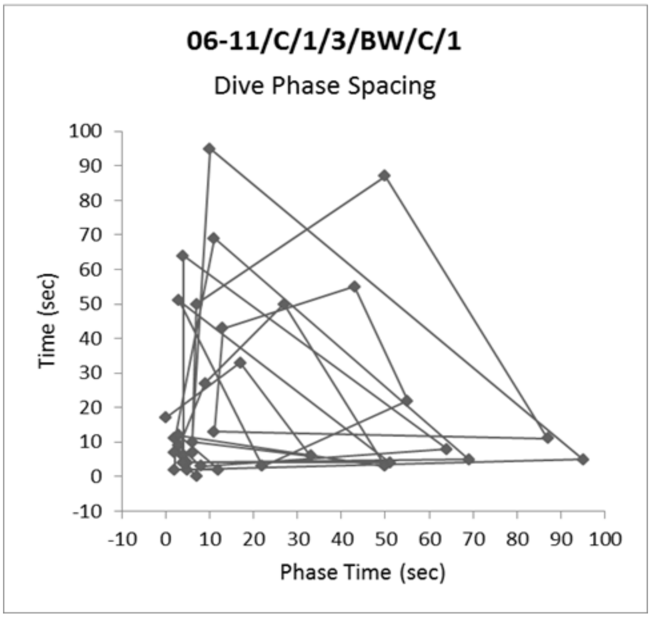

05-11/B/1/3/BW/C/3
Dive Phase Spacing
Time (sec)
Phase Time (sec)

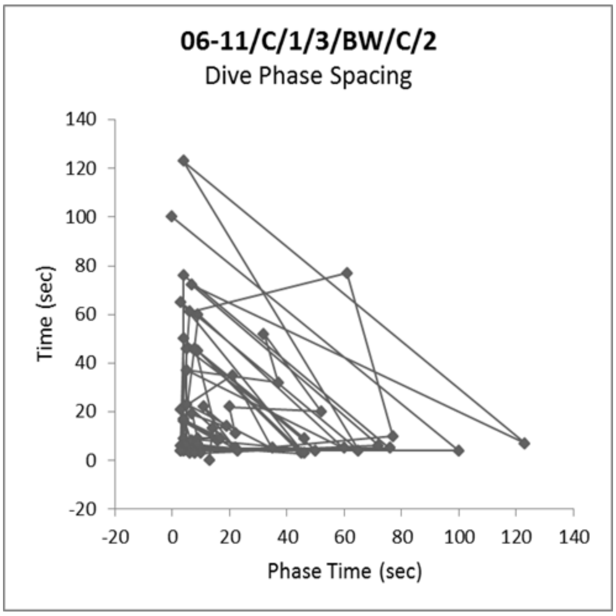

05-11/B/1/3/BW/C/4
Dive Phase Spacing
Time (sec)
Phase Time (sec)

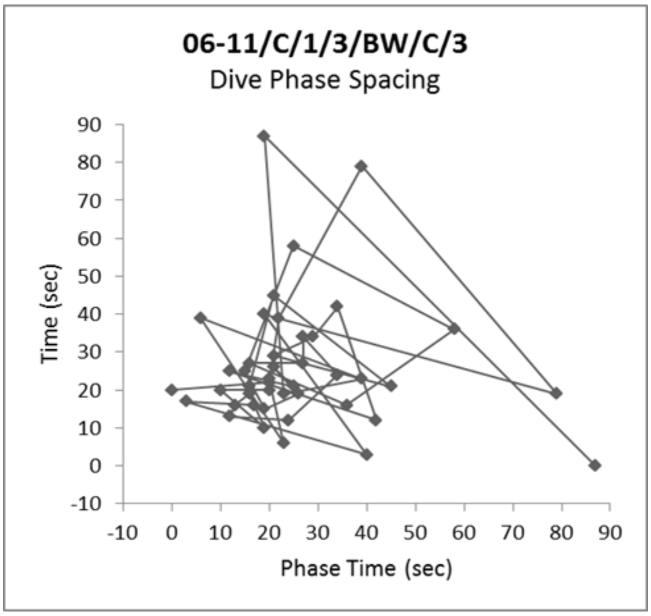

05-11/B/1/3/BW/C/5
Dive Phase Spacing
Time (sec)
Phase Time (sec)


05-11/B/1/3/BW/C/6
Dive Phase Spacing
Time (sec)
Phase Time (sec)


05-11/B/1/3/BW/C/7
Dive Phase Spacing
Time (sec)
Phase Time (sec)


06-11/C/1/3/BW/C/1
Dive Phase Spacing
Time (sec)
Phase Time (sec)


06-11/C/1/3/BW/C/2
Dive Phase Spacing
Time (sec)
Phase Time (sec)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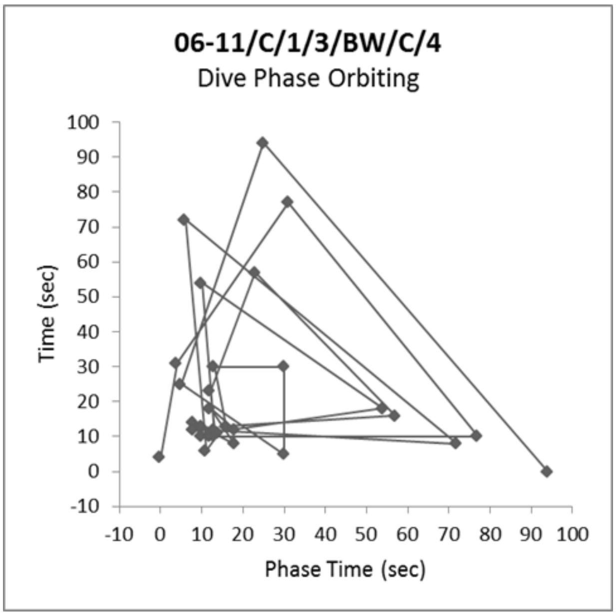
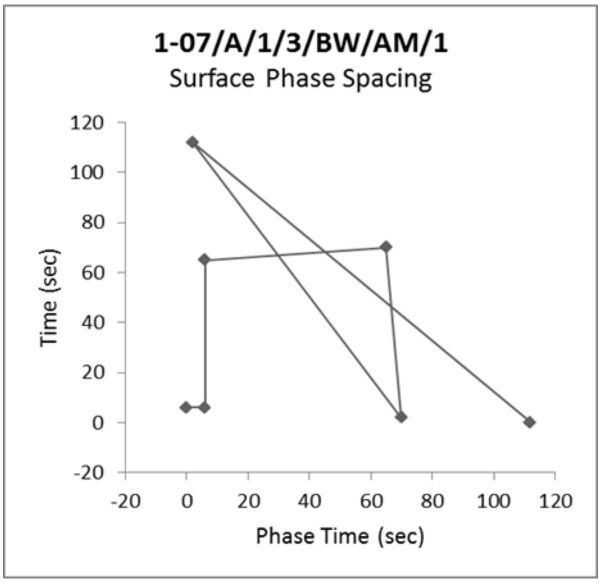
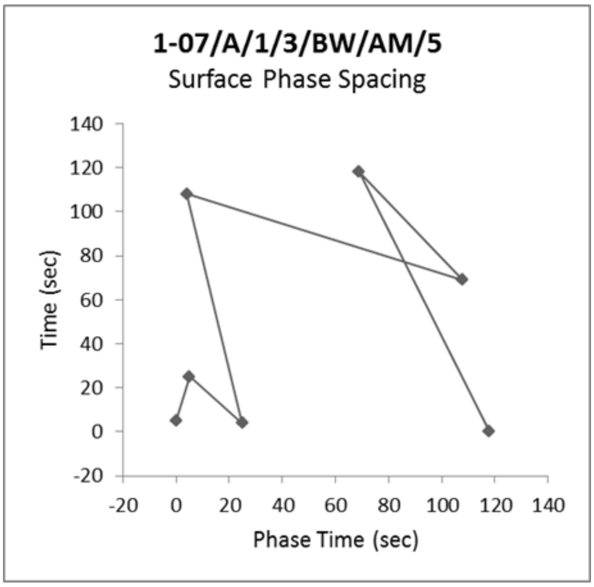
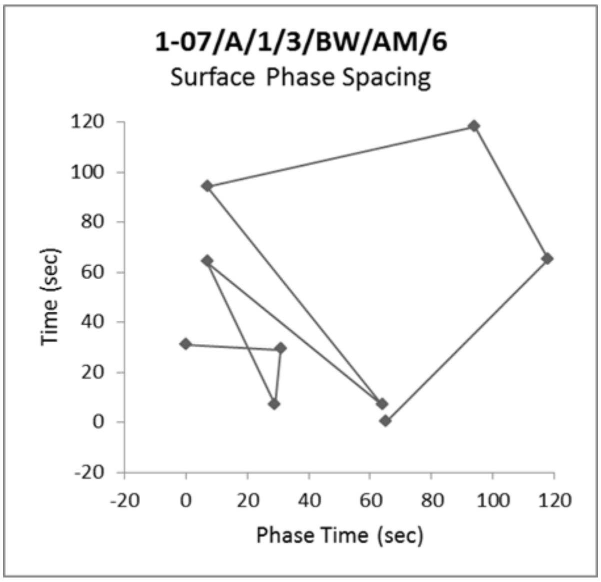
Dive Phase Spacing
Time (sec)
Phase Time (sec)

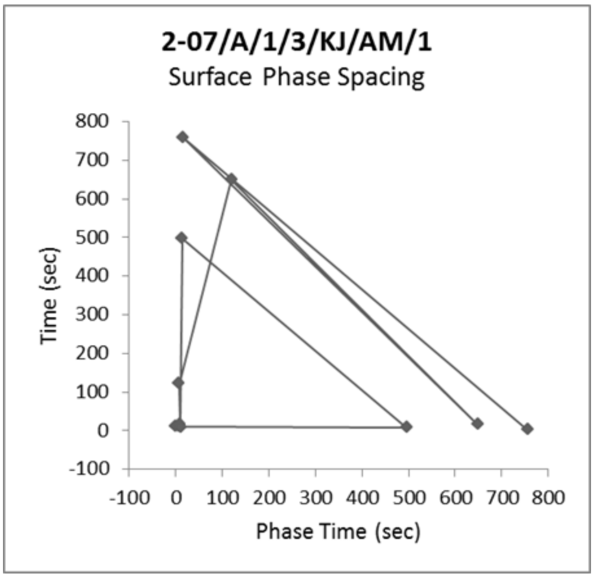

06-11/C/1/3/BW/C/4
Dive Phase Orbiting
Time (sec)
Phase Time (sec)

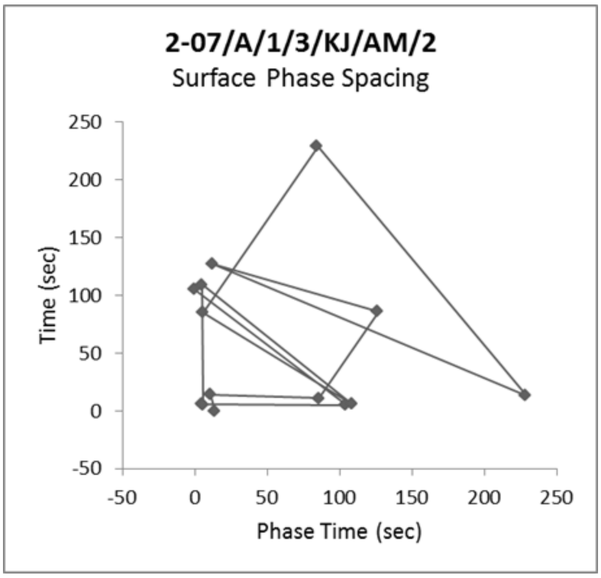
e: Surface Phase Spacing in Accompanied Mothers

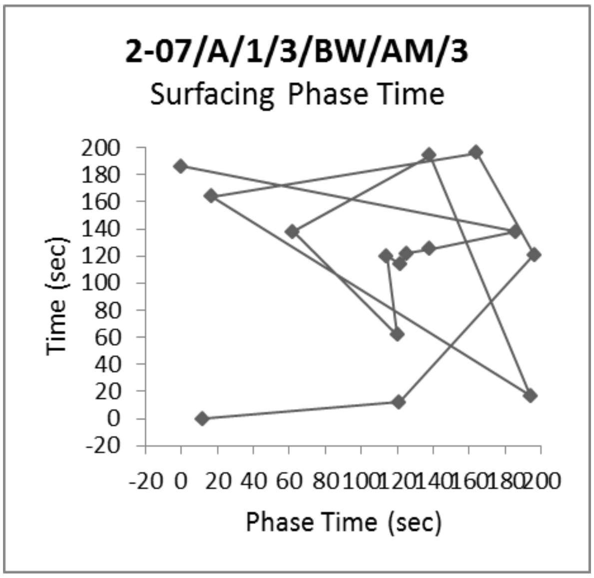


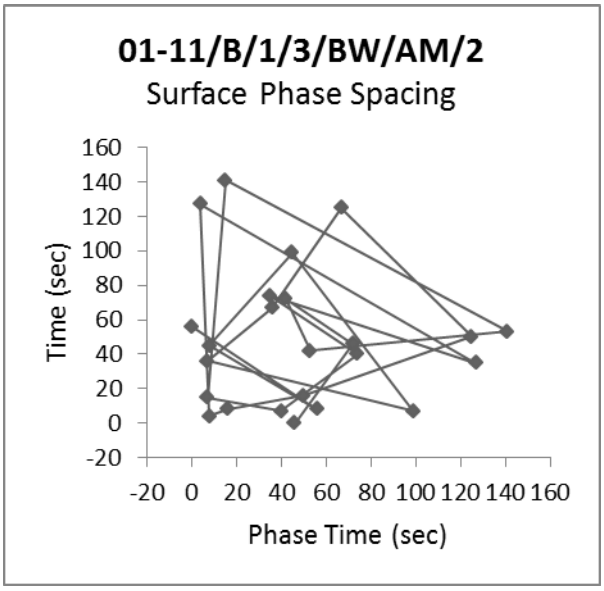


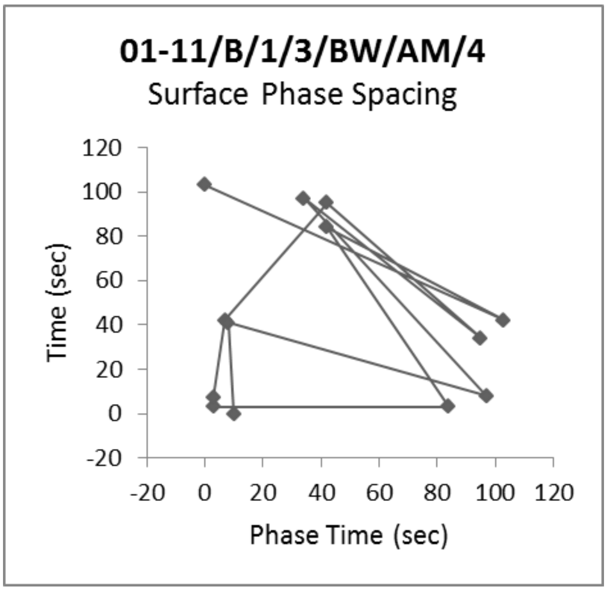


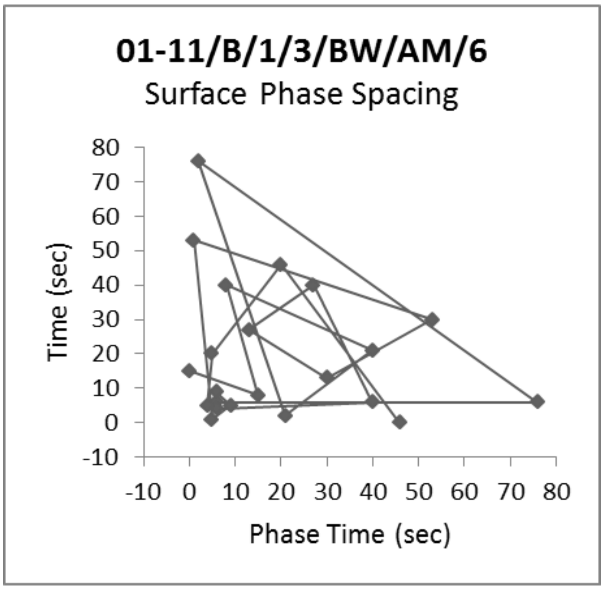


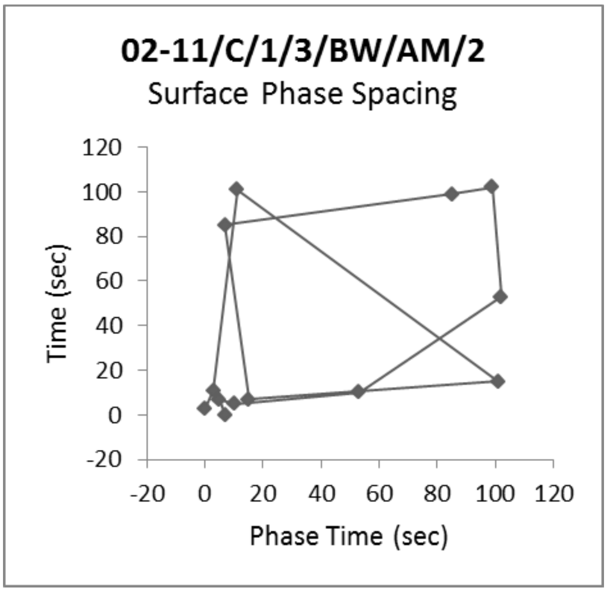


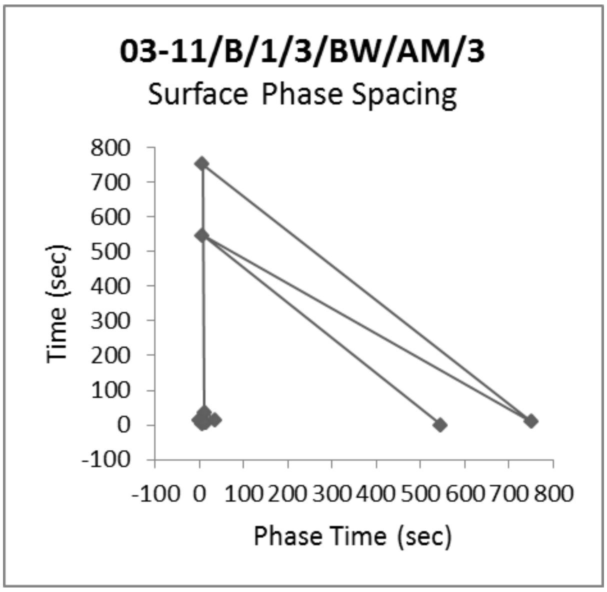


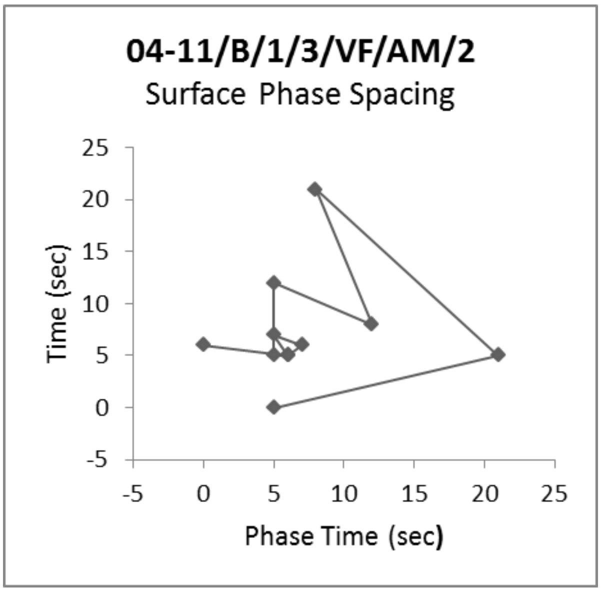

01-11/B/1/3/BW/AM/2
Surface Phase Spacing
Time (sec)
160 140 120 100 80 60 40 20 0 -20
-20 0 20 40 60 80 100 120 140 160
Phase Time (sec)

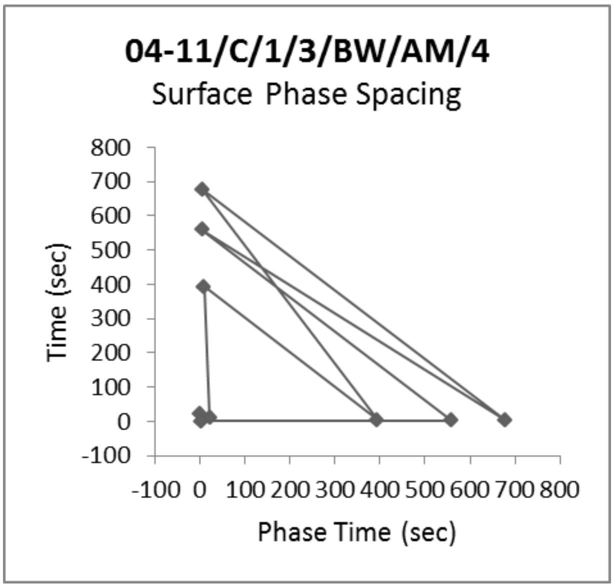

01-11/B/1/3/BW/AM/4
Surface Phase Spacing
Time (sec)
120 100 80 60 40 20 0 -20
-20 0 20 40 60 80 100 120
Phase Time (sec)

