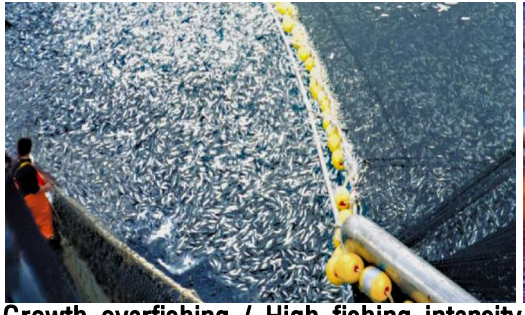
Major field of study

Marine Animal Taxonomics for Smart Fishery Resource Management

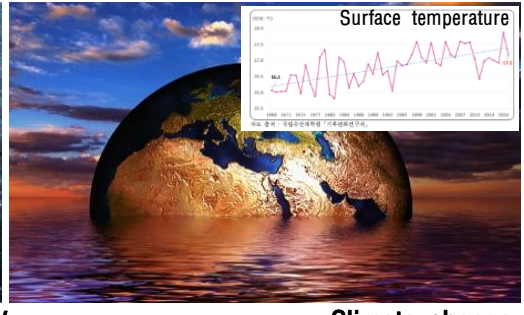
Prof. Jeong, Man-Ki

Background

Due to overfishing and climate change, fishery production continues to decline



Growth overfishing / High fishing intensity



Climate change

	1970년		2017년
전갱이류	21	11,200% ▲	2,373톤
명태	11,411	100% ▼	1톤
꽁치	22,281	96.7% ▼	725톤
도루묵	13,767	64.4% ▼	4,907톤
살오징어	67,922	52.2% ▼	32,500톤