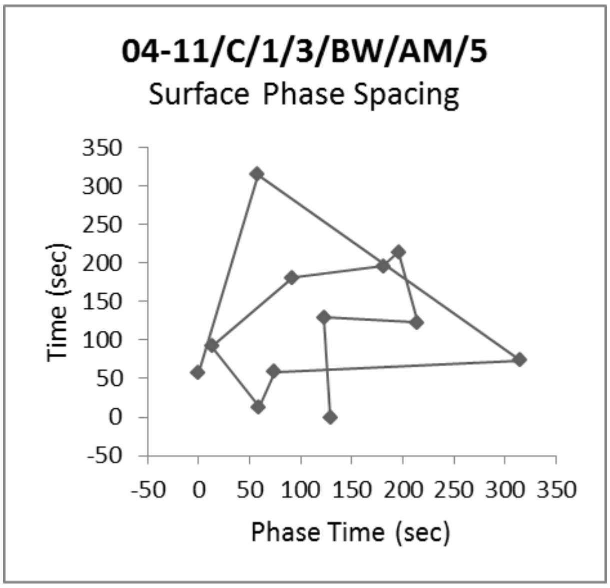

01-11/B/1/3/BW/AM/6
Surface Phase Spacing
Time (sec)
80 70 60 50 40 30 20 10 0 -10
-10 0 10 20 30 40 50 60 70 80
Phase Time (sec)

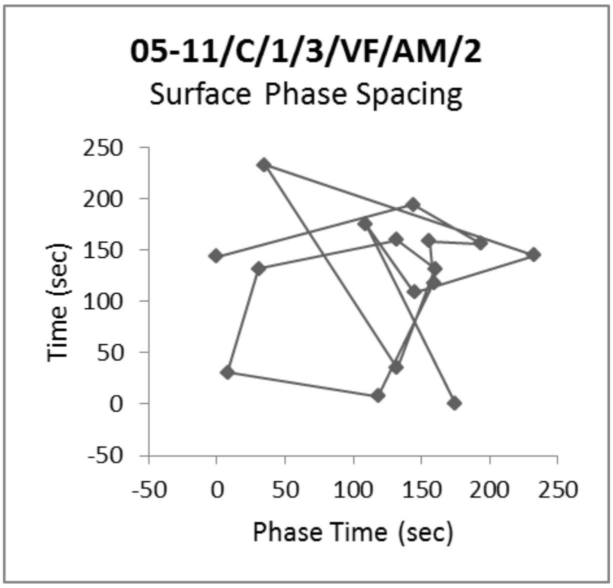

02-11/C/1/3/BW/AM/2
Surface Phase Spacing
Time (sec)
120 100 80 60 40 20 0 -20
-20 0 20 40 60 80 100 120
Phase Time (sec)

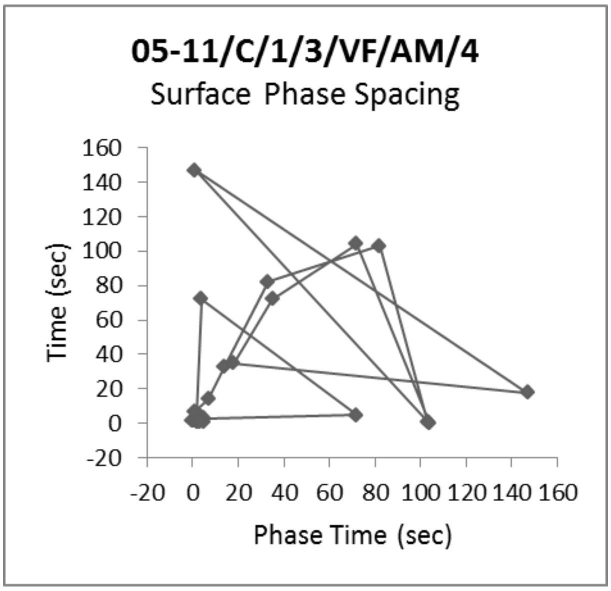

03-11/B/1/3/BW/AM/3
Surface Phase Spacing
Time (sec)
800 700 600 500 400 300 200 100 0 -100
-100 0 100 200 300 400 500 600 700 800
Phase Time (sec)

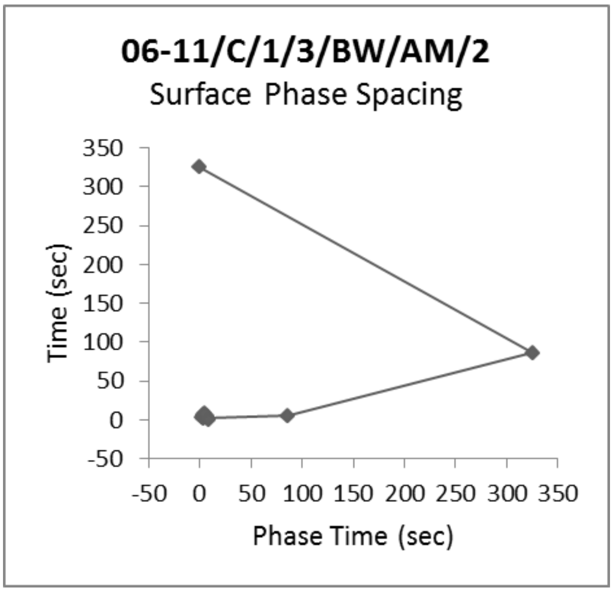

04-11/B/1/3/VF/AM/2
Surface Phase Spacing
Time (sec)
25 20 15 10 5 0 -5
-5 0 5 10 15 20 25
Phase Time (sec)


04-11/C/1/3/BW/AM/4
Surface Phase Spacing
Time (sec)
Phase Time (sec)

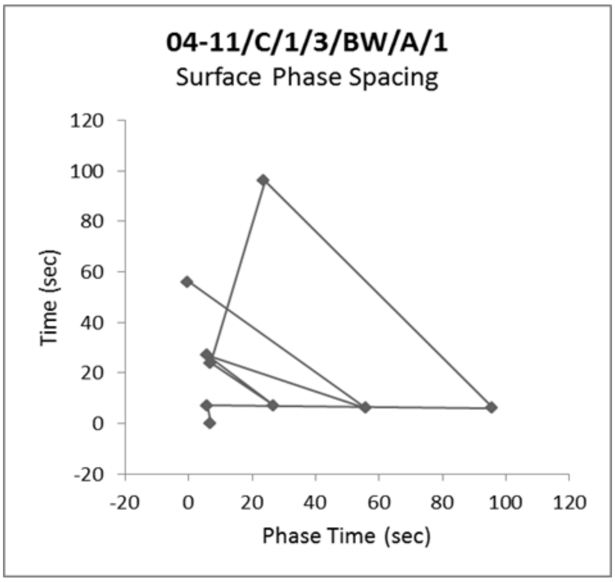

04-11/C/1/3/BW/AM/5
Surface Phase Spacing
Time (sec)
Phase Time (sec)


05-11/C/1/3/VF/AM/2
Surface Phase Spacing
Time (sec)
Phase Time (sec)

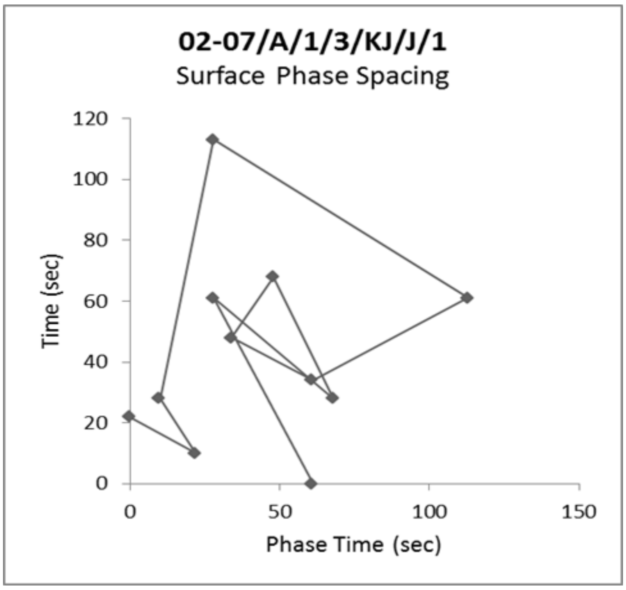

05-11/C/1/3/VF/AM/4
Surface Phase Spacing
Time (sec)
Phase Time (sec)

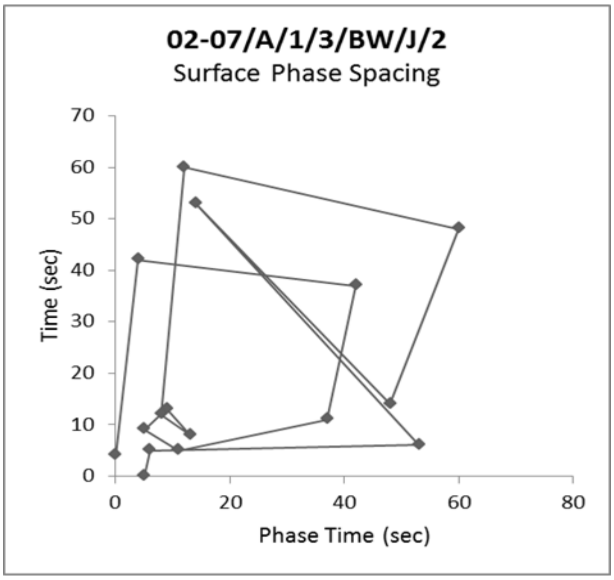

06-11/C/1/3/BW/AM/2
Surface Phase Spacing
Time (sec)
Phase Time (sec)

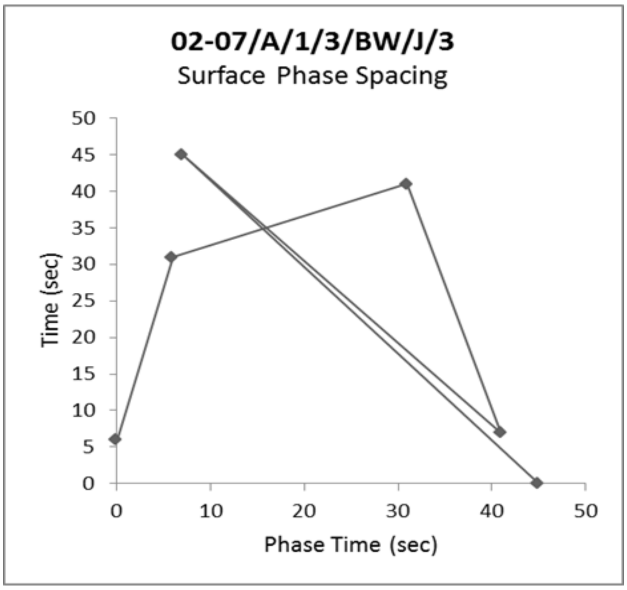
f: Surface Phase Spacing in Adults

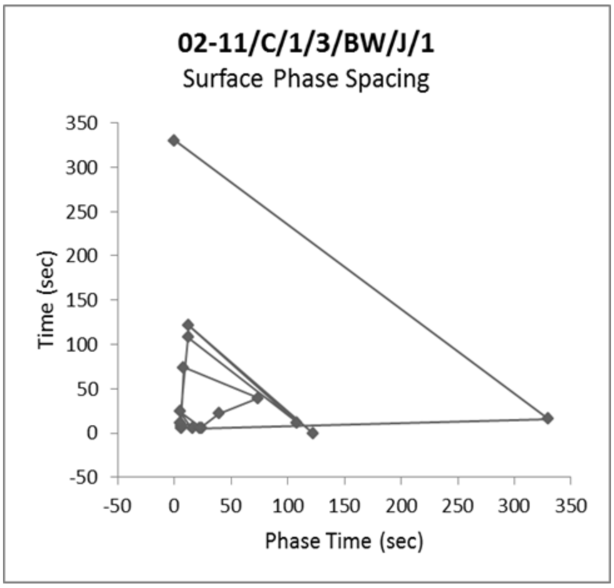


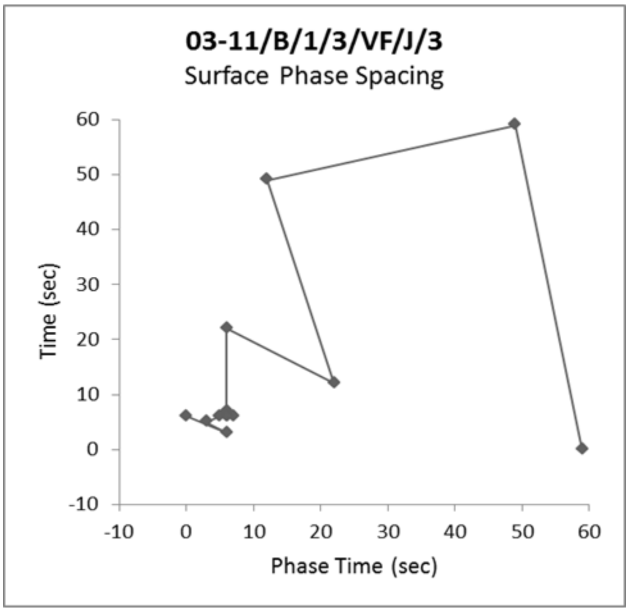
g: Surface Phase Spacing in Juveniles



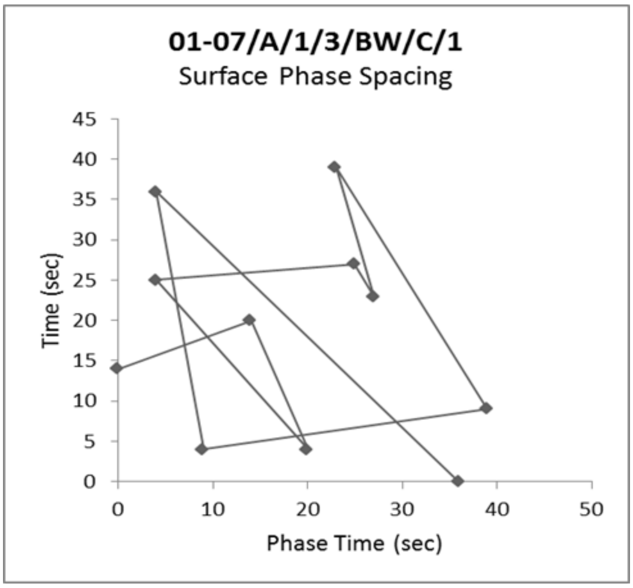


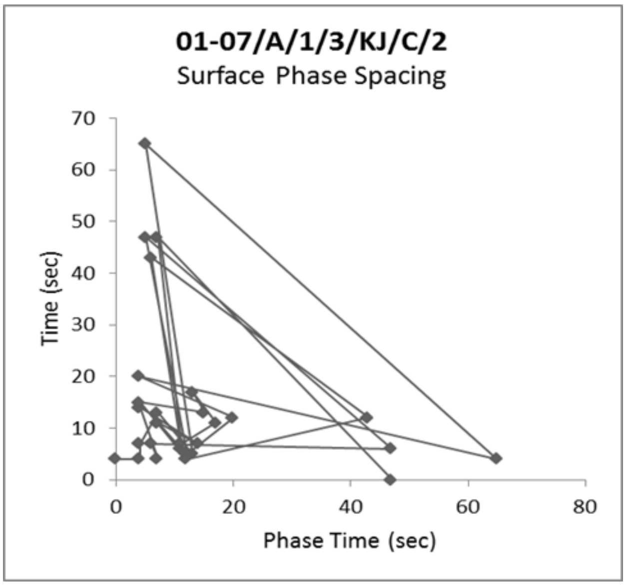


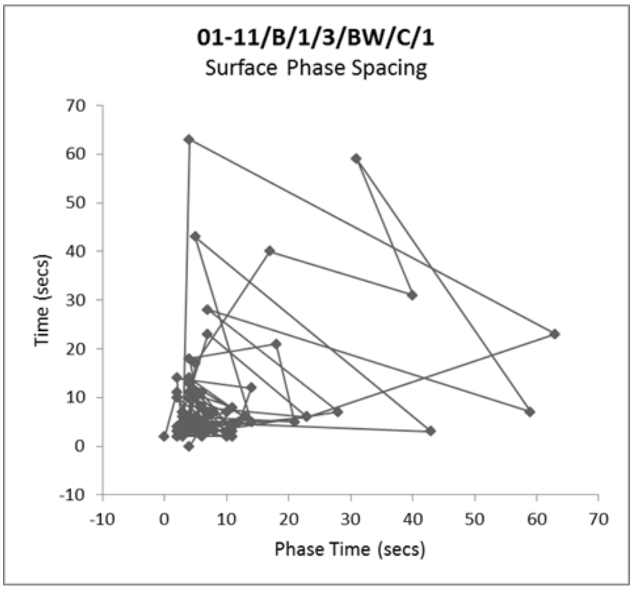


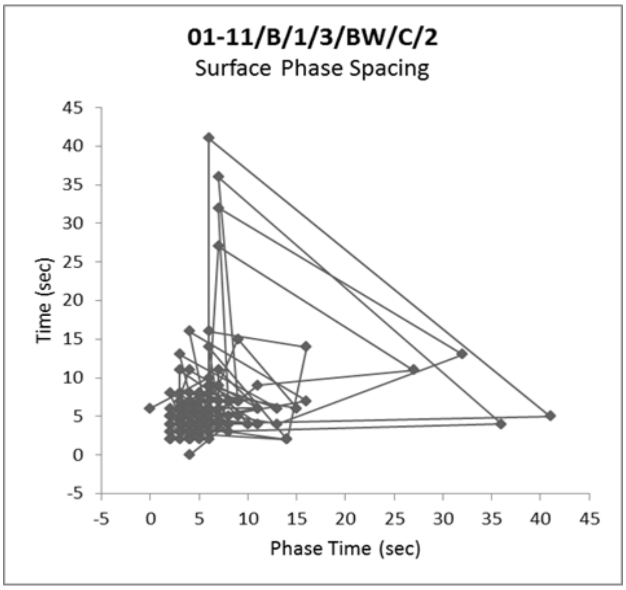


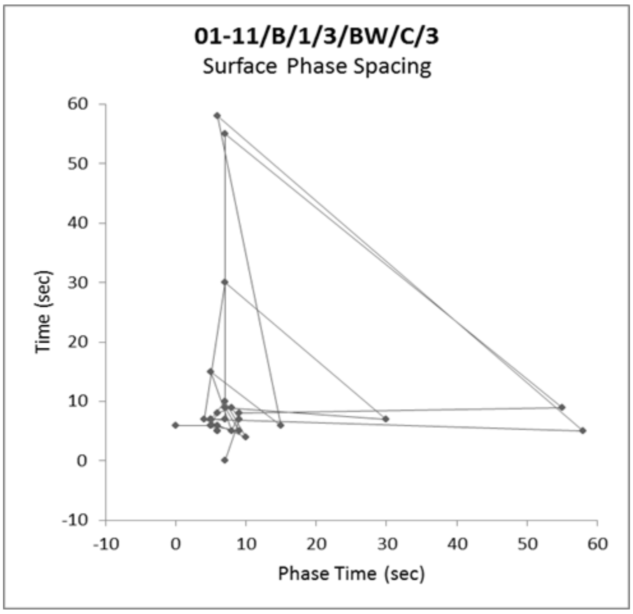
h: Surface Phase Spacing in Calves

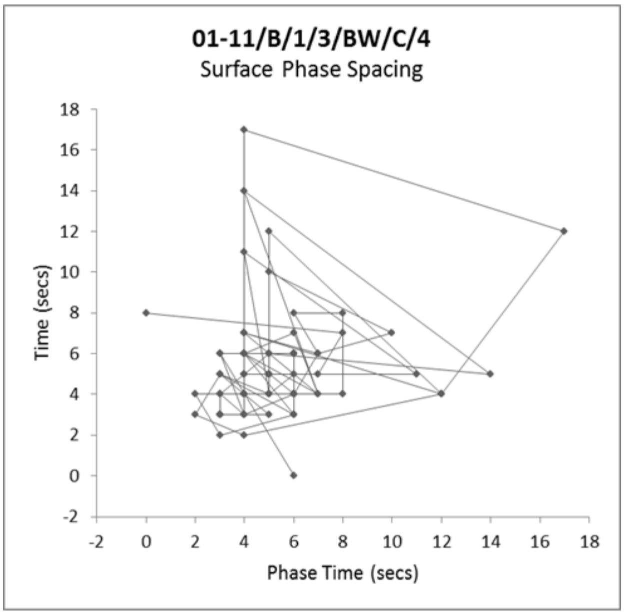


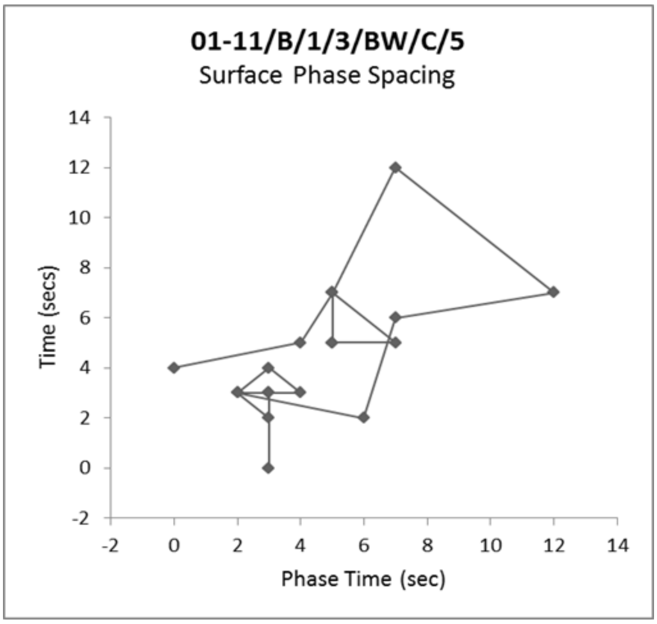


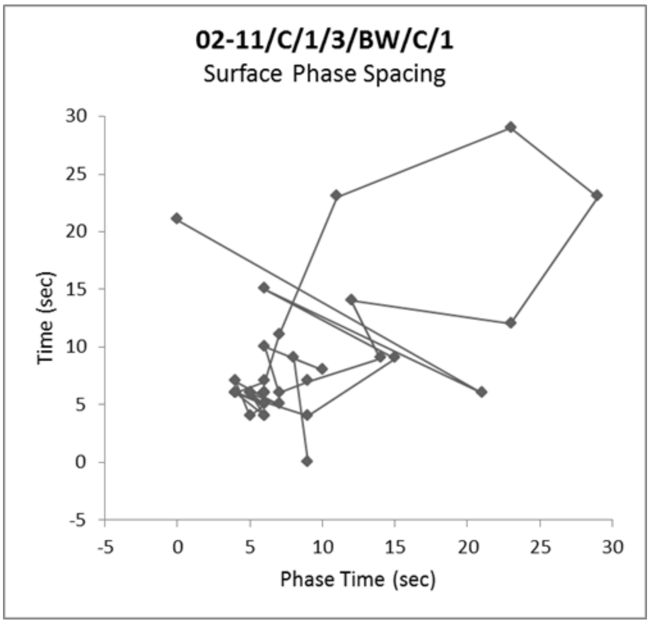


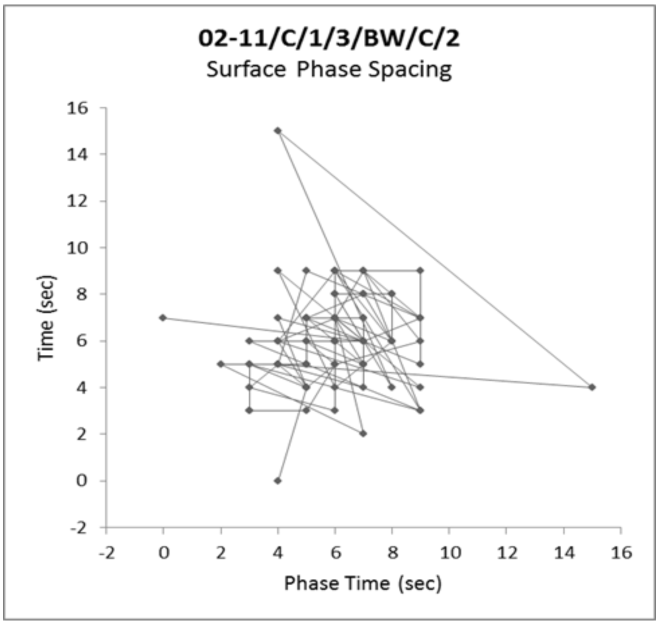


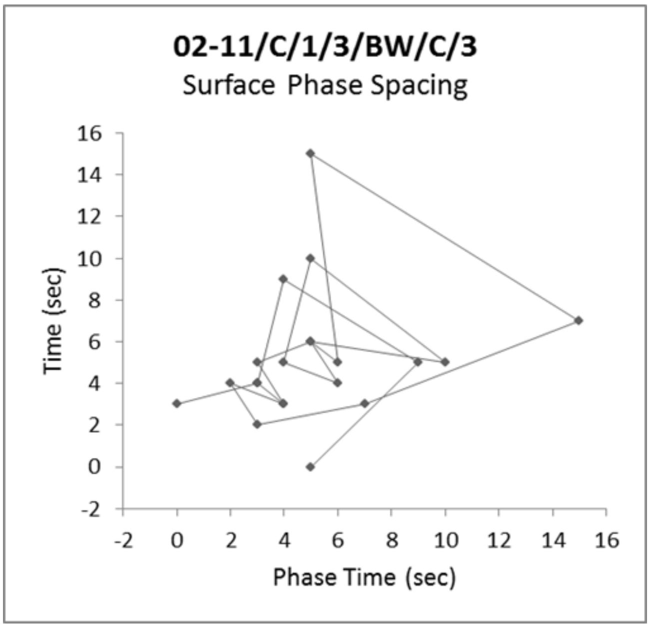





01-11/B/1/3/BW/C/5
Surface Phase Spacing
Time (secs)
Phase Time (sec)


02-11/C/1/3/BW/C/1
Surface Phase Spacing
Time (sec)
Phase Time (sec)


02-11/C/1/3/BW/C/2
Surface Phase Spacing
Time (sec)
Phase Time (sec)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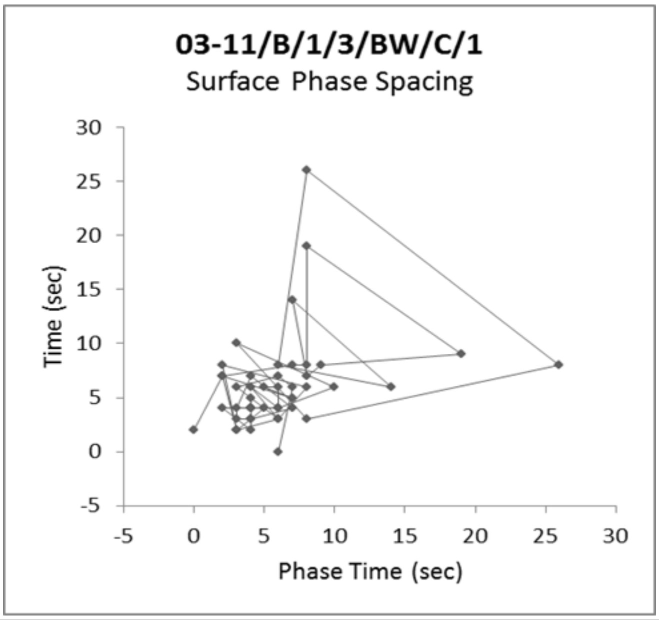
Surface Phase Spacing
Time (sec)
Phase Time (sec)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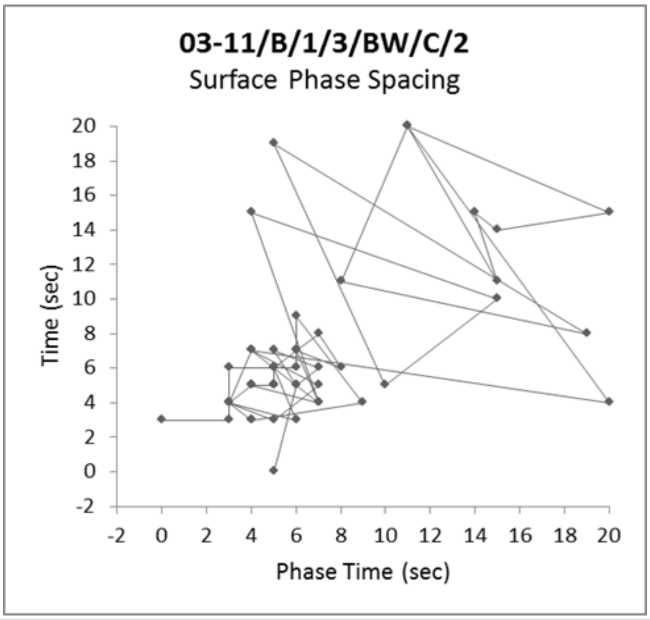
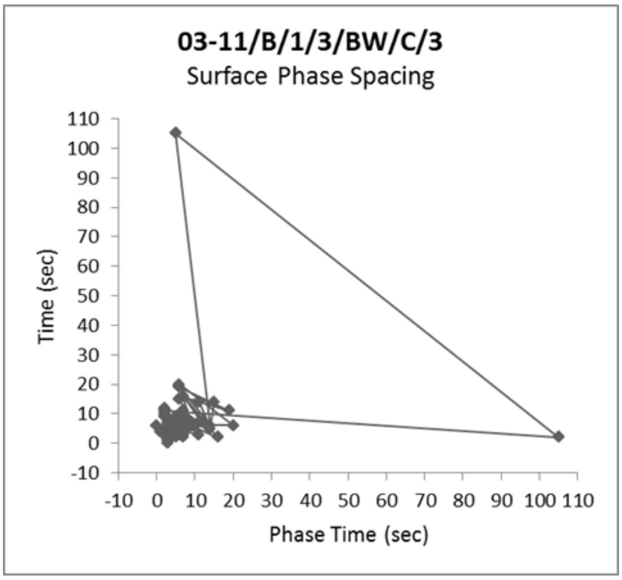
Surface Phase Spacing
Time (sec)
Phase Time (sec)


03-11/B/1/3/BW/C/2
Surface Phase Spacing
Time (sec)
Phase Time (sec)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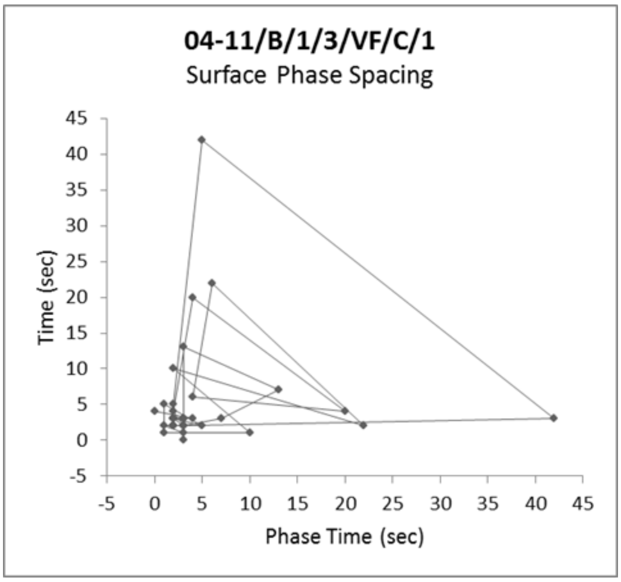
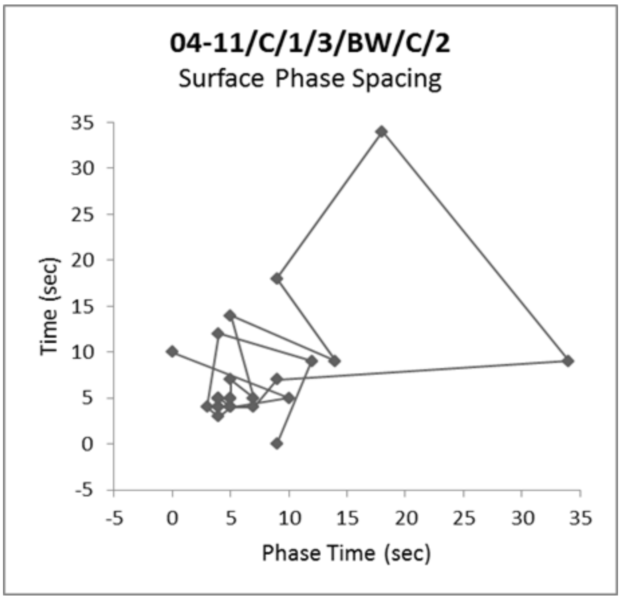
Surface Phase Spacing
Time (sec)
Phase Time (sec)


04-11/B/1/3/VF/C/1
Surface Phase Spacing
Time (sec)
Phase Time (sec)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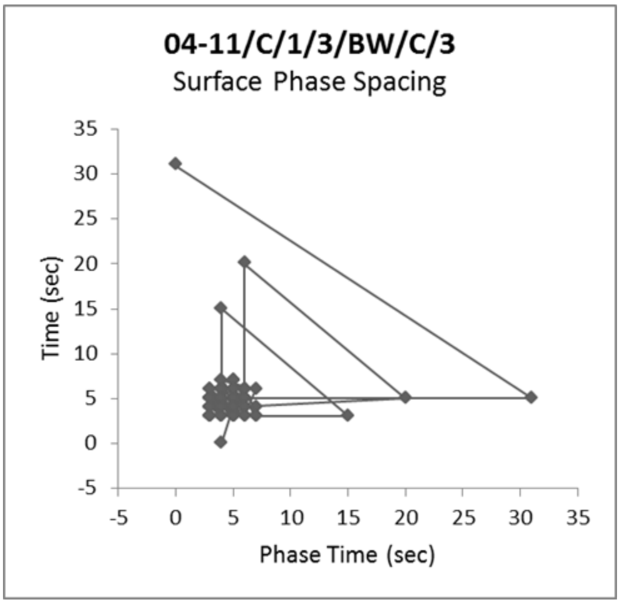
Surface Phase Spacing
Time (sec)
Phase Time (sec)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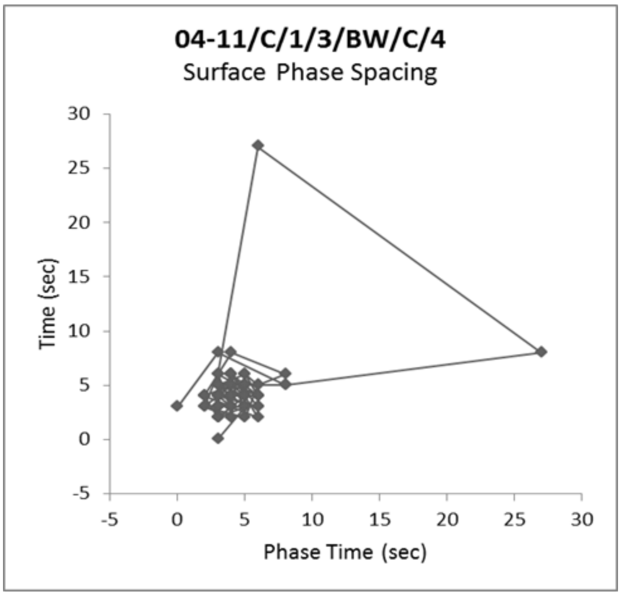
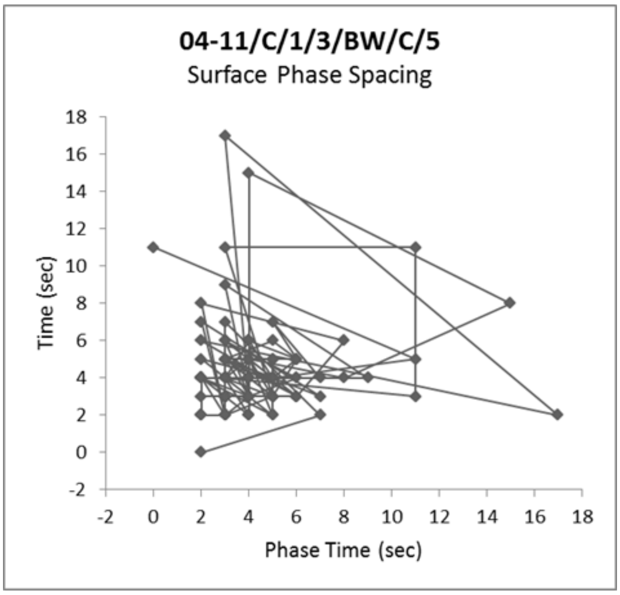
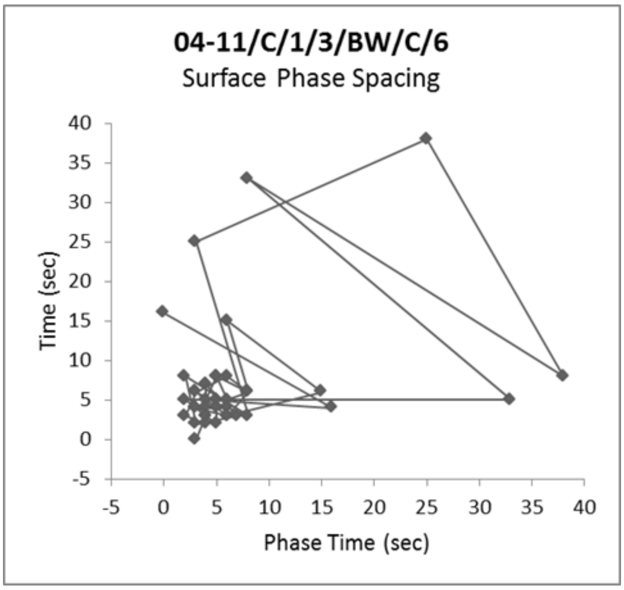
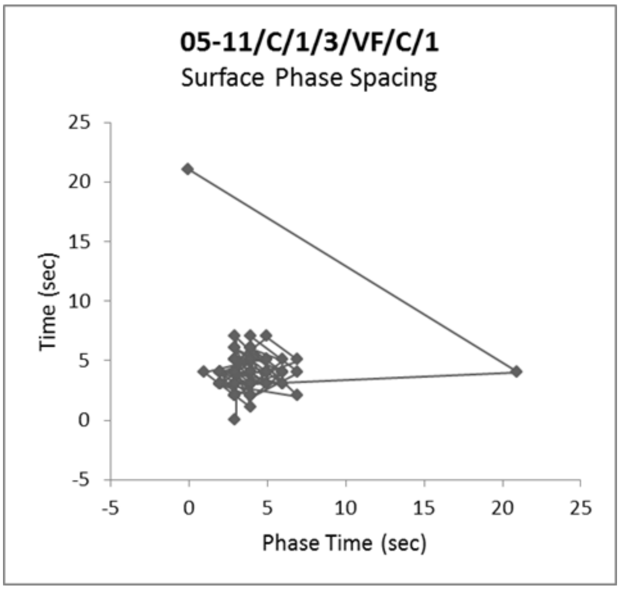
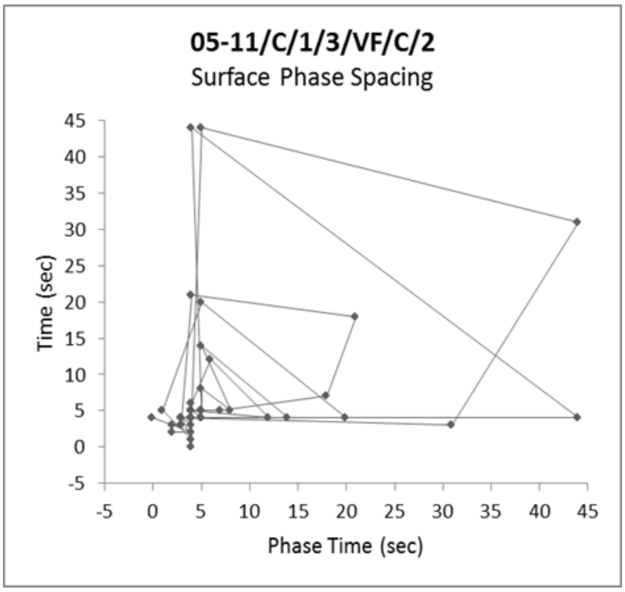
Surface Phase Spacing
Time (sec)
Phase Time (sec)


04-11/C/1/3/BW/C/4
Surface Phase Spacing
Time (sec)
Phase Time (sec)


04-11/C/1/3/BW/C/5
Surface Phase Spacing
Time (sec)
Phase Time (sec)


04-11/C/1/3/BW/C/6
Surface Phase Spacing
Time (sec)
Phase Time (sec)
-5 0 5 10 15 20 25 30 35 40


05-11/C/1/3/VF/C/1
Surface Phase Spacing
Time (sec)
Phase Time (sec)
-5 0 5 10 15 20 25