(Kostat, 20

Paradigm shift in fisheries

Quantitative Growth of Fisheries

↓

Management Considering Ecosystems

Prepare countermeasures after specific issues

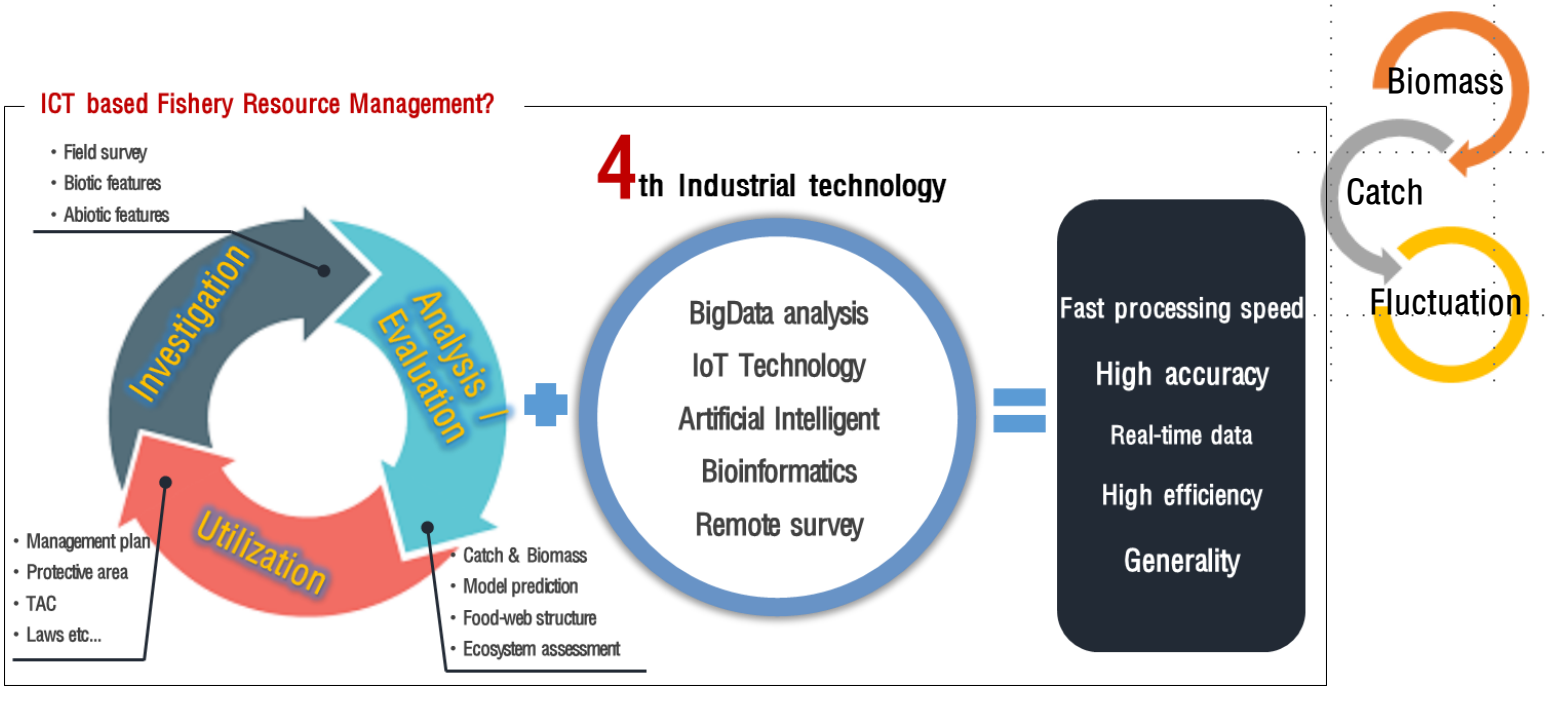
↓

Prediction and prevention

Background

What we need to know for Fishery Resource Management

▷ Biomass in marine ecosystem + Fishery catch → predict fishery resource fluctuations



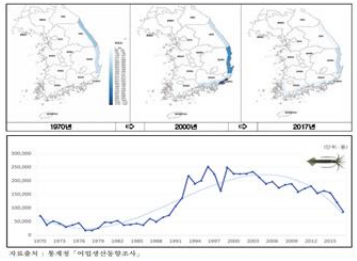
Background

Problems in traditional fishery resource management

Biomass

Catch

Fluctuations & Prediction



(Kostat, 2018)

Problems for each part

- Time consuming
- High cost
- Need specialists
- Local / temporary survey

+

- Inaccurate data
- high labor force
- illegal fishing

→

- No standardized data
- No Big Data
- Use only limited factors (temp. / Chl *a* / Catch etc..)

Previous problems : local scale, inaccurate and insufficient data

→ Large-scale, precise, and automated analysis

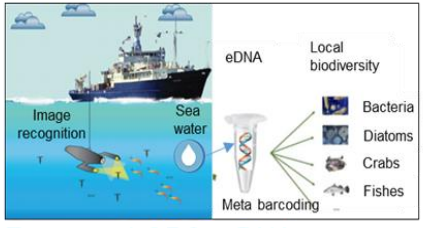
ICT is suitable for producing large and accurate data.

* ICT = Information and communication technology

Background

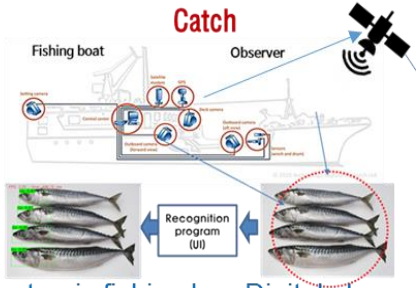
How does smart technology apply to the fisheries?

Biomass



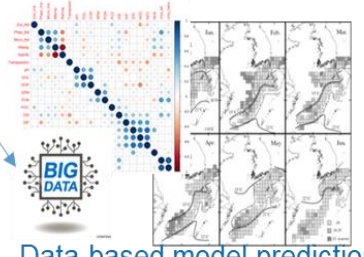
Zooscan, LOPC, eDNA…

Catch



Electronic fishing log, Digital observer

Fluctuations & Prediction



Data-based model prediction

Step1

- **Species specific Image data**
- Species specific **DNA data**
- Species specific **ecological data** (Distribution, food, development…)
- **Comprehensive Data library**

+

Step2

- **Solve labor problems**
- **Produce accurate catch data** (location, species, amount…)
- **Real-time data transmission (5G)**

→

Step3

- **Broad, accurate and large data**
- **Meaningful pattern analysis** (relation between factors without bias)
- **Improvement in prediction accuracy**

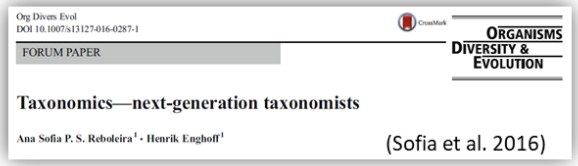
Basic process is important to produce large and accurate data

The fist step “Biomass” = directly related to “Marine animal ***Taxonomics***"

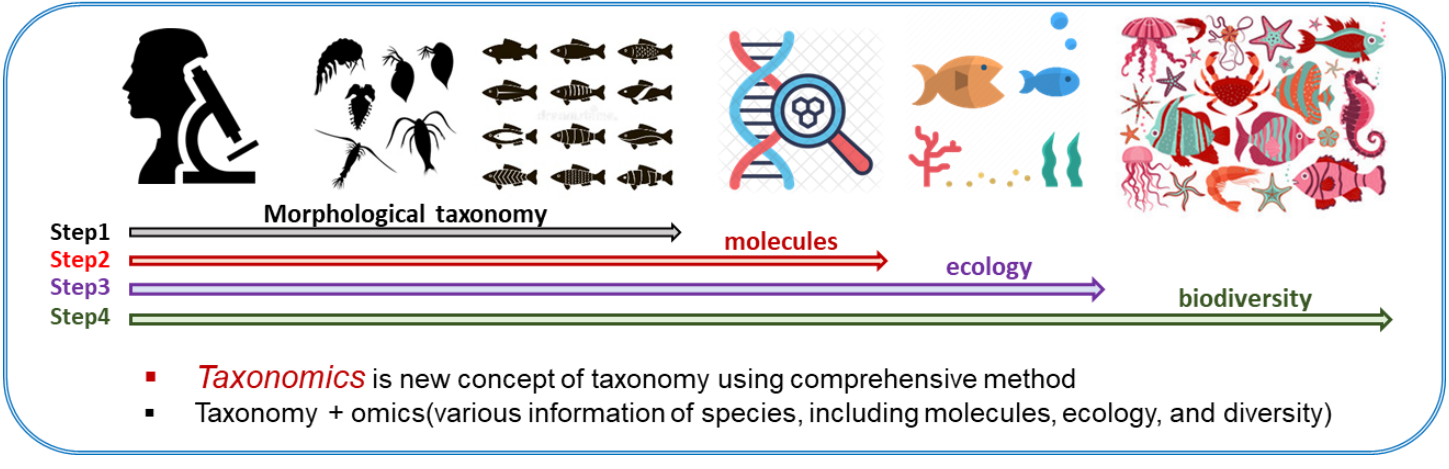
Definition of Marine Animal Taxonomics

What is the Marine Animal Taxonomics?

: Next generation taxonomists for marine animals



(Sofia et al. 2016)



- *Taxonomics* is new concept of taxonomy using comprehensive method
- Taxonomy + omics(various information of species, including molecules, ecology, and diversity)

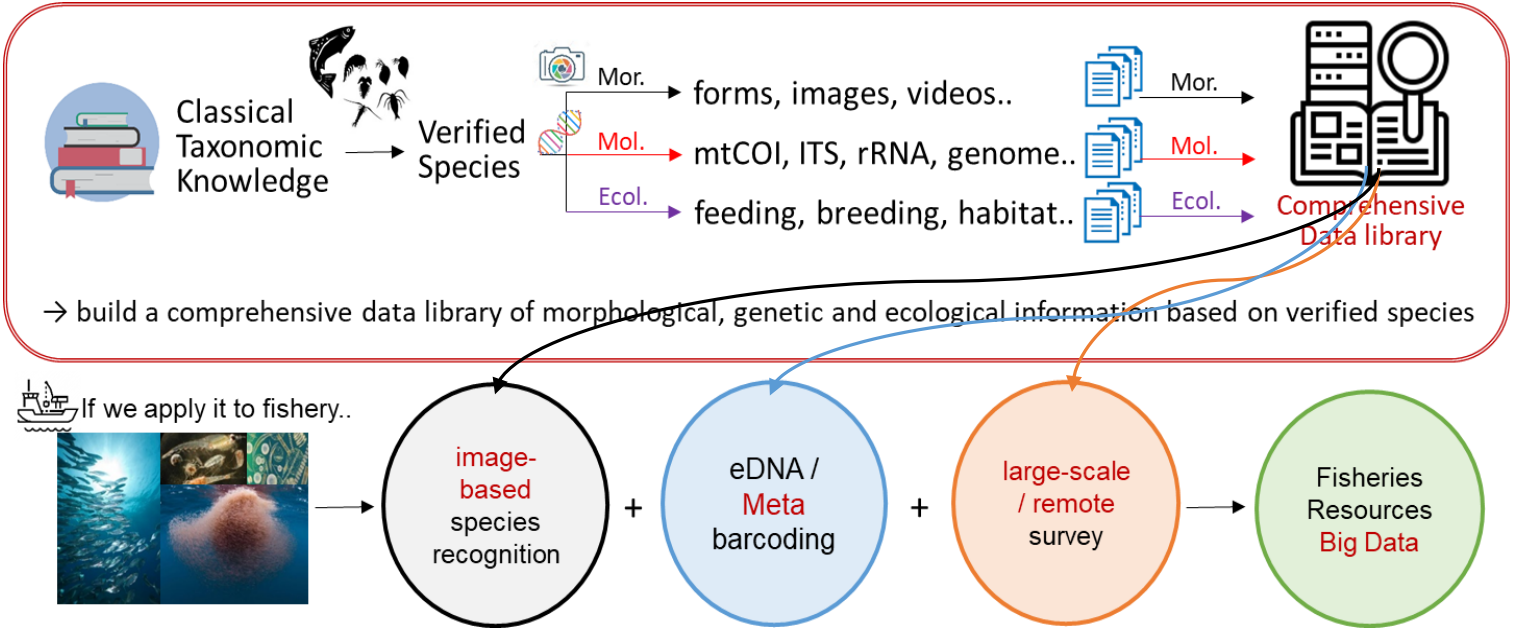
Past taxonomy = limited information for identification