05-11/C/1/3/VF/C/2
Surface Phase Spacing
Time (sec)
Phase Time (sec)
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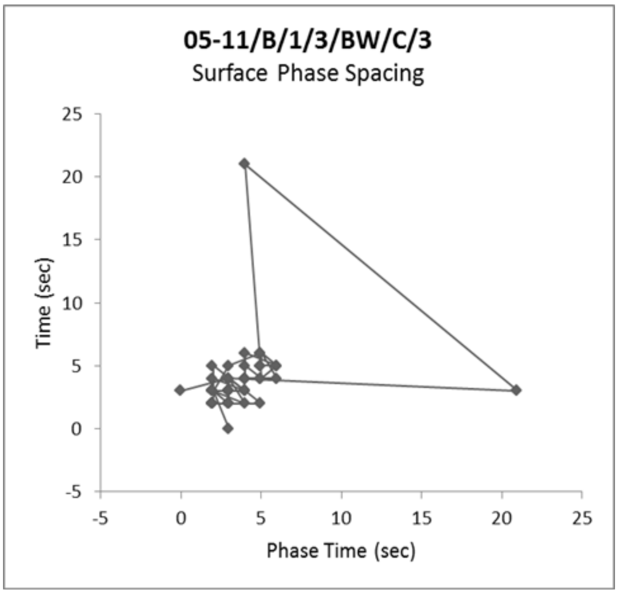
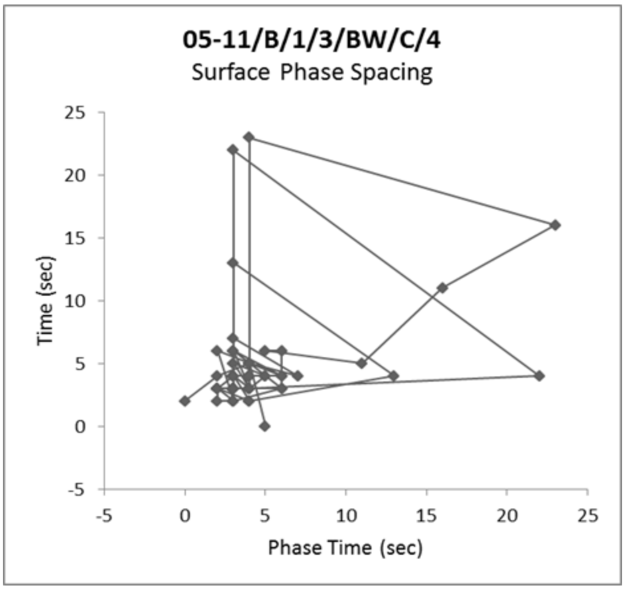
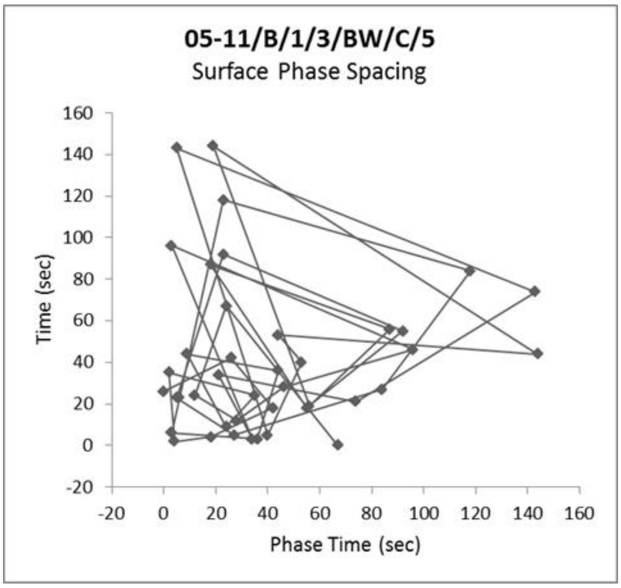
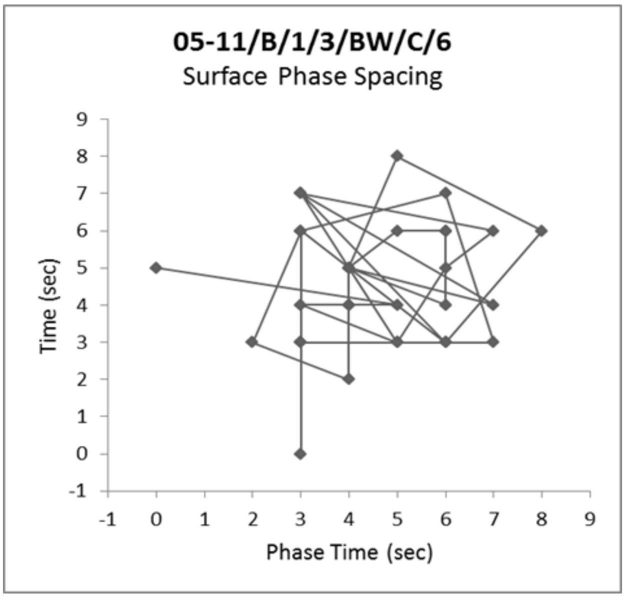
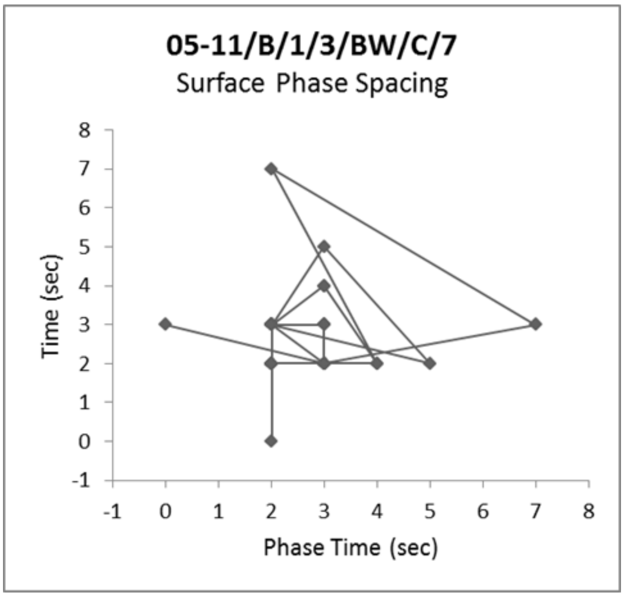
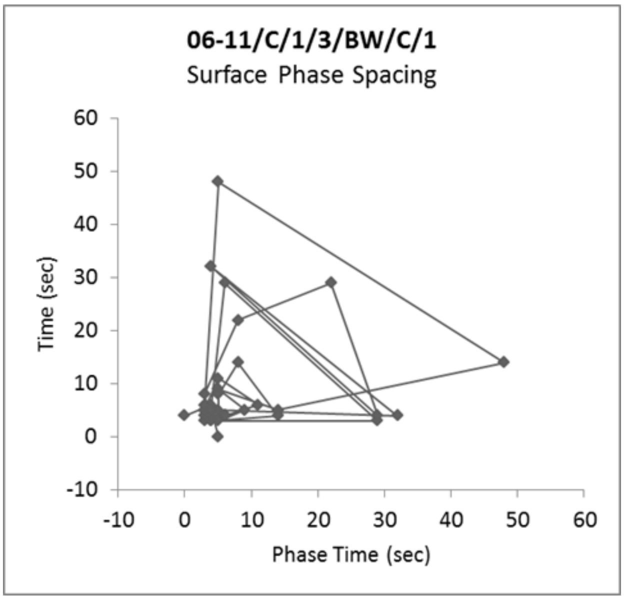

05-11/B/1/3/BW/C/3
Surface Phase Spacing
Time (sec)
Phase Time (sec)
-5 0 5 10 15 20 25

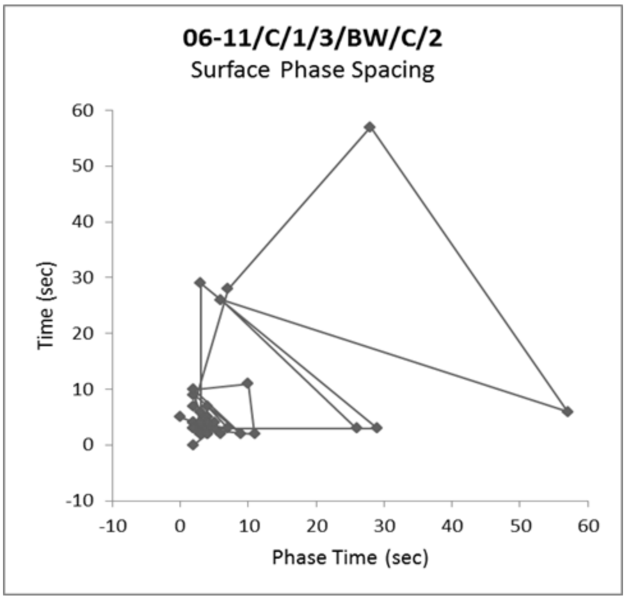

05-11/B/1/3/BW/C/4
Surface Phase Spacing
Time (sec)
Phase Time (sec)
-5 0 5 10 15 20 25

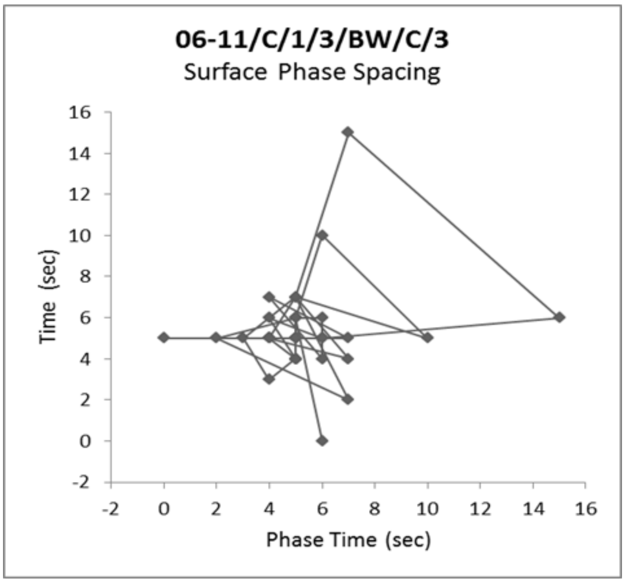

05-11/B/1/3/BW/C/5
Surface Phase Spacing
Time (sec)
Phase Time (sec)
-20 0 20 40 60 80 100 120 140 160

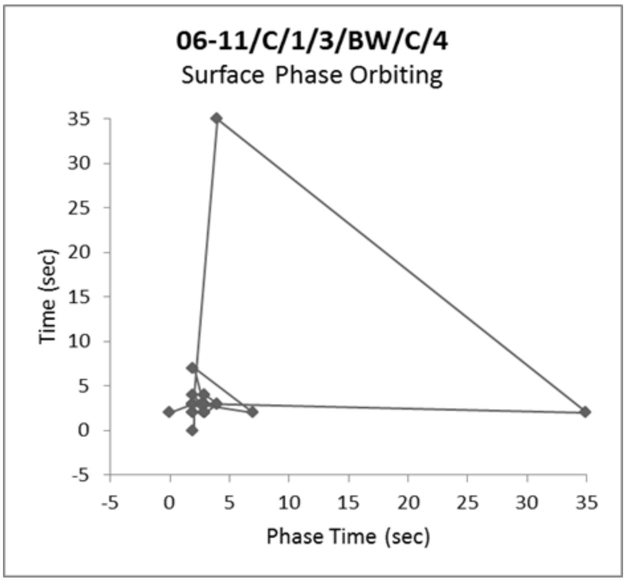

05-11/B/1/3/BW/C/6
Surface Phase Spacing
Time (sec)
Phase Time (sec)


05-11/B/1/3/BW/C/7
Surface Phase Spacing
Time (sec)
Phase Time (sec)


06-11/C/1/3/BW/C/1
Surface Phase Spacing
Time (sec)
Phase Time (sec)


06-11/C/1/3/BW/C/2
Surface Phase Spacing
Time (sec)
Phase Time (sec)


06-11/C/1/3/BW/C/3
Surface Phase Spacing
Time (sec)
Phase Time (sec)


06-11/C/1/3/BW/C/4
Surface Phase Orbiting
Time (sec)
Phase Time (sec)

Appendix B3: Tidal Influence on Foraging Dynamics

TITLE: TIDAL INFLUENCE ON FORAGING DYNAMICS IN THE PIED CORMORANT

(PHALACROCORAX VARIUS)

Running Head: Tides and foraging in P. varius

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ABSTRACT

This study investigated the diving behavior of Pied Cormorants (*Phalacrocorax varius*) within the mangrove estuary located at Garden Island, Port Adelaide, South Australia. The diving and surfacing rhythms of individual *P. varius* were a function of tidal height. Mean dive time at high tide was 31s, significantly different from the low tide value of 26 s ($P<0.001$). As maximum limits of oxygen reserves became depleted *P. varius* were shown to alter diving rhythms from dive to surface focused. Phase-space plots display spatial relationships between sequential points of data. Orbital circles within phase spacing plots of diving times displayed increased focus in diving and surfacing rhythms during high tides. Changes within tides have been shown to directly affect foraging times and through this rate of successful catch. Methods outlined within this investigation can be further utilized to statistically quantify total foraging ecology within diving marine birds. ~ 213 words. (no literature cited)

Key Words: Pied Cormorant, *Phalacrocorax varius*, diving, behavior, feeding, ecology, tides

Pages: 10 (normal format), 3648 words

INTRODUCTION

Cormorants are highly mobile foraging animals, displaying continuous diving and surfacing behavior as part of their feeding ecology (Dorfman & Kingsford 2001). Populations of the pied cormorant, *Phalacrocorax varius*, located at Garden Island, Port Adelaide provide an excellent opportunity for examination of diving behavior dynamics and foraging ecology. Estuarine habitats are believed to provide stable prey foraging cues, compared to the open ocean with changes within the environment, such as varying tides, influencing foraging behavior (Dorfman & Kingsford 2001). Alterations in available foraging area and escape margins for prey are hypothesized to increase the amount of diving time required for successful foraging (Dorfman & Kingsford 2001, Enstipp et al. 2001).

Behavioral ecology is separated into foraging and mating strategies with classic terrestrial foraging focus on monitoring the steps of prey selection, energetics of capture and caloric intake (Boran et al. 2001). Foraging ecology of marine bird species is complex and difficult to monitor, as feeding action predominantly occurs underwater. Diving and surfacing times can be used to regulate sub-surface activities. Diving cycles are important aspects of foraging success in cormorants and are largely unrecorded for inner shore birds in the wild. Unlike terrestrial birds, marine birds must regulate foraging between oxygen limited diving times and oxygen replenishment at the surface (Heath et al. 2007). Therefore, they need to employ optimal diving strategies when foraging to ensure maximum prey consumption (Wilson et al. 2006, Heath et al. 2007).

Dive duration depends on energy conservation and oxygen consumption rates (Corkeron & Martin 2004, Hastie et al. 2006, Richter et al. 2006). Respiration rate is directly related to metabolic rate, whereby increased metabolic flux increases the need to breathe (Yazdi et al. 1999). Long diving periods decrease oxygen reserves and increase energy consumption, resulting in elevated metabolic rates (Williams et al. 1999, Enstipp et al. 2001). Elevated metabolism affects the length of time that cormorants can afford to dive for, as well as surface recovery time, while still maintaining an optimal diving strategy (Corkeron &

Martin 2004, Wilson et al. 2006). Allocation of time underwater could possibly be affected by the longer surface durations required for digestion, with increased oxygen consumption during these periods reloading oxygen reserves (Heath et al. 2007). Regardless, diving models (Heath et al. 2007) predict long dive periods to result in increased respiration need and decreased diving times in diving birds (Williams et al. 1999, Richter et al. 2006).

Through this investigation we aim to increase understanding of feeding ecology in *Phalacrocorax varius* by examining their surface and diving rhythms. We intend to test the following hypotheses: H1: P. varius displays individual variation in diving and surfacing times, H2: *P. varius* displays variation in diving and surfacing times according to tidal levels. This work may have further implications on *P. varius* ecology within the environment.

METHOD

Study Design

This study utilized continuous individual frequency focal-sampling surveys (Rogosa & Ghandour 1991, Mann 1999) to formulate a statistically robust behavioural study (Altmann 1974). The sequential diving and surfacing times of individual *Phalacrocorax varius* were recorded for as long as they were observable. By providing records of both sub-surface and surface times we aimed to formulate dive/surface flow (which shows consecutive dive and surfacing rhythms) and dive phase spaces for each individual. Comparisons of each individual dive/surface flow were recorded to formulate mean dive and surface dive-series indices for the species.

Study Sites

Investigations were undertaken at Garden Island, South Australia (34º 55’ S, 138º 36’ E) from the 10th of October 2007 to January 29th, 2008. Opportunistic recordings were taken two to three times a month, from 9am to 4pm. Recording later in the day was ruled out after investigators found water glare to interfere with observations. Observations were taken from a land-based observation platform along the Garden Island boardwalk situated in the Port Adelaide Dolphin Sanctuary. From this observation platform *Phalacrocorax varius* were easily observed during high and low tide, during which times extended areas of mangroves and island were above the water. Thirty recordings of *P. varius* were taken with twenty-four providing sufficient surfacing/diving runs for analysis. Of these twenty-four, fifteen were taken during low tides and nine during high tide. Differences in results caused by variation of cormorant numbers per tidal group observed is negated by the longer dive/surface times recorded during high tides. Thus, data between tidal groups balanced out.

Observations

The main observations undertaken on each individual *Phalacrocorax varius* were achieved utilizing a small timer that allows the observer to time either one behaviour for four individuals, two behaviours for two individuals or four behaviours for one individual. The time, weather, and tide were recorded during observations. Additional behavioural changes were noted as they occurred for later comparison with diving times. During periods of watercraft presence along the strait, all recordings ceased, whether a bird remained water-bound or not, and resumed fifteen minutes after the watercraft had passed. Diving and surfacing starting times were designated from the moment *P. varius* would fully submerge, ignoring periods of 'head-dunking' and 'feather-soaking' behaviour when the *P. varius* would quickly dip parts of its anatomy underwater.

Dive/Surface Pattern

Each behavioural activity is stipulated as a binary sequence [z(i)] where z(i) = 1 when surfacing and z(i) = -1 when diving. From this binary sequence z(i), 'random walk' y(t) was generated:

$$y(t) = \sum_{i=1}^{N} z(i)$$

where t is the time interval chosen to record behavioural activity. The time series developed provides information related to the level of persistence of the behavioural sequences. Data found within the time series is formulated into a joined-line scatter plot describing dive/surface flow, such that an organism consistently spending more time surfacing than diving will be characterized by an increasing trend, and vice versa.

Deviations within dive/surface flow are indicated by the standard deviation (SD). Higher differentiation indicates larger variation within the cormorants' regulation of dive-surface flow.

Orbital Phase Spacing

Phase spacing creates a spatial relationship between sequential points. Shifting data by one record allows examination of internal structure of the behavioural episode (see Table 1). Regulated behaviour forms orbits within the data series, displayed as circular patterns in a scatter plot. Randomised or unregulated behaviour does not display formulated patterns of movement. When orbital or random behaviour fails to exceed the other (greater than 60% of behaviour displayed) it is designated as small orbits. Should orbiting occur within the data series during repeated tidal, time or weather events it will be possible to determine whether these forces influence species behaviour.

In order to determine variation of movement seen in randomized behaviour we formulated a random phase space plot (Figure 1) utilizing an excel random number generator: randbetween(1-60). Numbers were limited to the highest dive time experienced during *Phalacrocorax varius* recordings. Random numbers were phase shifted (see Table 1) then graphed against original random times utilizing a scatter plot (Figure 1).

RESULTS

H1: Phalacrocorax varius displays individual variation in diving and surfacing times

ANOVA results for difference between individual surfacing and diving times were significant (P = <0.001, <0.001, F = 26.18, 3.53, Fcrit = 1.55, 1.55). ANOVA analysis further showed significant difference between surfacing and diving times (P = 0.001, F = 3.62, Fcrit = 1.55). These results showed individual variation to be significant and indicates acceptance of H1.

H2: Phalacrocorax varius displays variation in diving and surfacing times according to tidal level

Tidal categories showed significant difference (P = <0.001) in the amount of time *Phalacrocorax varius* spent above and below the surface. Changes between diving and surfacing times from low to high tides are seen in Figure 1. Mean diving and surfacing times are seen to increase from low tide (surface: *m* = 7s, *SE* = 0.56, *n* = 15)(dive: *m* = 27s, *SE* = 1.09, *n* = 9) to high tide (surface: *m* = 22s, *SE* = 4.53, *n* = 15)(dive: *m* = 31s, *SE* = 3.11, *n* = 9). Large variation (19s) is seen between mean surface and diving times for low tide. Smaller variation (9s) is seen between surface and dive times for high tide. These results show that not only does variation occur between tidal groups but greater variation is seen between the surface and dive times in low tide than high tide. Thus H_2 is accepted.

Dive/Surface Pattern

Dive/surface pattern increased in structured dive/surfacing rhythms from low to high tide (Figure 2 and 3). Low tide pattern (Figure 2) displays consistent diving over surfacing ratios. High tide pattern (Figures 3) shows diving and surfacing rhythms to follow structured long then short diving/surfacing times. Diving/surfacing times vary from long to short times in regulated intervals. Figure 3 additionally demonstrates a singular dive surface interchange with dive time originally exceeding surfacing times, before *Phalacrocorax varius* switches to oxygen-saving, longer surfacing rhythms.

Standard deviations of difference in diving/surfacing times were used to determine variation in diving rhythms between high and low tides. Results showed deviation to increase only slightly from low tide (12s) to high tide (11s). Tests showed the data series to be too small to perform dive-series index comparisons (>100 data points required). Preliminary results did display differentiation in dive slope between high and low tides, but dive plot points were too small to accurately determine the amount of variation.

Orbital Phase Spacing

Examination of diving and surfacing times found dive phase spaces to display clearest results for phase spacing orbits. Surfacing and dive/surfacing phase spaces were too small and/or cluttered to determine if orbital or randomised behaviour was occurring. From dive phase space results, orbits were only displayed in high tide phase spaces. High tide phase spacing showed large orbits to occur 44% of the time, small orbits 33% of the time and randomised behaviour 22% of the time. During low tide phase spacing, *Phalacrocorax varius* was shown to display large orbits 0% of the time, small orbits 21% of the time and random behaviour 79% of the time.

Figures 4a and b show orbital behaviour experienced by *Phalacrocorax varius* during high tide. Scatter plot data formed a clear circular pattern in 4a. Data flow in 4b was insufficient to determine a clear orbital pattern when displayed by time (sec), but is shown when data is placed in a logarithmic scatter plot. Figures 4c and d display randomised pattern used by *P. varius* during low tides. *P. varius* only showed randomisation in long and short diving sequences during low tides. Randomisation during high tide was limited to smaller diving sequences.

DISCUSSION

Individual Variation

Individual variation was shown to be an important aspect in *Phalacrocorax varius* foraging behavior and therefore individual-focus (not group-focus) investigations need to be utilised in foraging research.

Individual variation may be inadvertently affected by sexual bias, with difference between sexes influencing surface and diving times. Sexual variations in foraging strategies were shown to occur between male and female specimens of giant petrels' (Gonzales-Solis et al. 2007). Gender of *P. varius* were not recorded in this study as determination of sex involved tagging and interference. Interaction with birds has been shown to negatively alter behavior displayed. However further research into *P. varius* diving times will determine whether variation is caused by sexual bias, or individual differences.

Variation in diving/surfacing times in comparison to tides

Significant variation was observed between high tide and low tide. Large variation (15s) was seen between the mean diving and surfacing time for low tides. A smaller difference (4s) was seen between the mean diving and surfacing times in high tides. High tide individual dive/surface flow (Figure 3) visually showed these differences in surfacing and diving rhythms. Increased diving time leads to amplified oxygen debt which creates a greater surface time requirement. For this reason, large differences between mean individual surface (27s) and diving (26s) time is seen. Initial dive/surface flow showed high diving; low surfacing times. As oxygen debt occurs diving times shorten and surfacing times increase.

Large variation in surfacing versus dive time during low tide (Figure 2) reflects the consistent diving/surfacing behavior seen in Figure 3. *Phalacrocorax varius* displayed continually high diving times in comparison to surfacing times. However, mean dive times for high tides were 6s higher than the mean dive time for low tides. Lower diving time negates oxygen debilitation within the diving series and allows the cormorants to engage in consistently large diving times. Continuous long diving time ensures greater likelihood of foraging success. High and low tide observations were taken during both spring and summer and during the same time every day, negating differentiation caused by season or time.

Dive/Surface Pattern

Results showed an increase in structured rhythm during high tides. Cumulative binary time-series enabled visual examination of trends being experienced by individuals during different tides (Figures 2 and 3). Variation in individual results meant that it was not possible to utilise models to replicate a continuance in data series after recordings ended. Figure 2 shows the trends experienced by *Phalacrocorax varius* during low tides. Diving rhythms displayed consistent downward movement, with little to no variation in surfacing time.