Recently the diversity of biological data has become important

Toxonomics can play a key role in fishery management (= various & accurate data)

Features of Marine Animal Taxonomics

What can we do with Marine Animal Taxonomics?



→ These core technologies enable high capacity & efficiency, and fast speed analysis

Marine Animal Taxonomics for Biomass Estimation

I. Morphological methods

II. Molecular methods

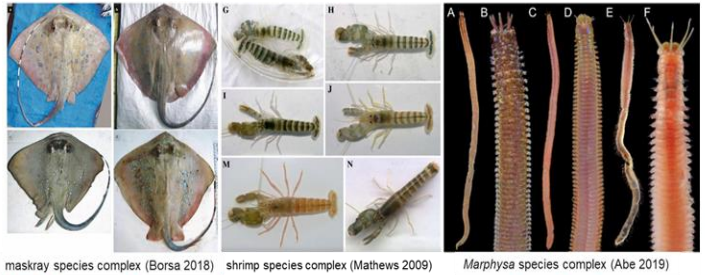
III. Ecological methods

IV. Future study plan

Morphological methods

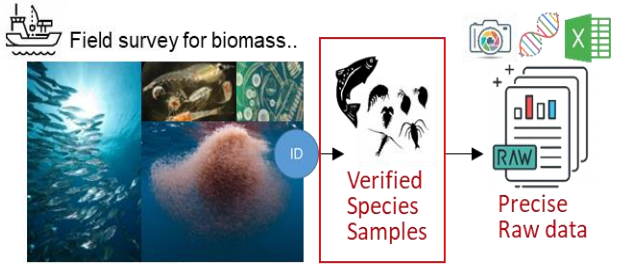
Importance of morphological experts and verified species sample

Who's who? – species complex



maskray species complex (Borsa 2018) shrimp species complex (Mathews 2009) *Marphysa* species complex (Abe 2019)

Similar species are difficult to distinguish at species level



Without morphology, precise raw data could not exist

For precise raw data, we need morphologists (copepods, shrimps, fishes…)

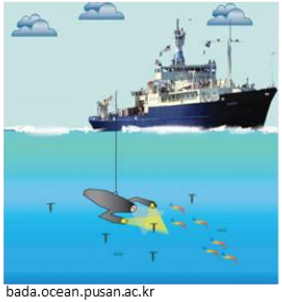
Morphological verification = very essential, but time consuming

Reference DBs (morphology → molecules → ecology)