Figure 3 shows diving rhythms experienced by *P. varius* during high tide. Diving/surfacing times varied from long to short times in regulated intervals. Figure 3 demonstrates affects of limited oxygen reserves and extended diving times with ratios switching from dive-over-surface to surface-over-dive, as oxygen reserves become depleted and must be re-established. Furthermore, it provides a snapshot of changes in diving frequency during high tides. Diving behaviour is in focal concentration for the first 125 secs before oxygen reserves are depleted and *P. varius* begin to display recovering dive times. Surfacing times increase over diving times and dive/surface flow begins to incline. This change in behavior may inadvertently affect foraging success rates as lower dive (and higher surface times) reduce likelihood of prey capture. These results could explain why more *P. varius* were observed during low tide (n = 15) than in high tide (n = 9). *P. varius* is an opportunistic feeder, but must balance feeding with energy conservation; therefore, feeding during low tides decreases energy wastage and increases likelihood of foraging success.

Variations in diving patterns shown by standard deviation were slight, with an increase of only 1s seen. Whether these deviations indicate total variation between dive/surface flows can only be determined by a dive-series index. The current data is insufficient (<100 data points) to determine the affects of high tide on behavioural deviation, or complexity that can be shown within dive-series.

Orbital Phase Spacing

Examination of dive phase spacing in *Phalacrocorax varius* found large orbital behavior (Figure 4a and b) to occur only during high tides. During low tides randomization within data was prominent (Figure 4c and d), indicating that only high tides exert pressure on diving rhythms of *P. varius*. These results coincide with diving and surfacing times and dive/surface flow seen in Figures 2 and 3. Higher tides increase the depth at which *P. varius* needed to dive to catch prey, as well as influencing foraging success. Lack of successful catch would also negate the possibility of refuelling oxygen reserves during surface consumption of caught prey. It is the recommendation of this paper that future research examine the effect of extended diving times during low tide on oxygen reserves and foraging success. The findings have shown foraging during low to be essential in maintaining high success rate with disturbances during these times (such as boat traffic that frequents Garden Island) potentially having large effects on *P. varius* health (Carney & Sydeman 1999, Bejder & Samuels 2003).

CONCLUSION

The findings have shown that *Phalacrocorax varius* display significant variation in individual and tidal diving/surfacing times. *P. varius* display variation in functional rhythm within dive/surface flow. Furthermore, dive/surface flow displayed detrimental effects of oxygen capacity during high tides, with *P. varius* changing from higher diving times to elevated surfacing times. Dive-series indices will provide a statistically quantifiable way to determine differences between dive/surface flows. Insufficient data (<100 data points) meant dive-series indices could not be performed in this investigation. Phase spacing results showed high tides (and not low tides) to be a driving force behind diving times displayed by *P. varius*. The findings showed that tides affect diving times of *P. varius*, influencing feeding ecology, and possibly foraging success. The diving and surfacing methods utilized within this investigation can be used in the future to establish a statistically viable range of results for marine bird foraging behavior in conjunction with individual, and possibly behavioral, variation. This investigation examined the affects changes within tides have on *P. varius* ecology and can be used to predict consequences of ecology, prey or habitat change.

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FIGURES

Figure 1. Phalacrocorax varius mean surface and diving times (seconds) for high and low tides. Bars indicate the highest and lowest mean times experienced by individuals of each tidal group. Middle line within the boxes shows the mean time experienced by individuals. Results shows decreased variation between surface and dive times during high tides. Low tides show high dive times in comparison to surface times.

Figure 2. Phalacrocorax varius individual dive/surface flow, displaying differences between flow, focus and pulse, during Low Tide. Horizontal axis indicates diving time with every data point equalling 2 seconds in the data flow. Vertical axis indicates diving and surfacing data. Diving times = -1 and are indicated by a decreasing slope. Surfacing times = +1 and are indicated by an increasing slope.

Figure 3. Phalacrocorax varius individual dive/surface flow, displaying differences between flow, focus and pulse, during High Tides. Horizontal axis indicates diving time with every data point equalling 2 seconds in the data flow. Vertical axis indicates diving and surfacing data. Diving times = -1 and are indicated by a decreasing slope. Surfacing times = +1 and are indicated by an increasing slope.

Figure 4. Phalacrocorax varius dive phase spacing results. (a) and (b) show examples of orbital behavior being experienced by individual *P. varius*. Scatter plots (c) and (d) show examples of randomised behavior being experienced by individual *P. varius*.

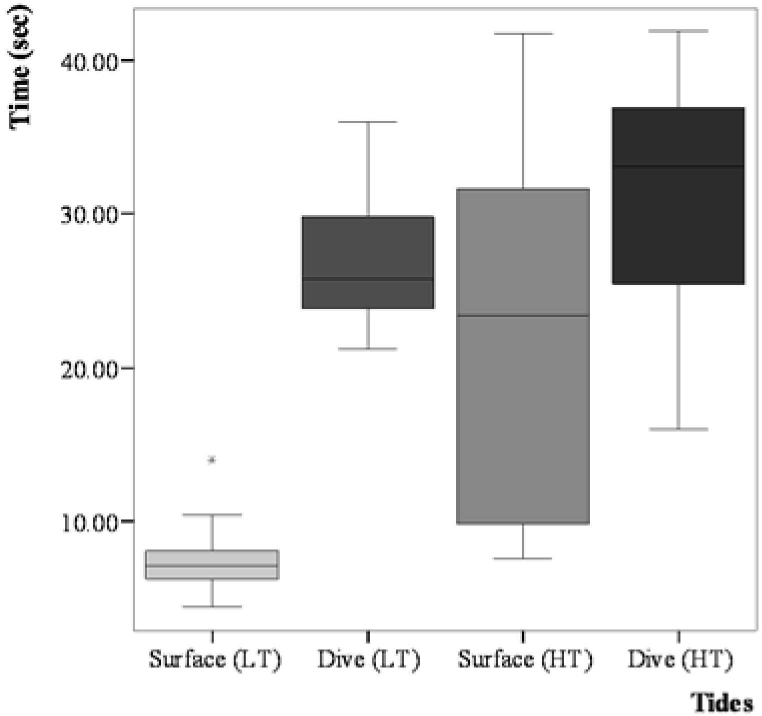
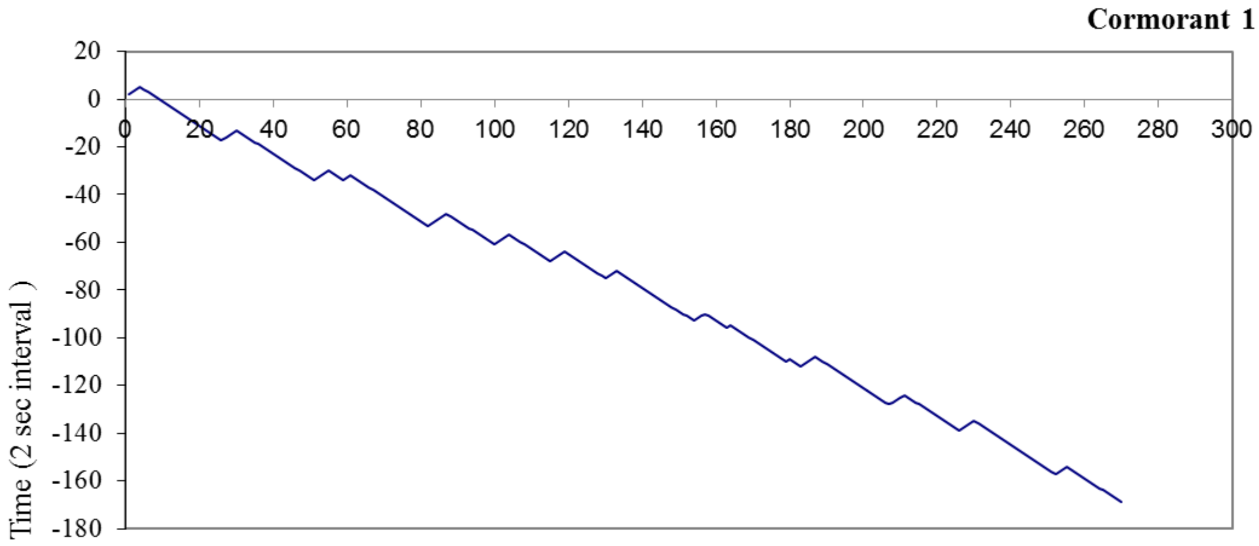
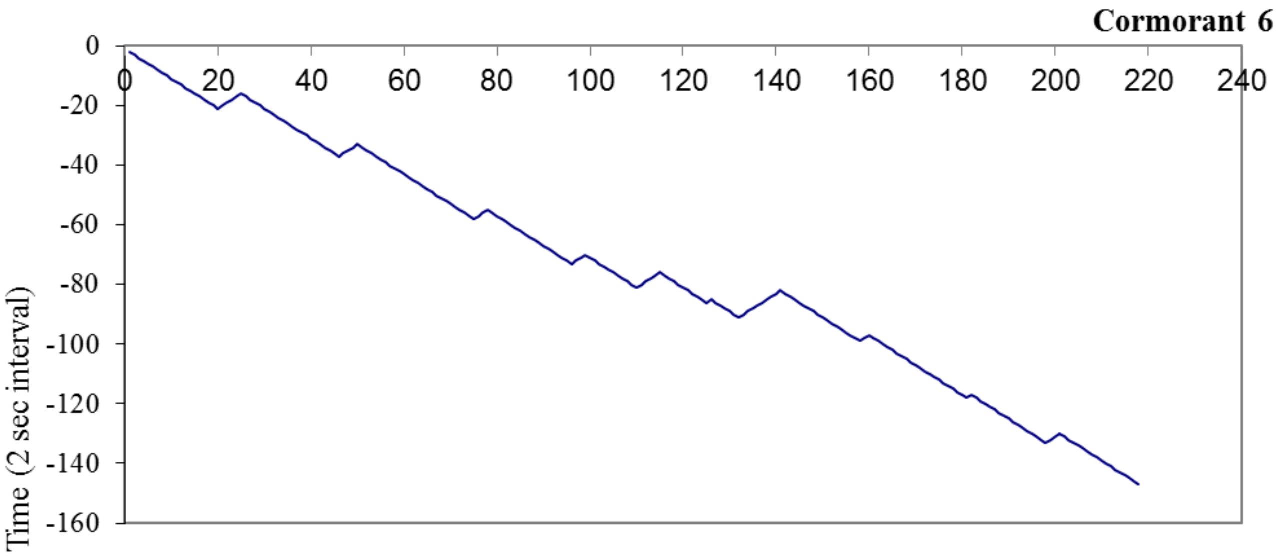


Figure 1. Phalacrocorax varius mean surface and diving times (seconds) for high and low tides.


Cormorant 1
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
Time (2 sec interval)


Cormorant 6
0
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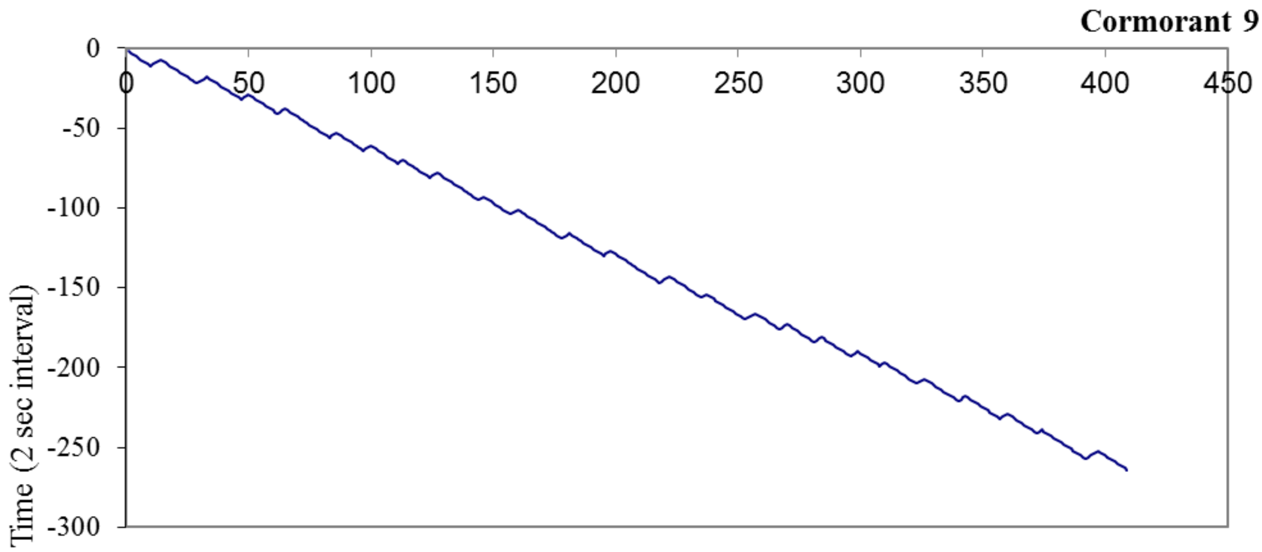
-40
-60
-80
-100
-120
-140
-160
0
20
40
60
80
100
120
140
160
180
200
220
240
Time (2 sec interval)


Cormorant 9
0
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-300
0
50
100
150
200
250
300
350
400
450
Time (2 sec interval)

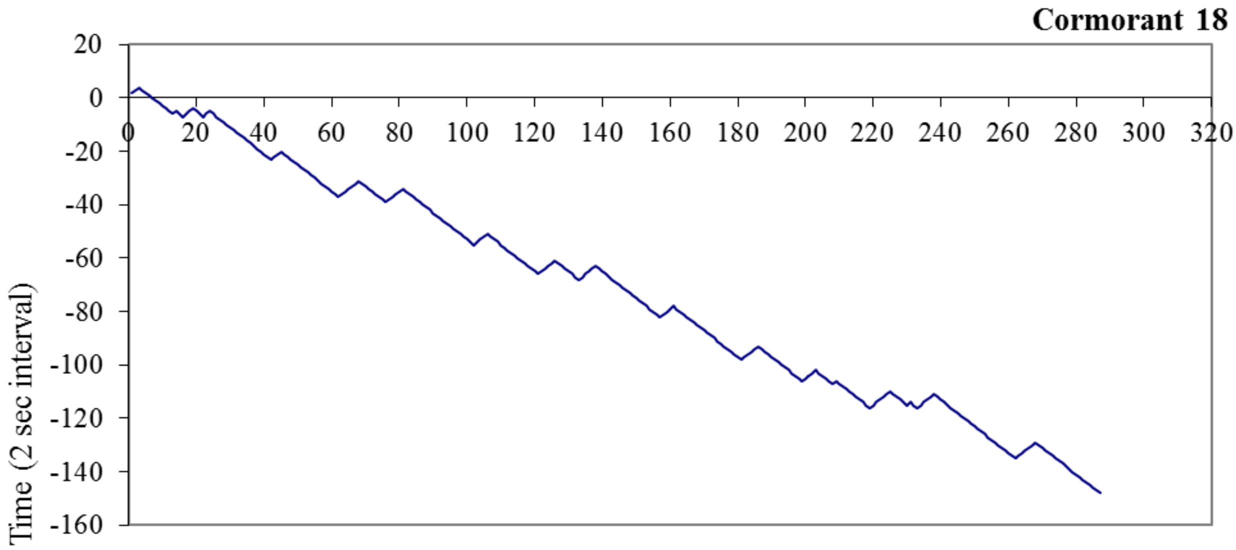
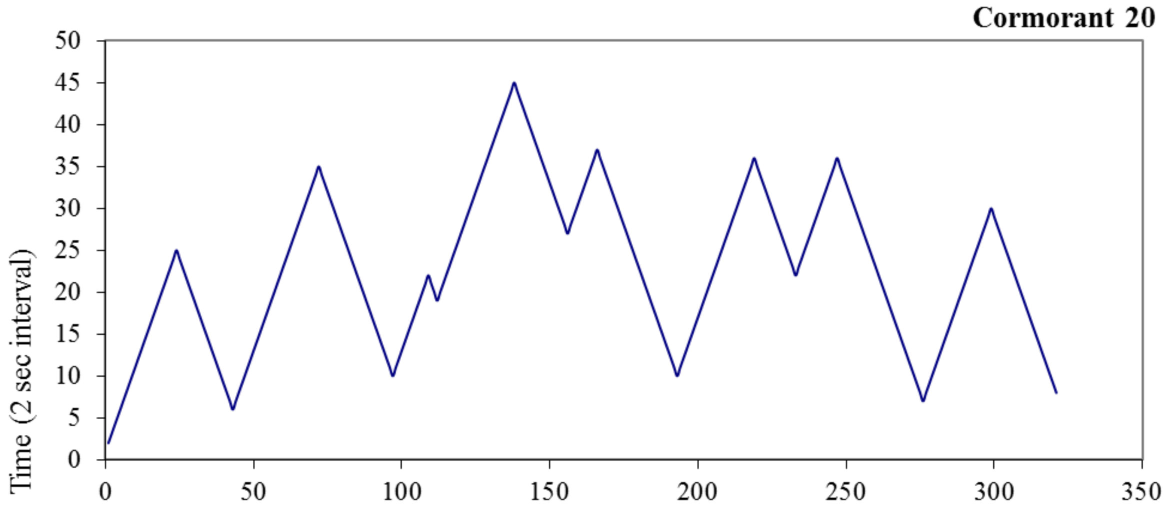
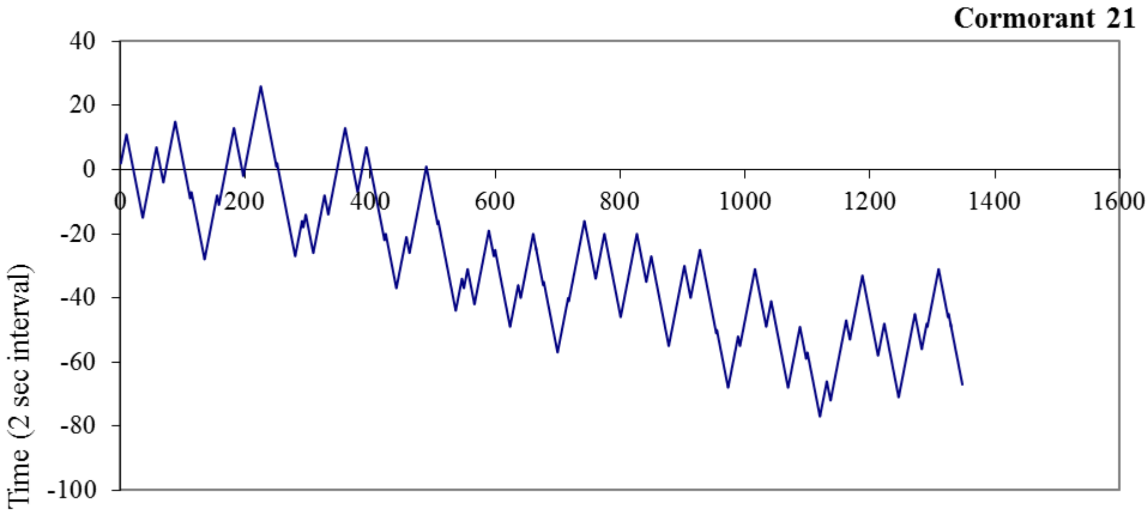


Figure 2. Phalacrocorax varius individual dive/surface flow, displaying differences between flow, focus and pulse, during Low Tide.


Cormorant 20
Time (2 sec interval)
0
5
10
15
20
25
30
35
40
45
50
0
50
100
150
200
250
300
350


Cormorant 21
Time (2 sec interval)
40
20
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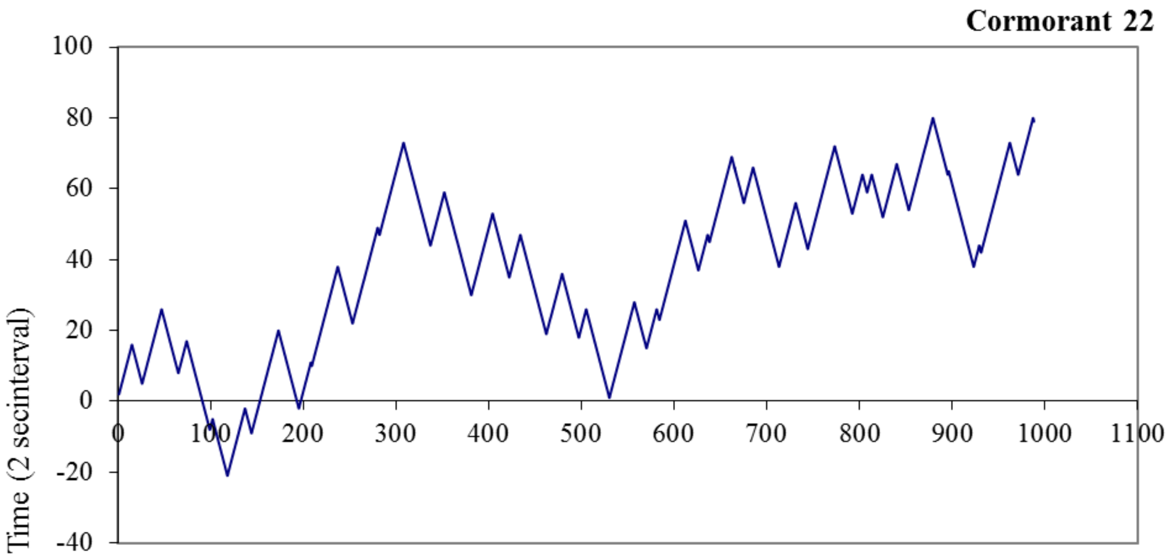
-20
-40
-60
-80
-100
0
200
400
600
800
1000
1200
1400
1600


Cormorant 22
Time (2 secinterval)
100
80
60
40
20
0
-20
-40
0
100
200
300
400
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700
800
900
1000
1100

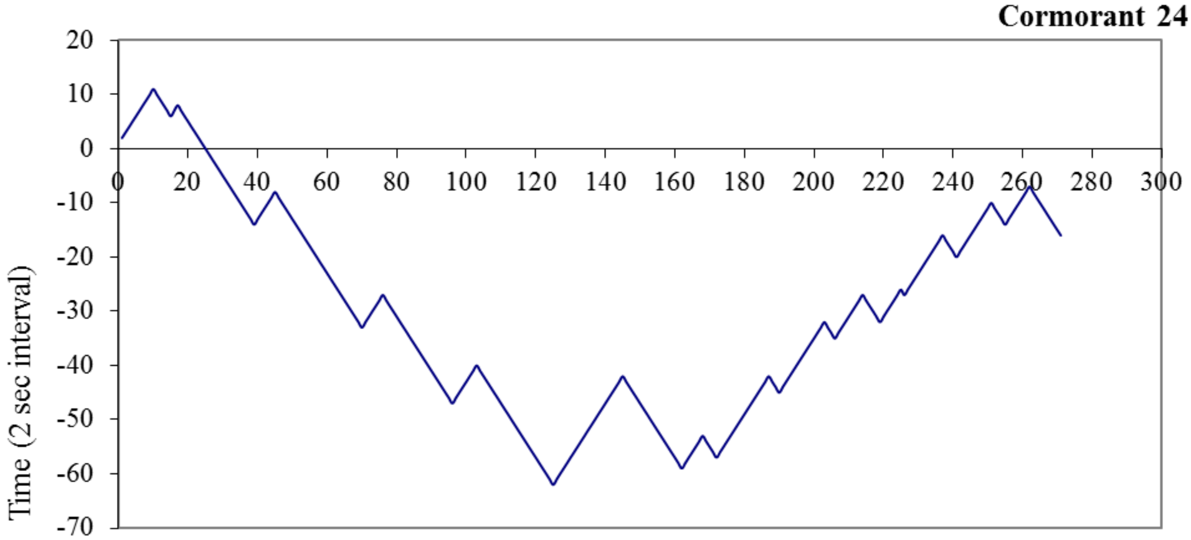

Figure 3. Phalacrocorax varius individual dive/surface flow, displaying differences between flow, focus and pulse, during High Tides.

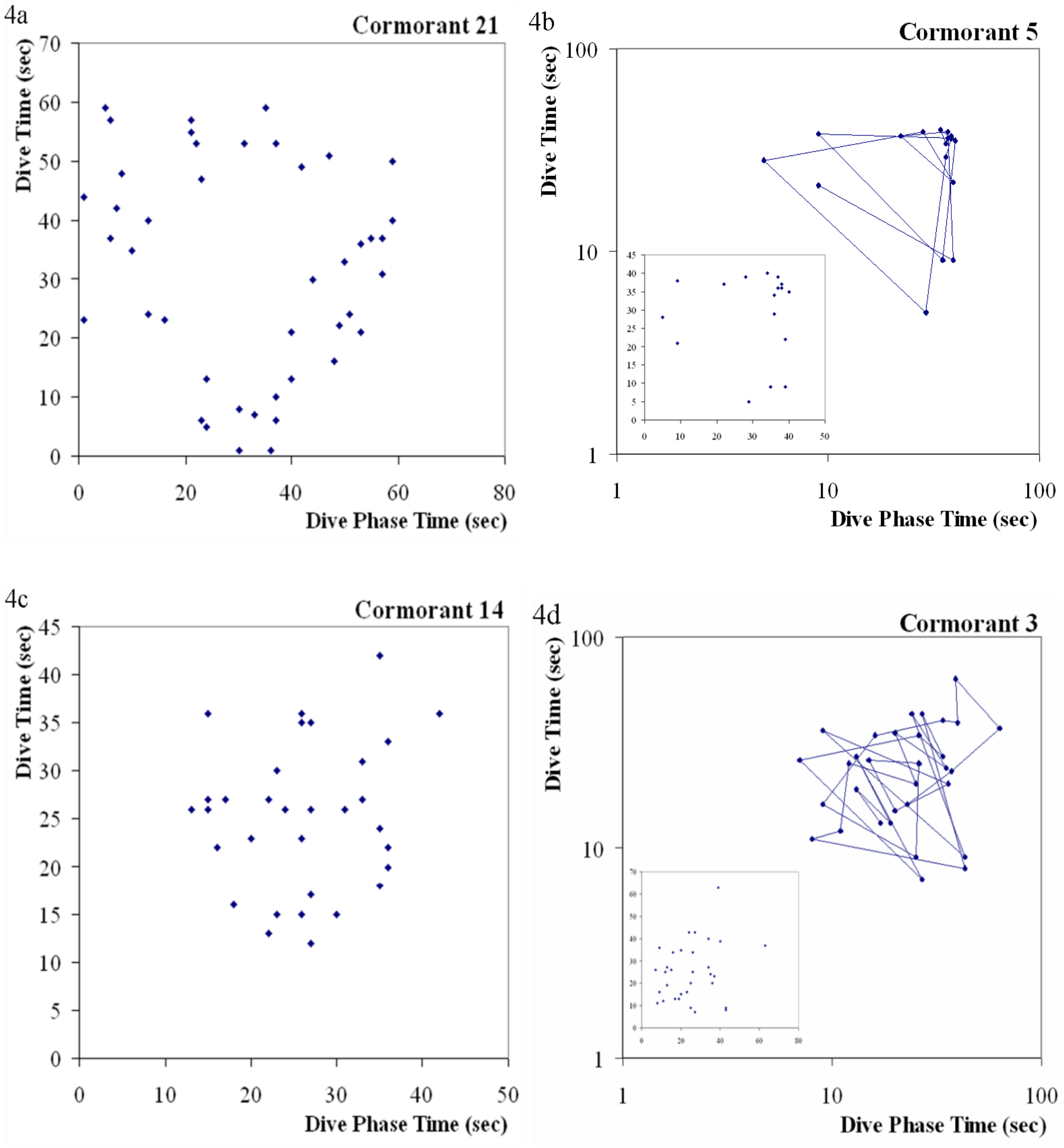

Figure 4. Phalacrocorax varius dive phase spacing results.

Appendix C: Survey Modelling

Appendix C1: Using simulated cetacean photo-identification data to assess consistency, bias and precision of closed mark-recapture population estimates.

Appendix C2: Formatting a cetacean survey; statistical model of percentage success.

Appendix C1: Population Survey Modelling

USING SIMULATED CETACEAN PHOTO-IDENTIFICATION DATA TO ASSESS CONSISTENCY, BIAS AND PRECISION OF CLOSED MARK-RECAPTURE POPULATION ESTIMATES

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ABSTRACT

Estimating population size is often one of the key objectives of cetacean photo-identification studies. However, the ability to validate results from associated mark-recapture models is dependent on numerous assumptions and conditions being met. This study used simulated cetacean photo-identification data to examine statistical measures and distribution of closed mark-recapture model population estimates when the factors sighting probability of individual animals, number of surveys, and the true population size were allowed to vary. This approach established guidelines for expected level of bias and precision at given factor levels and also highlighted situations in which inconsistent results would be likely. These results demonstrate that the use of simulations is helpful in establishing a measure of confidence in estimating demographic parameters from given survey conditions. Our findings also highlight the importance of considering accuracy, bias and normality in survey results – as their underlying distribution and pattern may have implications on inference and interpretation. In turn, this approach may prompt researchers to establish complimentary or interim research objectives particularly when it is evident that the time or resources required to estimate suitably useful population estimates might exceed the need to address important conservation goals or immediate threats. **~ Word Count:** 193 (no literature cited)

Keywords: photo-ID, cetaceans, mark-recapture, simulated data, accuracy, bias, precision, consistency.

INTRODUCTION

Mark-recapture techniques are commonly used in cetacean research in the form of photo-identification (photo-ID) surveys. This technique relies on sufficiently long-lasting and unique markings, pigmentations or features on the body, fins or flukes of the animals that are able to reliably identify and distinguish individuals (Wursig and Jefferson 1990). Photographing these natural markings enables the presence of given individuals to be documented during a given research survey. As these surveys are repeated over time a pattern of presence and absence for each uniquely marked individual (often termed a 'sighting history') is constructed. The combined set of sighting histories for all individuals of a given sample population are then used as the input data within mark-recapture models to estimate given demographic parameters of interest for the study population (Pollock 2000). However, major considerations in assessing the veracity of results from mark-recapture models is noted to depend on given conditions such as (1) appropriate survey methodology and analysis techniques, (2) correct correspondence of the mark-recapture model used for estimation with the underlying demographic characteristics of the sampled population, (3) appropriate coverage of the survey area, (4) sampling frequency of the survey area, and (5) the adequate number of captures and recaptures during the survey period.

Within the cetacean photo-ID literature, the implementation of appropriate survey methodology and analysis techniques has received the greatest attention (Wursig and Jefferson 1990). This focus has enabled the development of standard methodologies for data collection as well as the ongoing testing and validation of techniques and processes used to establish the identification of new individuals and repeat sightings of individuals (Stevick *et al*. 2001; Evans and Hammond 2004; Friday *et al*. 2008). However, the process of determining the correct population structure has received much less consideration. It has been noted that this condition requires that careful biological observations and overview are necessary to make an informed decision as to whether the population is demographically closed or open (to such processes as mortality, birth, immigration and emigration) throughout the duration of the study period (Pollock 2000).

However, a given population structure cannot overtly be 'tested' and so it is the onus of the researchers to ensure that aspects of good study design, information obtained from a pilot study, knowledge of the study species and environment, and data collection methodologies are used as effective tools to support the selected mark-recapture model used for data analysis. In many cases, a suite of models may be chosen for analysis with some decisions made to exclude particular configurations based on biological realism or appropriateness for the given setting. One example of this is that some researchers make a decision to exclude models that incorporate behavioural reactions due to the 'capture' process in cetacean photo-ID surveys (Wilson *et al.* 1997). The reasoning often given is that since individuals are identified via photograps that they would experience neither a negative (possibly due to invasive collection of material or physical marking) or positive (possibly due to methods that have used to attract individuals such as feeding) reaction to the 'capture' process that might result in a decreased or increased number of 'captures' or 'recaptures'[2] (Otis *et al.* 1978).

Appropriate coverage of the study area during the survey period is often also linked to an understanding of population structure. More specifically, if the geographical extent of the population is not sampled appropriately then the resulting population estimate will be biased given such omissions. If these limitations are noted it is important that researchers qualify exactly the geographical and temporal location to which their demographic estimates refer to, or else they will be misleading. Pilot studies or previous observations are sometimes used to assist in establishing boundaries for a given population (Kreb 2004). Furthermore, some attention has been given to issue of survey frequency in cetacean photo-ID studies with a focus on the ability to detect a trend through analysis of repeated population estimates (Gerrodette 1987; Taylor *et al.* 2007). These power analyses typically incorporate noted variance estimates within scenarios of different annual rates of increase or decrease in population to assess whether the designated population changes would be detected under a given sampling scheme. However, the focus in this work is typically not on the number of surveys required to estimate a given population size but rather

[2] In photo-ID surveys, the mark-recapture terminology of capture and recapture refers to sighting and resighting respectively.

on the use of either a series of population estimates or the magnitude and precision of a given population estimate within appropriate power analyses. To this point, sighting and resighting rates in cetacean photo-ID studies have generally been considered a data product rather than a point of survey design, and there has only been limited work on the sensitivity of the effect of number of surveys, sighting and resighting rates, and relative abundance of the study population on the estimates derived from mark-recapture models.

This study examines the impact that the factors sighting probability (encompassing sighting and resighting rates), number of surveys, and the relative population size has upon closed mark-recapture population model estimates (with no variation) (Otis *et al.* 1978) derived from cetacean photo-ID data. Given the difficulties in being able to determine the influence of model assumptions and survey conditions on strictly observational data we chose to construct simulated datasets against which we could investigate important statistical measures such as bias and precision against output data, and also explore the distribution of results. Furthermore, the construction of simulated data allowed the factors under investigation to be set at both reasonable, and a range of, levels. For this study the issues of correct population structure and appropriate survey design (and implementation) were assumed to be satisfactorily accomplished. Inference and discussion of our study focuses on the implication of these results on survey design and the application of this knowledge for setting realistic and efficient research objectives.

METHODS

A mark-recapture survey records presence or absence of a given individual on each survey day (Figure 1a). A dataset of sighting histories for input into a mark-recapture survey is typically set up with rows referring to each unique individual and columns referring to survey periods (Figure 1b). This type of dataset was simulated within a binomial framework by (1) setting the parameters for ‘success’ of an individual binomial event (the result of which is always a 1 or a 0), and (2) manipulating the number of trials for such a parameterization. Within this approach the following three factors related to photo-ID surveys were examined: sighting probability (P), true population size (T) and number of surveys (S). Sighting probability (P) was established by setting the probability of success for each binomial event at the desired level. The true population size and the number of surveys were set by setting the number of trials to the product of these two factors and then arranged into an input file with appropriate dimensions. More specifically each set of trials was configured into a matrix with number of rows equaling the designated true population size (T) and the number of columns fixing the number of surveys (S) (Figure 1c). Sighting histories for combinations of these factors at the following levels were developed: survey sighting probability (0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8), true population size (100, 250, 500, 1000), and number of survey periods (2, 3, 4, 5). Each of these 112 sighting history combinations ('SHCs') were simulated 1000 times. Normality of each set of SHCs was assessed using the Shapiro-Wilks test (alpha value = 0.05). Patterns of normality in these initial results were summarized.

Closed model (M_0, no sources of variation as per Otis *et al.* 1978) population estimates and summary statistics of each of the SHCs sets was undertaken using the Rpackage (Baillargean and Rivest, 2008) within R statistical software (version R-2.10.1 available at www. http://cran.r-project.org). For normally distributed SHCs the population size estimate (POP), population size estimate standard deviation (SD) and coefficient of variation (CV) were estimated. For non-normal SHCs the median (M) and inter-quartile range (IQR) were calculated as relative measures of centrality and dispersion respectively. Patterns in normality of each SHC were examined using a logistic regression. In this case normality being met (as assessed using the Shapiro-Wilks test) was used as the response variable with the three factors and their interactions (P, T, S, P*T, P*S, S*T, P*S*T) being used as explanatory variables. A p-value of 0.05 was used as indicating a significant factor or interaction.

The relative bias and precision of SHCs was examined. In order to include all SHCs within the analysis, bias was defined as the difference between the median value (M) and the true population size

(N). The interquartile distance (IQR) was used as a proxy for precision. Overall trends in bias and precision were examined by visual inspection against the levels of the three factors P, T, and S. Regression analyses using precision and bias as response variables against the three factors and their interactions were also undertaken with significance values of p = 0.05 being used as cut-off points for these findings. Observations from graphical displays and regression analyses were then used to determine appropriate factors for an ANOVA analysis to determine the significance of selected factors or interactions on precision or bias. When appropriate, post-hoc Tukey HSD tests were used to identify levels of each factor (or combination in the case of interactions) contributing to the significant results. For all analyses the p-value was set at 0.05.

RESULTS

Results from 112 SHC combinations were used for considering the impact of sighting probability, number of surveys and true population size on population estimates derived from simulated cetacean photo-ID surveys. Initial inspection of Shapiro-Wilks tests for normality of each of the SHCs indicated that 72 (64.3%) had p-values of less than 0.05. Centrality and dispersion was presented as the median and interquartile distance respectively for all SHCs. In addition, the mean and standard deviation values were calculated for normally distributed SHCs (Table 1a-d). A logistic regression of normality upon the three factors (true population size, probability of sighting and number of surveys) and their interactions indicated significant results for probability of sighting, P (p = 0.0247), number of surveys, S (p = 0.0251), and the interaction of these two terms, P*S (p = 0.0275). Trends in precision and bias were then examined graphically for all three factors (Figures 1 and 2). The relative spread of these measures was most noticeable for number of surveys and probability of sighting with lower number of survey and lower sighting probability being correlated with increased bias and less precision. Increased true population size appeared to have an impact on precision yet not bias. These observations coupled with the logistic regression results prompted a further analysis of both precision and bias using a 2-way ANOVA with interactions using the factors number of surveys and probability of sighting. Significant F-values were estimated for all three dependent variables on both response variables. Post-hoc Tukey HSD tests were then examined to identify levels of each factor contributing to the significant results. Similar trends in main effects for both response variables were noted (Tables 2 and 3). Significant differences for both precision (lower) and bias (higher) were found for SHCs that simulated the collection of data on only 2 survey periods (Table 2). Bias was also significantly different between SHCs that simulated the undertaking of 3 surveys versus 5. Precision showed a low p-value also (0.0119) for this same contrast. For probability of sighting comparisons, SHCs that simulated a probability of sighting value of 0.2 were significantly higher in bias and lower in precision than observed in all other levels with the exception of one comparison for the value of bias (0.2 - 0.3, p-value = 0.09). Additional significant differences for bias were found in the following combinations: 0.3 - 0.6 and 0.3 - 0.8. Precision was also found to significantly differ between SHCs of 0.3 sighting probability and those that were set with higher values (0.5, 0.6, 0.7 and 0.8). SHCs with sighting probabilities of 0.4 also showed significantly lower levels of precision than SHCs of both 0.7 and 0.8 for this same parameter.

DISCUSSION

The use of simulated data proved to be instructive in demonstrating potential limitations and points of consideration when using closed mark-recapture models to estimate population size from cetacean photo-ID sighting histories data. The ability to investigate and validate potential research results incorporates an important step of gauging the feasibility of achieving the proposed project outcomes prior to data collection. This study investigated relative consistency, bias and precision of results against known settings and parameters for sighting probability, number of surveys and population size. In the case of the true population size, precision was impacted at larger sizes whereas bias was not. The study also clearly highlighted a relationship between bias and precision of population estimates with sighting probability, number of surveys as well as the interaction between these two factors. Results became increasingly normal as the number of surveys increased while there was a tendency for SHCs with both relatively low and high sighting rates to be non-normally distributed.

The lack of normality in SHCs with smaller number of surveys and relatively low sighting rates was expected. However, significant p-values in Shapiro-Wilks tests for SHCs with higher sighting probabilities and including a higher number of surveys was not. Rather it would seem intuitive that as these two factors increase they would also increase sighting and resighting rates – and therefore sample size also. Examination of results from these two situations provides some insight into these results. Table 4 presents the full results for two SHCs that both demonstrated non-normal results. The first SHC represents a situation in which sighting rate and number of surveys was relatively low (P = 0.2, S = 2), whereas the second SHC is an example in which these two factors are set at higher values (P = 0.7, S = 4) (Table 4). Examination of the median value indicates that neither is markedly different from the true population value although the index used for bias (i.e., T – M) indicates that the 'low' set is higher (5.063) than the 'high' set (0.288). However, examination of the range of values in each SHC demonstrates a telling contrast. The range of population estimates for the 'low' set is exceptionally large, spanning 11 degrees of magnitude (31.25 - 1.402 x 10^{12}). Clearly the consistency of estimates resulting from this set of parameters is unpredictable. The range of values for the 'high' set shows a much different pattern with a much tighter and consistent pattern of estimates (981.202 - 1007.735). In this second case both accurate and precise estimates are produced. It therefore hypothesized that the high rate of sighting and resightings in the 'high' set may be delivering a dataset that is close to a census rather than a sample of the population. Such results do not adhere to a Gaussian distribution but are clearly of high scientific value. However, it should also be noted that such results necessitate the use of non-parametric techniques for summary purposes and any further inference.

The present study presents a case study in which the population was assumed to be demographically closed, all individuals had equal probability of being sighted, and that there were no differences in probability of sighting between surveys. These characteristics comply with the assumptions inherent within the Otis *et al.* (1978) closed population model, M_0, which was also used as the reference model in our results. Williams *et al.* (1993) implemented closed population models on a bottlenose dolphin population in Doubtful Sound, New Zealand. However, in this instance they chose to investigate a variety of population models including some with no variation (M_0) (and 2 sampling periods) as well as some that incorporated heterogeneity, behaviour and time (and 8 sampling occasions). No significant differences were found between different models and a total population size of 58 was reported once correction was made for the percentage of marked individuals in the population. Sighting probability rates from the models with variation incorporated indicated rates from 0.28 and 0.41. Given these results, an approximate way to compare the findings of Williams *et al.* 1993 with the results of the simulated SHCs from this study would be to consider the output of the SHC with T = 100, P = 0.3 and S = 2. Table 1 indicates that this combination produced a non-normal result with relatively low bias (2.4) and a moderate amount of precision (34.6). Williams *et al.* (1993) reports more precise results as per the small confidence intervals calculated. Kreb (2004) produced a comparable population estimate for a 2 sample closed population estimate in their study of Irrawaddy dolphins in Indonesia. Although sighting rates are not reported in this case, the confidence intervals are wider than the example SHC chosen above, and in fact appear to be less precise than the SHC results. Although less variability was observed in the precision of SHCs with lower population sizes (Figure 2) future studies may look to incorporate a selection of population sizes under 100 individuals. Furthermore, expansion of the current work into simulations which actively incorporate behavioural responses, differences in sightability between surveys and individuals, covariates and demographically open populations would also be valuable. Wilson *et al.* (1999) found good fit for a closed population of bottlenose dolphins in the Moray Firth when temporal variability (of surveys) and heterogeneity (of individuals) was considered within their underlying population structure. A longer term dataset (1989-1999) on northern bottlenose whales in Nova Scotia necessitated the use of open population models by Gowans *et al.* (2000). Although not directly comparable it is interesting to note that sighting rates observed in Gowans *et al.* (2000) were similar in range (0.23 to 0.69) to those used in the current study. Finally, it is possible that future work may choose to increase the number of simulations to more than 1000 to enable a more comprehensive study of the resulting distributions and properties of given SHCs.