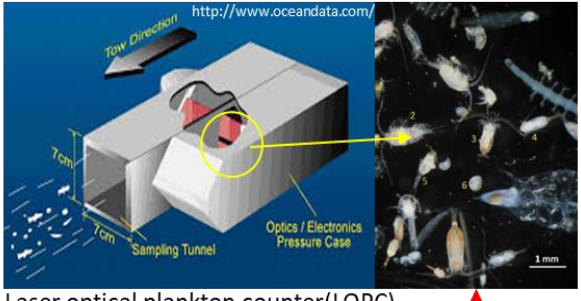
Morphological methods

Recent issue in morphological methods? Image based species recognition

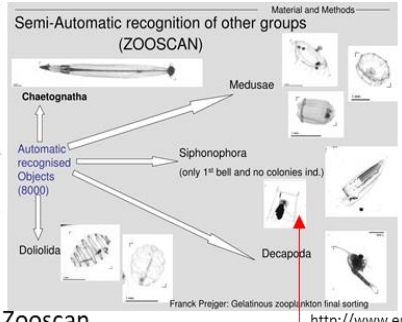
Large-scale image analysis (LOPC / Zooscan) : effective for biomass estimation



bada.ocean.pusan.ac.kr



Laser optical plankton counter(LOPC)



Zooscan

http://www.ems-ocean.com/

Accuracy of current image recognition systems = order level (80-95%)

+ optimized for European species (No Korean reference DB)

Species-level image DB → speed and accuracy will be improved

No reference data for Korean species

Morphological methods

My expertise in building a reliable reference database

reported scientific results
- 8 new records (zooplankton)
- 7 new species (polychaete worm)
- 5 new species (crustacean)

→ Assurance of morphological expertise

Expansion

Image DB

taxonomic DB

1K+ images of 442 Korean species (Fishes, Shellfish, Crabs..)

Reported 20 new marine species → expanding research subject

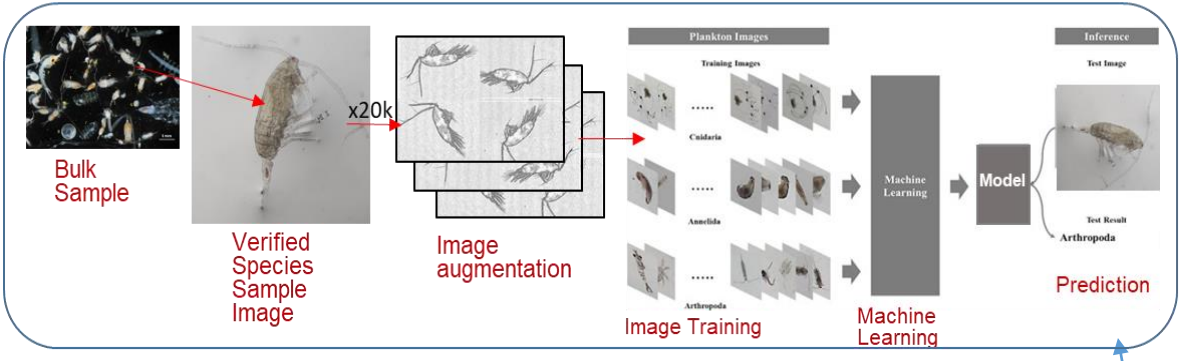
Collected 1.2 K images of Korean species → image DB

Identification key, images, and distribution patterns → taxonomic DB

→ Goal : Use Korean image DB to the automated counting system

Morphological methods

Ongoing work: Deep learning based Image recognition



Final Goals

Over 80% accuracy

Detailed ID (Species-level)

Various taxon (zooplankton to fish)

Large-scale survey (local to national)

Early stage research **:** image analysis on major copepods in Korea

System recognizes a species based on machine learning process (CNN)

Problems : low accuracy (20-40%) & time consuming (10-20 hours)

→ **Goals :** 80% ↑ accuracy, species-level identification etc…

→ **Extra results :** automated ID, abundance, distribution, length…

*CNN: Convolutional Neural Network

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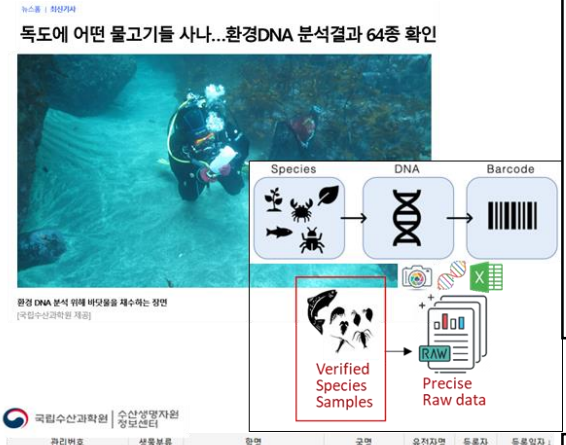
Molecular methods