This study demonstrates the potential benefits of using simulated data to provide a measure of success in estimating demographic parameters within a given time frame and resource availability. Furthermore, it is evident that following standard survey protocols for cetacean photo-ID surveys does not guarantee useful results, particularly when sighting probability and number of surveys is low. It would therefore be useful for researchers to incorporate simulations within their survey design procedures to be able to guide realistic time-frames and resources required for achieving survey objectives. Parameters within such simulations would be well-guided by a short pilot study. This initial effort could gain much more useful research results. In turn, the process of establishing minimum levels of effort (for meeting research objectives) may make researchers more open to establishing complimentary or interim research objectives, particularly in cases when it is apparent that given conservation objectives or immediate threats need to be addressed within the study population (Jaramillo-Legorreta *et al.* 2007). This perspective may be instrumental in progressing more strategic cetacean research plans.

Furthermore, these results highlight the importance of considering normality, accuracy and bias in survey results – as their underlying distribution and pattern, and value, may have important implications on inference and interpretation. In the case of normality, general properties of the distribution of estimates may be examined by setting up simulations constructed using the parameter and effort levels of the given study. However, such a process is reliant on the fact that the correct population structure has been chosen to model the data, and that relevant methodological assumptions for cetacean photo-ID have been adhered to within the set-up of the study design. The statistical measures assessed here, accuracy and precision, would improve the defensibility, and arguably would decrease in relative magnitude with attention to survey design issues also. Hence, a proactive approach and investment in appropriate survey design (Dawson *et al.* 2008; Williams and Thomas 2009) would have multiple positive repercussions for cetacean photo-ID survey results.

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FIGURES

(a)

Survey	1	2	3	4
Individual 1	1	0	0	1
Individual 2	1	1	1	1
Individual 3	0	0	0	1
Individual 4	0	1	0	0
Individual 5	1	1	0	1
Individual 6	0	1	1	1
Individual 7	0	1	1	1
Individual 8	0	1	1	1
Individual 9	1	1	1	1
Individual 10	0	1	1	1
Individual 11	1	1	0	1
Individual 12	0	1	1	0
Individual 13	1	1	1	0
Individual 14	0	0	0	1
Individual 15	0	0	1	0
Individual 16	0	0	0	1
Individual 17	1	1	0	0
Individual 18	1	0	1	1
Individual 19	1	0	0	1
Individual 20	0	0	1	0
Individual 21	1	0	1	1
Individual 22	0	1	1	0
Individual 23	1	1	1	1

(b)

```
*/001/* 1001
*/002/* 1111
*/003/* 0001
*/004/* 0100
*/005/* 1101
*/006/* 0111
*/007/* 0111
*/008/* 0111
*/009/* 1111
*/010/* 0111
*/011/* 1101
*/012/* 0110
*/013/* 1110
*/014/* 0001
*/015/* 0010
*/016/* 0001
*/017/* 1100
*/018/* 1011
*/019/* 1001
*/020/* 0010
*/021/* 1011
*/022/* 0110
*/023/* 1111
*/024/* 0000
```

(c)

100111110001010011010111011101111111011111010110111000010010000111001011100100101011011011110000

Figure 1. Demonstration of the relationship between (a) original cetacean photo-ID survey data, (b) typical input required for analysis within mark-recapture software, and (c) the initial file produced via simulations from this study. (a) Sighting histories for 24 individuals over 4 different surveys are presented. Each given individual is designated by an individual row. Each column represents a different survey. The presence or presence of each individual on a given survey is designated by a “1” or “0” respectively. (b) Original survey data is simplified to produce a text file with individuals again designated by row (and appropriate syntax) with each position within a given row referring to presence or absence on a given survey. (c) The simulation process in this study produced a string of binomial events of length equal to the dimensions of the number of surveys multiplied by the number of individuals (i.e., 4 x 24 = 96). The probability of ‘success’ (and output of ‘1’ which therefore signified presence of an individual) in each binomial event was set to the required probability of sighting an individual.

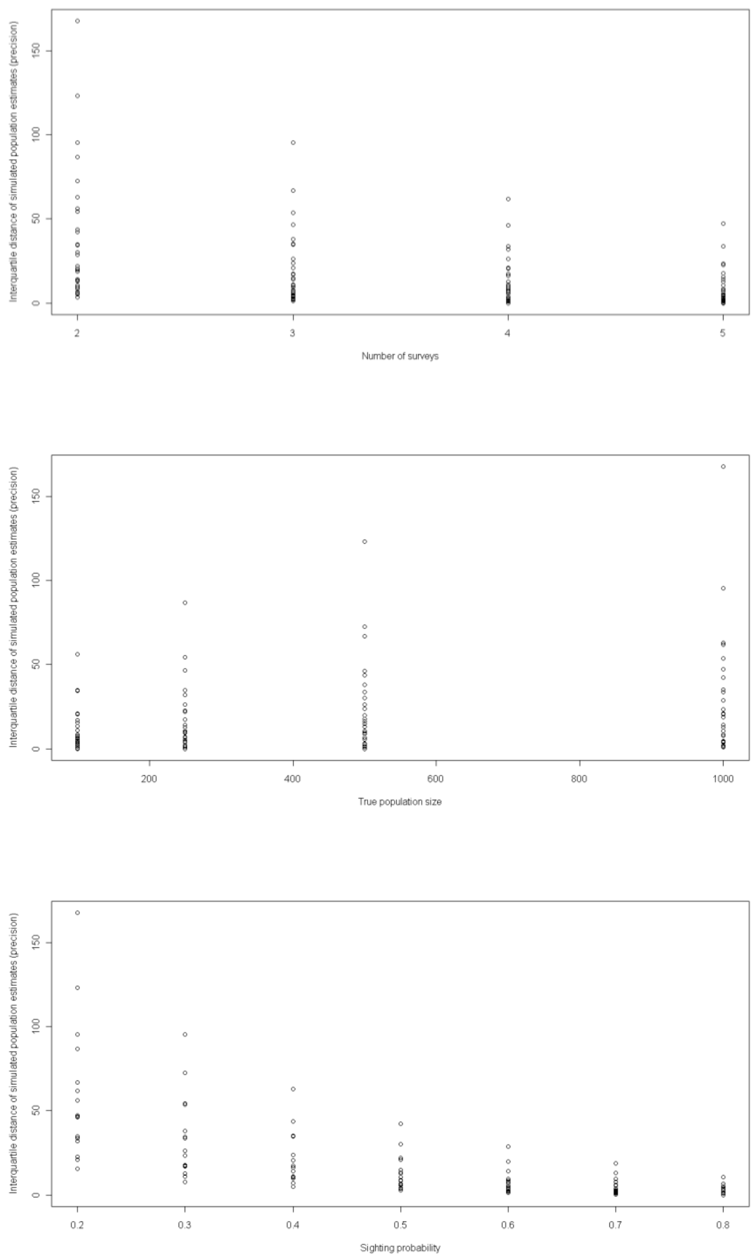

Figure 2. Visual display of the level of precision (as measured per the interquartile distance of the simulated population estimates) against designated levels of number of surveys, true population size, and sighting probability.

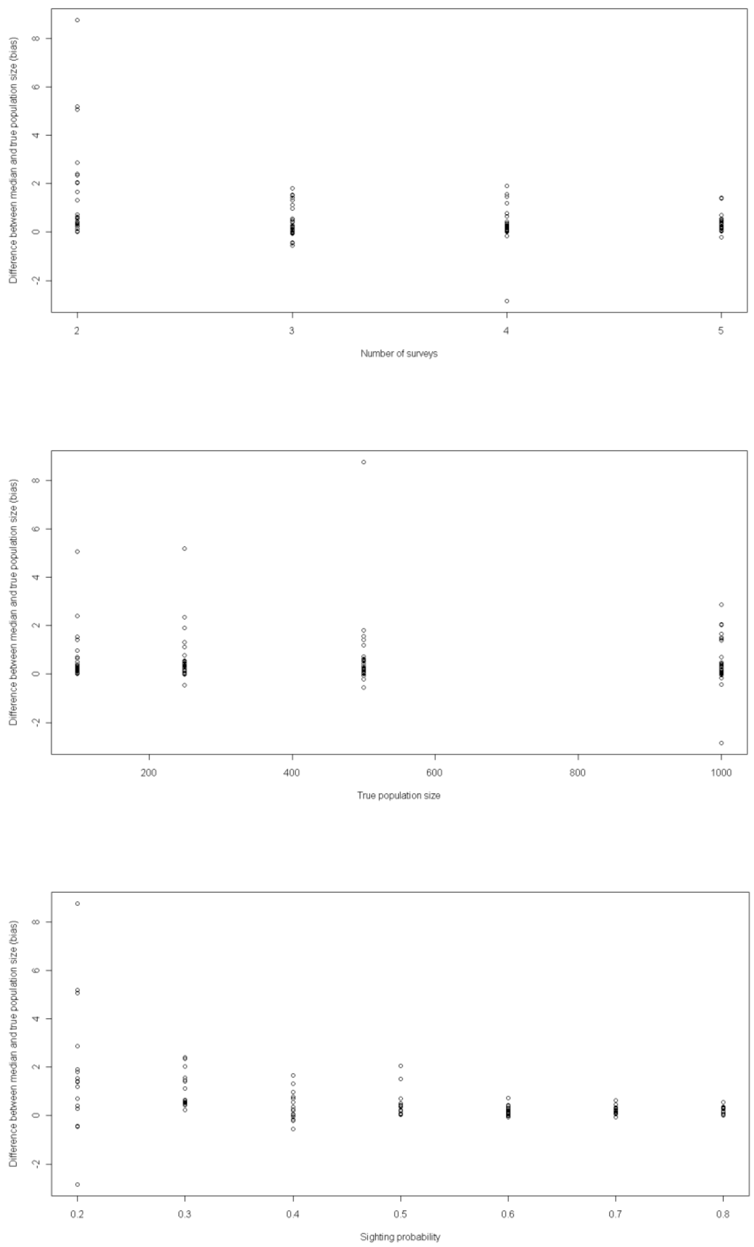

Figure 3. Visual display of the level of bias (as measured per the difference between the median and the true population size) against designated levels of number of surveys, true population size, and sighting probability.

TABLES

Table 1a.

S = 2		Probability of Sighting (P)						
N		0.2	0.3	0.4	0.5	0.6	0.7	0.8
100								
	POP							100.18
	SD							2.52
	CV							2.52
	M	105.06	102.4	100.35	100.41	100	100.24	100.32
	IQR	56.13	34.63	20.43	13.32	8.36	6.16	3.42
250								
	POP							250.1
	SD							4.12
	CV							1.65
	M	255.19	252.36	251.31	250.04	250.28	250.32	250.02
	IQR	86.75	54.35	34.68	22.17	14.31	9.54	5.34
500								
	POP					501.35	500.76	500.48
	SD					15.01	9.72	5.52
	CV					2.99	1.94	1.10
	M	508.76	500.60	500.04	500.43	500.73	500.62	500.55
	IQR	123.11	72.56	43.60	30.17	19.92	12.93	6.84
1000								

POP					1000.44	1000.50	1000.26
SD					21.15	13.72	7.93
CV					2.11	1.37	0.8
M	1002.87	1002.03	1001.65	1002.05	1000.44	1000.13	1000.04
IQR	167.66	95.41	63.08	42.42	28.77	18.63	10.55

Table 1b.

S = 3		Probability of Sighting (P)						
N		0.2	0.3	0.4	0.5	0.6	0.7	0.8
100								
	POP					100.18	100.14	
	SD					3.2	1.82	
	CV					3.19	1.82	
	M	101.55	101.41	100.97	100.50	100.10	100.24	100.19
	IQR	34.99	16.89	11.12	6.41	4.48	2.43	1.29
250								
	POP					249.94	250.23	
	SD					5.01	2.96	
	CV					2.0	1.18	
	M	249.55	251.13	251.31	250.51	249.98	250.19	250.28
	IQR	46.44	26.34	17.50	10.62	6.98	4.01	2.02
500								
	POP				500.1	499.82	499.91	
	SD				11.24	7.05	4.04	
	CV				2.25	1.41	0.81	
	M	501.81	500.56	499.44	500.05	499.95	499.94	500.02
	IQR	66.82	38.13	23.73	14.99	9.59	5.51	2.77
1000								
	POP		1000.81		1001.42	1000.3	1000.12	
	SD		40.48		15.87	10.48	6.02	

CV		4.04		1.58	1.05	0.6	
M	999.57	1000.44	999.95	1001.52	1000.40	1000.21	1000.18
IQR	95.49	53.82	35.02	20.78	14.25	7.92	4.14

Table 1c.

S = 4		Probability of Sighting (P)						
N		0.2	0.3	0.4	0.5	0.6	0.7	0.8
100								
	POP			100.28	99.97			
	SD			5.10	3.03			
	CV			5.09	3.93			
	M	100.28	100.65	100.22	100.06	100.10	100.05	100.15
	IQR	20.91	11.10	7.07	3.93	2.33	1.20	0.11
250								
	POP		250.81	250.58	250.16			
	SD		13.12	7.63	4.91			
	CV		5.23	3.04	1.96			
	M	251.92	250.23	250.76	250.42	250.17	250.18	250.33
	IQR	32.13	17.49	9.77	6.76	4.01	1.88	0.98
500								
	POP			500.0		500.03		
	SD			11.66		3.97		
	CV			2.33		0.79		
	M	501.18	501.57	500.26	500.18	500.22	500.11	500.03
	IQR	46.18	26.16	16.19	8.79	5.60	2.82	1.09
1000								
	POP		1001.31	1000.5	1000.09	1000.01		
	SD		26.03	15.74	9.41	5.68		

CV		2.6	1.57	0.94	0.57		
M	997.16	1001.48	999.84	1000.08	1000.00	1000.29	1000.36
IQR	62.03	33.74	20.69	12.58	7.59	3.93	1.35

Table 1d.

S = 5		Probability of Sighting (p)						
N		0.2	0.3	0.4	0.5	0.6	0.7	0.8
100								
	POP			100.09				
	SD			3.48				
	CV			3.48				
	M	100.70	100.22	100.06	100.23	100.14	100.22	100.03
	IQR	15.58	7.92	4.78	2.69	1.45	0.15	0.02
250								
	POP		250.58	250.51				
	SD		9.57	5.15				
	CV		3.82	2.06				
	M	250.40	250.52	250.56	250.34	250.08	250.46	250.08
	IQR	22.87	12.65	7.18	4.16	2.20	1.06	0.03
500								
	POP	501.52	500.66	499.89	500.13			
	SD	24.78	13.75	7.84	4.27			
	CV	4.94	2.75	1.59	0.85			
	M	501.41	500.52	499.79	500.24	500.33	500.19	500.15
	IQR	33.81	17.70	10.46	5.52	3.25	1.82	0.05
1000								
	POP		1000.67	1000.69	1000.55			
	SD		18.24	10.87	6.06			

CV		1.82	1.09	0.61			
M	1001.39	1000.49	1000.7	1000.7	1000.07	1000.3	1000.3
IQR	47.22	23.51	14.01	8.51	4.68	2.17	0.97

Tables 1 a-d. Summary statistics from SHCs for cases of 2 (a), 3 (b), 4 (c) and 5 (d) survey periods (S) with a range of sighting probabilities (P) and true population sizes (N). Dark columns indicate that Shapiro-Wilks tests had p-values of less than 0.001, gray columns refer to SW p-values of between 0.005 – 0.001, and white columns refer to p-values of greater than 0.05. Median (M) and IQR (interquartile) calculations are presented for all SHCs. Population size estimate (POP), population size estimate standard deviation (SD), and the coefficient of variation (CV) are presented only in cases when normality was met at the 0.05 level.

		Precision			
	Number of surveys	2	3	4	5
	2		< 0.001	< 0.001	< 0.001
	3	< 0.001		0.170	0.012
Bias	4	< 0.001	0.924		0.705
	5	< 0.001	0.996	0.977	

Table 2. Estimated p-values of ad-hoc comparisons of the precision (upper half) and bias (lower half) of population estimates generated from simulated SHCs containing differing number of completed surveys. Significant results (at the 0.05 level) are shaded in gray.

		Precision						
	Probability of sighting	0.2	0.3	0.4	0.5	0.6	0.7	0.8
	0.2		< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
	0.3	0.090		0.145	0.001	< 0.001	< 0.001	< 0.001
	0.4	< 0.001	0.338		0.686	0.152	0.025	0.005
Bias	0.5	< 0.001	0.413	0.999		0.960	0.636	0.309
	0.6	< 0.001	0.040	0.960	0.929		0.992	0.881
	0.7	< 0.001	0.061	0.984	0.967	0.999		0.998
	0.8	< 0.001	0.041	0.962	0.932	1.00	0.999	

Table 3. Estimated p-values of ad-hoc comparisons of the precision (upper half) and bias (lower half) of population estimates generated from simulated SHCs containing differing probability of sighting for individual animals. Significant results (at the 0.05 level) are shaded in gray.

Variable or estimate	‘low’ SHC	‘high’ SHC
Probability of sighting	0.2	0.7
True population size	100	1000
Number of surveys	2	4
Shapiro-Wilks statistic	0.048	0.983
Shapiro-Wilks p-value	$< 2.2 \times 10^{-16}$	1.372×10^{-09}
Median	105.063	1000.288
Range	$31.25 - 1.402 \times 10^{12}$	981.202 - 1007.735
Interquartile range	56.125	3.927

Table 4. Comparison of two SHCs in which the Shapiro-Wilks test indicated normality was not met. The first SHC included a relatively low probability of sighting (‘low’) and the second has a relatively high probability of sighting (‘high’).

Appendix C2: Statistical Model of Percentage of Success – Part Paper

Title: Formatting a Cetacean Survey; Statistical Model of Percentage Success

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ABSTRACT

Cetaceans inhabit areas of vast ocean, and large stretches of coastal waters. In order to undertake investigations on populations, habitats, abundances, behavior and photo-identification it is necessary for researchers to formulate investigative surveys. These surveys can be undertaken on a variety of bases: land, boat, plane; but due to the nature of cetacean behavior and their ability to move quickly under the water and across large areas, reliability of such surveys are unknown. Utilizing the Program R we have formulated a model that puts together percentage of survey success using set limits of both population number and time constraints. Furthermore we have put together a table stipulating differing characteristics that can influence survey success, following the broad categories: weather condition, size, noise level, behavior, survey, land-based, boat-based and interference. Each characteristic has a series of sub-classifications and adjoining points of effect, from low to high, depending on whether the 'effect' is detrimental or influential to spotting a marine mammal. Once these survey characteristics are defined, the points of effect are added together to determine a total percentage of influence. This total percentage is used in conjunction with the survey model to determine the number of surveys required for a successful investigation. We test our model using two case studies: Case Study 1 – Indo-Pacific Bottlenose Dolphins of the Port Adelaide River and Case Study 2 – Southern Right Whales of the Great Australian Bight. Results show…..

Keyword: cetacean, survey, marine mammal, model, Southern Right Whale, *Eubalaena australis*, Indo-Pacific Bottlenose Dolphin, *Tursiops aduncus*, photo-identification, behavior, Program R.

Word Count:

INTRODUCTION

Survey structure for marine mammal investigations can severely affect research success. Due to the environmental and funding limitations in researching species that inhabit vast areas of ocean, successful data collection is an imperative (Wade and Angliss 1997, Ingram and Rogan 2002, Johnston et al. 2005). Environmental heterogeneity has also been shown to influence habitat use by marine mammals (Ingram and Rogan 2002)

Environmental factors such as weather conditions (Holt et al. 1987, Evans and Hammond 2004, Bailey and Thomspon 2009), clear or clouded skies and rain (Dick and Hines 2011), glare (Marsh and Sinclair 1989. Evans and Hammond 2004), sea-states (above $\geq$2) (Marsh and Sinclair 1989, Jefferson 1991, Bailey and Thompson 2009) and visibility (Marsh and Sinclair 1989, Hooker et al. 2002, Dick and Hines 2011) can both positively and negatively be influenced by cetacean presence and visibility (Holt et al. 1987, Evans and Hammond 2004, Bailey and Thompson 2004)

Individual and group size can influence whether researchers can locate cetaceans and the ability of investigators to determine behaviors and interactions being displayed. Behavior itself also affects survey structure. Cetaceans that travel known habitat areas or are restricted to smaller, predictable travelling patterns are naturally easier to survey then wide-ranging, unpredictable species (Ingram and Rogan 2002, Johnston et al. 2005). On the same note species that spend the majority of their time underwater (up to 90% in some recorded cases) provide less data then those that regularly surface (Baird et al. 2006, Dick and Hines 2011)

Survey structure itself can have the biggest influence on viability of results and amount of data gathered. Surveys that have high survey effort, experienced recorders, numerous observers and good quality equipment have a higher percentage of a successful survey (Ingram and Rogan 2002, Evans and Hammond 2004, Baird et al. 2006). Land-Based surveys have been shown to reduce impact on cetacean behavior. However they are also restricted to near-shore species. In addition certain variables like number of bases, height of base and distance of base from shore can all influence survey success. Boat based surveys have shown to be a negative influence on cetacean behavior (Curran 1996, Mann 1999, Hastie et al. 2003, Mattson et al. 2005). However for surveys on distribution and photo-identification they are often ideal, as they are able to expand survey area and increase encounter rate (Turchin 1988). For boat-based behavioral studies level of boat noise, boat speed and boat size can all impact behavior being displayed and therefore negate data reliability (Wilson et al. 1997, Dawson et al. 2004, Pierpoint and Allan 2004).

Interference to cetaceans can be caused by factors outside of the survey itself, the most prominent being human interaction. (Mann 1999, Williams et al. 2002, Richter et al. 2006). Number of boats (Constantine et al. 2003, 2Lusseau 2003), boat speed (Lusseau 2005, Mattson et al. 2005), boat noise (Williams et al. 2002, 2Lussea 2003),, outside noise (ie. such as those seen in highly populated areas) (Pierpoint and Allan 2004), frequency of vehicle (plane or boat) interaction (Constantine et al. 2004) and closeness of interaction (Pierpoint and Allan 2004).