DNA barcoding, "global bio-identification system"



국립수산과학원 | 수산생명자원 정보센터

관리번호	생물분류	학명	국명	유전자명	등록자	등록일자 ↓
NF--AA-FI-04125190	수산동물	*Oplegnathus fasciatus*	돌돔	1	김동군	2020-11-09
NF--AA-FI-04125053	수산동물	*Foetorepus altivelis*	도화양태	1	김동군	2020-11-09
NF--AA-FI-04125184	수산동물	*Minous monodactylus*	일지말락쏠치	1	김동군	2020-11-09
NF--AA-FI-04125185	수산동물	*Minous monodactylus*	일지말락쏠치	1	김동군	2020-11-09
NF--AA-FI-04125186	수산동물	*Minous monodactylus*	일지말락쏠치	1	김동군	2020-11-09
NF--AA-FI-04125131	수산동물	*Lophius litulon*	황아귀	1	김동군	2020-11-09
NF--AA-FI-04125132	수산동물	*Lophius litulon*	황아귀	1	김동군	2020-11-09
NF--AA-FI-04125133	수산동물	*Lophius litulon*	황아귀	1	김동군	2020-11-09
NF--AA-FI-04125117	수산동물	*Takifugu niphobles*	복섬	1	김동군	2020-11-09
NF--AA-FI-04125150	수산동물	*Johnius grypotus*	민태	1	김동군	2020-11-09
NF--AA-FI-04125051	수산동물	*Terapon theraps*	네줄벤자리	1	김동군	2020-11-09
NF--AA-FI-04125124	수산동물	*Tarphops elegans*	줄넘지	1	김동군	2020-11-09
NF--AA-FI-04125140	수산동물	*Tarphops elegans*	줄넘지	1	김동군	2020-11-09
NF--AA-FI-04125060	수산동물	*Sirembo imberbis*	동갈머기	1	김동군	2020-11-09
NF--AA-FI-04125063	수산동물	*Pleuronichthys cornutus*	도다리	1	김동군	2020-11-09
NF--AA-FI-04125055	수산동물	*Acropoma japonicum*	반딧불게르치	1	김동군	2020-11-09
NF--AA-FI-04125285	수산동물	*Thunnus orientalis*	참다랑어	1	김동군	2020-11-09
NF--AA-FI-04125286	수산동물	*Thunnus orientalis*	참다랑어	1	김동군	2020-11-09
NF--AA-FI-04125287	수산동물	*Thunnus orientalis*	참다랑어	1	김동군	2020-11-09
NF--AA-FI-04125288	수산동물	*Thunnus orientalis*	참다랑어	1	김동군	2020-11-09

DNA barcoding : use of specific genes to identify species

Target : Mega fauna such as birds, mammals and fishes

Usage : Distribution and biodiversity research

[North Sea] Most crustaceans can be identified (97%)