Survey success can be directly and indirectly influenced by the variables mentioned above. Environmental factors can influence cetacean movement patterns (Johnston et al. 2005, Bailey and Thompson 2006). Viability of data, information recovered are all affected by cetacean distribution, abundance and visibility (Whitman and Garrod 1990, Buckland et al. 2001), The focus of this study is to formulate a model that takes into consideration survey variables in order to determine percentage of survey success in comparison to number of surveys undertaken. Using this data, researchers will be able to design their surveys and apply for funding around these restrictions.

METHOD

Insert Model Explanation in Here, with simulated results.

If we know probability of success (using table 1 calculations) and we know each survey will go for x amount of hours, how many surveys need to be conducted to get the required results.

In order to determine which model result correlates to the survey parameters it is first necessary to determine what the parameters are. A set list of possible parameters, with corresponding points of effect (POE) can be seen in Table 2. By completing an initial survey of the area and species that is being investigated, in conjunction with the knowledge of funding, time, equipment and personnel restraints, a tabulated list of the differing parameters for each specific investigation can be formulated. From this list (and the aligning POE) the percentage of likelihood of a successful survey can be determined.

Table 2: Percentage of influence on statistical modelling success. Clarification of Variables: *No. Behav. (R)* = number of behaviours to be recorded, *% Time Underw.* = percentage of time the cetacean spends underwater, *No. Trips Pos.* = number of boat trips that are possible (due to time limitations/fuel restrictions etc), *Height of Base* = height of the base from sea level, *Distance (Shore)* = distance of the land-base from the shore, *Cetacean Dis.* = distance of the cetacean from the edge of shore, *Outside Noise* = noise influence from sources other than boats.

Variables	**Percentages**					
	100	**83**	**67**	**50**	**33**	**17**
Weather Conditions						
Skies	*Clear/Fine*	*Cloud*	-	*Overcast*	*Stormy*	-
Glare	*None*	*Low*	-	-	*Medium*	*High*
Waves	*Calm*	*Ripples*	-	*Waves*	-	*Whitecaps*
Wind	*None*	*Small Breeze*	-	*High Breeze*	*Gusty*	*High Wind*
Opacity	*Clear*	*Cloudy*	-	*Blank*	-	-
Size						
Mammal	-	*Large*	-	*Small*	-	-
Group	*Multitudes*	*Large*	*Medium*	-	*Small*	-
Behaviour						
Trav. Habitat	*Consistent*	*Occasional*	-	-	*Small*	-
No. Behav. (R)	-	*+4*	*3*	*2*	*1*	-
% Time Underw.	-	*25%*	*50%*	*75%*	*90%*	-
Survey						
Hours	*+7*	*6-5*	*4*	*3-2*	*1-2*	-
Volunteer No.	*+5*	*4*	*3*	*2*	*1*	-

Volunteer Exp.	-	*Experienced*	*Moderate*	*Beginner*	*None*	-
Volunteer Equip.	-	*Individual*	*Shared*	-	*None*	-
<u>Land Based</u>						
No. of Bases	*+4*	*3*	*2*	-	*1*	-
Height of Base	*+100m*	*100-50m*	*50-10m*	*>10m*	*Shore*	-
Distance (Shore)	-	*On Shore*	-	*10m*	*+10m*	-
Cet Distance	*Near Shore*	*>50m*	*<100m*	-	*>100m*	-
<u>Boat Based</u>						
Size	-	-	*Small*	*Medium*	*Large*	-
Noise	*None*	-	*Low*	*Medium*	-	*Large*
No. Trips. Pos	*+ 10*	*9-8*	*7-6*	*5*	*4-3*	*2-1*
Type	*Canoe*	*Row*	*Sail*	-	*Motor*	*Speed*
<u>Interference</u>						
No. Boats	*None*	*1-2*	-	*3-4*	*5-6*	*+7*
Noise of Boats	*None*	-	*Low*	*Medium*	-	*Loud*
Outside Noise	*None*	*Low*	-	*Medium*	*Loud*	-
Plane Height	*None*	*+150m*	-	*100m*	*50m*	*>50m*
Freq. WWW	*None*	*Monthly*	*Weekly*	*Daily*	*Twice*	*Hourly*
Closeness WWW	-	-	*None*	-	*Distant*	*Close*
Boat Speed	-	*Slow*	-	*Medium*	*High*	-

Note = Percentage of influence for each variable was calculated from previous research results.

'Variables' is a broad initial category, under which are several sub-categories. From each sub-category are listed all possible variations of the variable with corresponding POE, showing their influence on survey success from low to high. High numbers have a positive influence on surveys, with low number indicating the effect to be detritus. These effects have been calculated from the accumulated results of several peer-reviewed cetacean surveys.

Once each categories percentage (*c%*) has been calculated the total percentage (*TC%*) is calculated using the following formula:

$$TC\% = \%(c1 + c7) / Nc$$

Where the percentages of categories 1 – 7 are added together and divided by the number of categories to give the total percentage for all categories.

Once *TC%* is calculated, the findings of the model can be compared with the percentage in order to determine the number of surveys required to obtain the results. For example using the simulated model results (Table 1), and assuming *TC%* = 65, over a period of one month, with each survey taken no more than 3 hours we see that in order to achieve a viable survey investigation we would need to undertake ---- surveys per day.

To test whether this method can be utilized in real life scenarios we have put together two case studies, in different regions of South Australia, using two different species of marine mammal. Previous surveys in this region have provided detailed knowledge of the area and mammals involved. Equipment and personnel limitations are taken from the limitations imposed during the above mentioned previous investigations.

CASE STUDY 1: Indo-Pacific Bottlenose Dolphins (*Tursiops aduncus*) of the Port Adelaide River

The Port Adelaide Dolphin Sanctuary, South Australia (34° 55'S, 138° 36'E) was established on June 1st (2005) to protect populations of >300 bottlenose dolphins (*Tursiops aduncus*) recorded within the Port Estuary and Barker Inlet (Coasts and Marine 2006). Three land-based sites were chosen in designated 'hotspot' areas where *T. aduncus* are sighted frequently. Observation platform 1: Garden Island, Observation platform 2: Snowdens Beach, Observation platform 3: Lighthouse.

The hypothetical investigation is based around a photo-identification survey of *Tursiops aduncus* to determine individual characteristics. Investigations will be undertaken for a period of one month, twice a year, three days a week, Monday, Wednesday and Friday. Three high powered telephoto lens cameras will be used, from three different land-based bases, by three different camera crews, none of whom are experienced in photo-identification. Utilizing preliminary survey data we formulated two tables showing the conditions likely to be present during surveys (Tables 3 and 4). Each table represents a different season (Summer and Winter), with a focus on formulating a survey based around photo-identification.

Table 3: *Turpiops aduncus* Survey % (S)

Variables	**Percentages**					
	100	**83**	**67**	**50**	**33**	**17**
<u>Weather Conditions</u>						
Skies	●	○	○	○	○	○
Glare	○	○	○	○	○	●
Waves	●	○	○	○	○	○
Wind	○	●	○	○	○	○
Opacity	○	○	○	●	○	○
C%	70					
<u>Size</u>						
Mammal	○	○	○	●	○	○
Group	○	○	○	○	●	○
C%	42					
<u>Behaviour</u>						
Trav. Habitat	●	○	○	○	○	○
% Time Underw.	○	○	●	○	○	○
C%	84					
<u>Survey</u>						
Hours	○	○	○	●	○	○
Volunteer No.	○	○	○	●	○	○
Volunteer Exp.	○	○	○	○	●	○
Volunteer Equip.	○	○	●	○	○	○

C%	50					
<u>Land Based</u>						
No. of Bases	○	●	○	○	○	○
Height of Base	○	○	○	○	●	○
Distance (shore)	○	●	○	○	○	○
Cet. Distance	○	●	○	○	○	○
C%	71					
<u>Interference</u>						
No. of Boats	○	○	○	○	●	○
Noise of Boats	○	○	○	●	○	○
Outside Noise	○	○	○	●	○	○
Freq. WWW	○	○	○	○	●	○
Closeness WWW	○	○	●	○	○	○
Boat Speed	○	●	○	○	○	○
C%	53					
TC%	**62**					

Table 4: ***Tursiops aduncus*** **Survey % (W)**

Variables	**Percentages**					
	100	**83**	**67**	**50**	**33**	**17**
Weather Conditions						
Skies	○	○	○	●	○	○
Glare	●	○	○	○	○	○
Waves	○	●	○	○	○	○
Wind	○	○	○	●	○	○
Opacity	○	○	○	●	○	○
C%	67					
Size						
Mammal	○	○	○	●	○	○
Group	○	○	○	○	●	○
C%	42					
Behaviour						
Trav. Habitat	●	○	○	○	○	○
% Time Underw.	○	○	●	○	○	○
C%	84					
Survey						
Hours	○	○	○	●	○	○
Volunteer No.	○	○	○	●	○	○
Volunteer Exp.	○	○	○	○	●	○
Volunteer Equip.	○	○	●	○	○	○

C%	50					
Land Based						
No. of Bases	○	●	○	○	○	○
Height of Base	○	○	○	○	●	○
Distance (shore)	○	●	○	○	○	○
Cet. Distance	○	●	○	○	○	○
C%	71					
Interference						
No. of Boats	○	●	○	○	○	○
Noise of Boats	○	○	○	●	○	○
Outside Noise	○	●	○	○	○	○
Freq. WWW	○	○	●	○	○	○
Closeness WWW	○	○	●	○	○	○
Boat Speed	○	●	○	○	○	○
C%	72					
TC%	**64**					

CASE STUDY 2: Southern Right Whales (*Eubalaena australis*) of the Great Australian Bight

The Head of Bight, the Great Australian Bight, South Australia (31° 48′ S, 131° 11′ E) is one of largest marine protected areas in Australia. Utilization of land-based platforms provides independent observation points of study (Scheidat *et al*. 2004), and are recommended when observing movements and behaviors of large, slow-moving coastal species (Bejder and Samuels 2003, Richter *et al*. 2006).

The hypothetical investigation is based around a behavioral survey of *Eubalaena australis* to determine differing resting behavior times displayed between age-groups. Investigations will be undertaken for one month, every day by two researchers of medium experience. Notes will be recorded once every 15 minutes on pad and paper, showing the number of animals displaying resting behavior by age-group. During the migrationary period that *E. australis* are located at the Great Australian Bight two weather patterns predominate, 'calm' and 'stormy'. Utilizing preliminary survey data we formulated table showing conditions likely to be present during a behavior based survey (Table 5 and 6).

Table 5: ***Eubalaena australis*** **Survey % (C)**

Variables	**Percentages**					
	100	**83**	**67**	**50**	**33**	**17**
Weather Conditions						
Skies	●	○	○	○	○	○
Glare	●	○	○	○	○	○
Waves	●	○	○	○	○	○
Wind	○	●	○	○	○	○
Opacity	●	○	○	○	○	○
C%	97					
Size						
Mammal	○	●	○	○	○	○
Group	○	○	●	○	○	○
C%	75					
Behaviour						
Trav. Habitat	●	○	○	○	○	○
% Time Underw.	○	○	○	●	○	○
C%	75					
Survey						
Hours	○	●	○	○	○	○
Volunteer No.	○	○	○	●	○	○
Volunteer Exp.	○	○	●	○	○	○
Volunteer Equip.	○	●	○	○	○	○

C%	71					
<u>Land Based</u>						
No. of Bases	○	○	○	○	●	○
Height of Base	○	●	○	○	○	○
Distance (shore)	○	●	○	○	○	○
Cet. Distance	○	○	●	○	○	○
C%	67					
<u>Interference</u>						
No. of Boats	●	○	○	○	○	○
Outside Noise	●	○	○	○	○	○
Plane Height	○	○	○	●	○	○
Freq. WWW	○	○	○	○	●	○
C%	71					
TC%	**76**					

Table 6: ***Eubalaena australis*** **Survey % (S)**

Variables	**100**	**83**	**67**	**50**	**33**	**17**
<u>Weather Conditions</u>						
Skies	○	○	○	●	○	○
Glare	●	○	○	○	○	○
Waves	○	○	○	●	○	○
Wind	○	○	○	○	●	○
Opacity	○	○	○	●	○	○
C%			57			
<u>Size</u>						
Mammal	○	●	○	○	○	○
Group	○	○	●	○	○	○
C%			75			
<u>Behaviour</u>						
Trav. Habitat	●	○	○	○	○	○
% Time Underw.	○	●	○	○	○	○
C%			92			
<u>Survey</u>						
Hours	○	●	○	○	○	○
Volunteer No.	○	○	○	●	○	○
Volunteer Exp.	○	○	●	○	○	○
Volunteer Equip.	○	●	○	○	○	○

C%			71			
Land Based						
No. of Bases	○	○	○	○	●	○
Height of Base	○	●	○	○	○	○
Distance (shore)	○	●	○	○	○	○
Cet. Distance	○	○	●	○	○	○
C%			67			
Interference						
No. of Boats	●	○	○	○	○	○
Outside Noise	●	○	○	○	○	○
Plane Height	○	○	○	●	○	○
Freq. WWW	○	○	○	○	●	○
C%			71			
TC%			**72**			

RESULTS

CASE STUDY 1: Indo-Pacific Bottlenose Dolphins (*Tursiops aduncus*)

CASE STUDY 2: Southern Right Whales (*Eubalaena australis*)

DISCUSSION

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Appendix D

Guidelines to Authors

Appendix D1: Marine Mammal Science

Appendix D2: Marine Ecology Progress Series

Appendix D1: Marine Mammal Science

GUIDELINES TO AUTHORS

Marine Mammal Science publishes significant new findings on marine mammals resulting from original research on their form and function, evolution, systematics, physiology, biochemistry, behavior, population biology, life history, genetics, ecology and conservation. Range extensions, unusual observations of behavior, and preliminary studies of a few individuals are published only where there is sufficient new information to render the manuscript of general interest. Low priority will be given to confirmatory investigations of local or regional interest.

The Journal endorses the principle that experiments using live animals should be undertaken only for the purpose of advancing knowledge. Consideration should be given to the appropriateness of experimental procedures, species of animals used, and number of animals required. All animal experimentation reported in Marine Mammal Science must be conducted in conformity with the relevant animal care codes of the country of origin. The Editor will refuse manuscripts in which evidence of adherence to such codes is not apparent.

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The manuscript should be concise, logical, and unequivocal. Publication is facilitated if authors double-check for typographical and other errors and ensure that manuscripts and figures meet the requirements outlined below. Manuscripts that do not conform will be returned for correction before consideration. If in doubt, consult the Editorial Office. Authors are charged for excessive changes in proof.

A full-length Article includes a title page, abstract, keywords, text, acknowledgments, literature citations, tables, figure captions, and figures. Notes and Letters do not have an abstract and are prepared in narrative form without headings, except for "Literature Cited."

All parts of the manuscript, including footnotes, tables, and figure captions, should be typewritten, double-spaced with margins at least 2.5 cm wide. Number all pages of the manuscript beginning with the title page and include line numbers on each page. Underline only when the material is to be set in italics. Use capital letters only when the letters or words are to be capitalized. Do not end a line of text with a hyphen.

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The first page should contain only the title and the name, affiliation, and complete address (plus current address, if different) of the author(s). The title should be brief and contain words useful for indexing and information retrieval.

Abstract and Key Words

The abstract, of not more than 200 words typed on a separate page, should precisely reflect the contents of the paper, and focus attention on the purpose of the study, principal results, conclusions and their significance. Below the abstract, provide and identify as such three to ten key words or short phrases that will assist in cross-indexing your article.

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As a general guide, The Chicago Manual of Style is recommended. Spelling should be standard U.S. (not British) to conform to Webster's Third New International Dictionary. Units should conform to the Système International d'Unités (SI). Non-standard abbreviations must be defined the first time they appear. Mathematical symbols, Greek letters, and unusual symbols should be identified clearly; superscripts and subscripts should be legible and carefully placed.

Standard Abbreviations

General: s, min, h (hour), d (day), wk, mo, yr, g (gram), mg, kg, Hz, kHz, MHz, km, m (meter), mm, cm, cc, mi (mile), ft, in. (note period), kn (knot), ha, gal, ml, l (liter, spell out when used alone).

Statistics: P (probability), (mean), SD, SE, CV, SEM, n (sample size), df, r (correlation coefficient), t, F, U, Z (statistical tests); letters in equations are italicized.

Latin words and phrases (always italicized): i.e., (note comma); e.g., (note comma), ca.; cf; in vivo; in situ; vs.; etc.; per se; et al.; via; sensu; sensu faro; sensu stricto; a priori.

Acknowledgements

List all acknowledgments briefly under a single heading at the end of the text on a separate page. If applicable, give the permit number under which the work was conducted.

Literature Cited

References should be cited in the text in the following form: Smith (1982); Smith (1982a, b); Smith (1983, 1984); Smith and Jones (1984); (Smith 1986); (Smith 1986, Jones 1987); (Smith 1986; Jones 1986, 1987); more than two authors, Smith et al. 1987.

References should be double-spaced and listed alphabetically as "Literature Cited" in the following standard form, giving the journal titles in full:

ARMSTRONG, W.A., and C.W. OLIVER. 1995. Recent use of fish aggregating device in the eastern tropical Pacific tuna purse-seine fishery: 1990-1994. National Marine Fisheries Service Center Administrative Report LJ-95-14 (unpublished). 47 pp. Available from SWFC, P.O. Box 271, La Jolla, CA 92038.

GENTRY, R.L., and J.R. HOLT. 1982. Equipment and techniques for handling northern fur seals. U.S. Department of Commerce, NOAA Technical Report NMFS SSRF-758. 15 pp.

HUBBS, C.L., W.F. PERRIN and K.C. BALCOMB. 1973. Stenella coeruleoalba in the eastern and central tropical Pacific. Journal of Mammalogy 54:549-552.

LEATHERWOOD, S., and R.R. REEVES. 1983. The Sierra Club handbook of whales and dolphins. Sierra Club Books, San Francisco, CA.

MURCHISON, A.E. 1980. Detection range and range resolution of echolocating bottlenose porpoise (Tursiops truncatus). Pages 43-70 in R.-G. Busnel and J.F. Fish, eds. Animal sonar systems. Plenum Press, New York, NY.

Multiple citations for an author and single co-author are arranged alphabetically according to co-author. If there is more than one co-author, citations are arranged chronologically.

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Tables

Excessive tabular data are discouraged. Tables should be typed separately and double-spaced. Tables should be numbered with Arabic numerals in the sequence first referenced in the text and have a brief title. Column headings and descriptive footnotes should be brief. Do not use vertical rules.

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Figures are costly and should be used with discretion. An illustration is justified only if it clarifies or reduces the text.

Please note that if accepted, figures will be requested in TIFF or EPS format. Please save line artwork (vector graphics) as Encapsulated PostScript (EPS) and bitmap files (halftones or photographic images) as Tagged Image Format (TIFF), with a resolution of at least 300 dpi at final size. More detailed information on the submission of electronic artwork can be found at: http://www.blackwellpublishing.com/bauthor/illustration.asp.

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Cover page

Title: Avoid the use of 'A', 'An', 'The', 'On', etc. at the beginning, eliminate unnecessary modifiers, and make the title as specific and concise as possible. It should preferably have up to 100 characters (ca. 15 words, 2 lines in print), and 150 characters at most. Compare

'A novel method for the production of monoclonal antibodies (MAbs) specific to an envelope protein (28kDa) of white spot syndrome virus (WSSV) of shrimp and detection of WSSV by MAb-based antigen-capture enzyme-linked immunosorbent assay'
(236 characters, 37 words)

vs.

'Detection of white spot syndrome virus (WSSV) of shrimp by means of monoclonal antibodies (MAbs) specific to an envelope protein (28 kDa)'
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Provide a running head with 3 to 6 words; e.g. 'Detection of shrimp WSSV'.

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Key words: Supply 3 to 8 key words, listed in order of importance; these may be composites (e.g. 'environmental assessment', 'population dynamics'), but should not be phrases or sentences.

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Please use numbered pages and lines, 12 point font, and double spacing. Do your very best to use correct English grammar, spelling and punctuation; if you are not a native speaker, you should have the text edited by someone who is, before sending the ms to IR. You may also wish to consult a 'How to' book such as Day & Gastel (2006) How to write and publish a scientific paper, 6th edn. . (Greenwood Press, Westport, CT).

Headings: Our main headings are in capital letters. Subheadings are bold type lower case, usually centered. Further subheadings can be used and you need not worry about details as long as their order is clear; they should be kept short and in the same style as described under 'Title'. We do not accept solitary subheadings, i.e. any section must contain at least 2 subheadings, or none at all.

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>
> 'Low salinities enhance oyster recruitment (Miller 1995, Smith 1998)'.
>
> 'This speed was chosen because past studies have shown this to be slightly greater than the maximum sustained swimming speed.'
>
> 'This speed is slightly greater than the maximum sustained swimmng speed.'

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Literature cites in text: In cites with 2 authors, use '&' (e.g. 'Fesefeldt & Pritchard 2002'); in cites with more than 2 authors use 'et al.' but not in italics. Note there is no comma between authors and dates. When listing several cites in a row, these should be ordered by year (the earliest first), and if there are several with the same date, then these should go in alphabetical order. Cites are separated by a comma. Websites can be given in the main text (or as footnotes if referred to more than once), and they must be dated and still accessible when the article is published.

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but: 'we studied organisms of size <0.5 µm'

Acknowledgements: Do not give first names in full, only initials (with period and space), e.g. 'We thank M. A. Smith and R. F. G. Miller'. Authors of the current ms should be given as initials only, e.g. 'We acknowledge a grant to M.A.S. from ...'.

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These should be self-explanatory; they must be referred to in correct numerical order in the text. Please prepare them very carefully; poor figures are a principal source of delay and additional work in the production process. High quality laser printouts, photographic prints (i.e. created by a camera), and electronic files in standard formats are acceptable.

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West TL, Amrose WG (1992) Abiotic and biotic effects on population dynamics of oligohaline benthic invertebrates. In: Colombo G, Ferrari I, Ceccherelli VU, Rossi R (eds) Marine eutrophication and population dynamics. Proc 25th Eur Mar Biol Symp. Olsen & Olsen, Fredensburg.

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