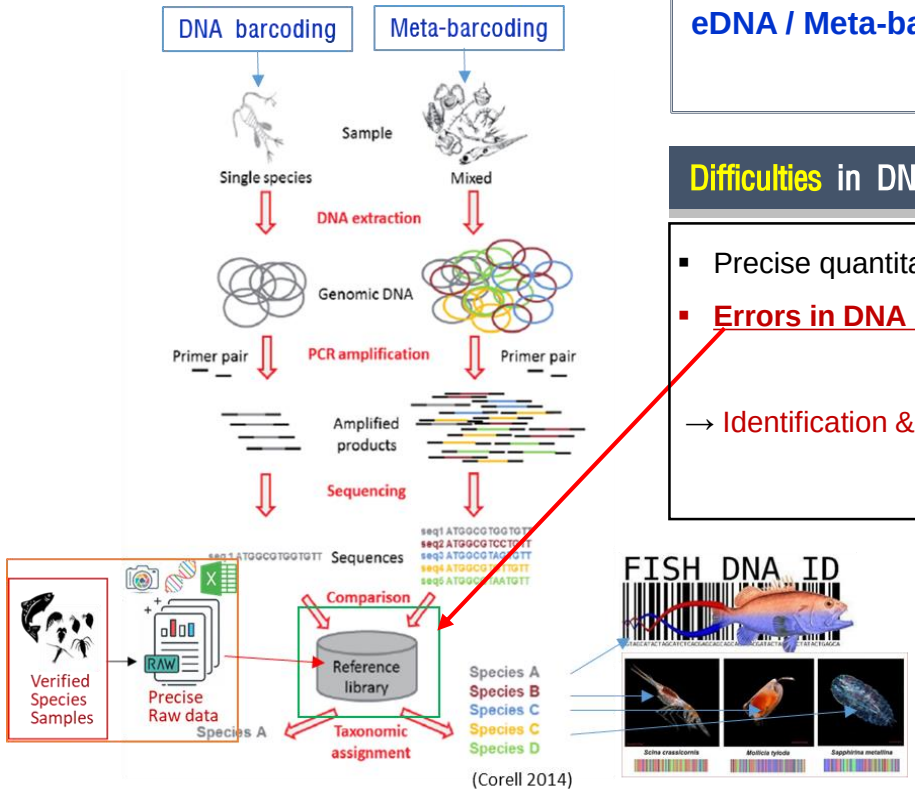
Limited DNA barcodes for Korean species

Available barcodes : only 4K in 36K species (11%)

Major fishery resource Barcodes : only 200 in public DB

* Fundamental reason = lack of verified marine samples

Molecular methods



eDNA / meta-barcoding, high speed and accuracy

eDNA / Meta-barcoding analyze distribution (in large area)
applied to soil, seawater & mixed samples

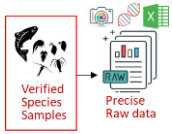
Difficulties in DNA barcoding

- Precise quantitative analysis (?)
- **Errors in DNA database** → misidentification

→ Identification & sequencing : performed at the same time
for securing reliable database

Molecular methods

Ongoing work: application to benthic ecosystem

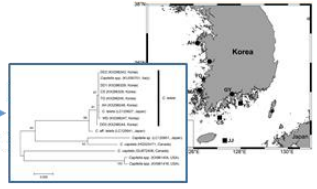


Past

Capitellid polychaetes

mtCOI, 16S, 18S, H3

DNA barcoding

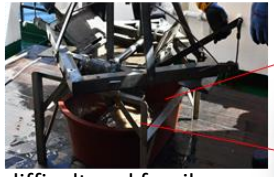


3 species (1978-2017)

12 species (2017-2020)

On
-going

Field work

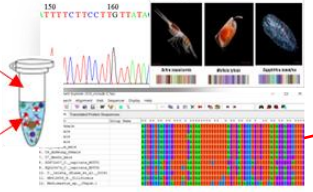


difficult and fragile

Sediment sample

Benthos sample

DNA Barcoding

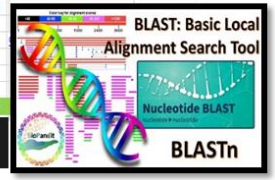


DNA data base (104/350 Korean polychaetes)

Family	Genus	Species	Korean	18S rRNA	MtCO1
Phyllodocidae	Mystl	ornata	혹부채발갯지렁이		
	Eteone	longa	작은부채발갯지렁이	partial sequence, 1814bp	partial cds; 66
		ornata	혹부채발갯지렁이		
	Nilsoniella	japonicum	달개부채발갯지렁이		
	Eulalia	viridis	녹색불꽃부채발갯지렁이	partial sequence, 1763bp	partial cds; 66
		bilineata	두줄불꽃부채발갯지렁이	partial sequence 1633bp	
	Phyllodoce	maculata	네모부채발갯지렁이	partial sequence, 1736bp	partial cds; 66
		chinensis	중국부채발갯지렁이		
		koreana	한국부채발갯지렁이		
	Nereiphylla	castanea	납작수염부채발갯지렁이	Genetyllis castanea	partial cds; 63
	Eumida	sanguinea	심장부채발갯지렁이		partial cds; 65
Paralacydoniidae	Paralacydonia	paradoxa	은갯지렁이	partial sequence, 1705bp	
Glyceridae	Hemipodia	yenourensis	반다리미갑갯지렁이	Hemipodus yenourensis	
	Glycera	capitata	큰머리미갑갯지렁이	partial sequence, 1700bp	partial cds; 61
		onomichiensis	오노미치미갑갯지렁이	partial sequence, 1610bp	partial cds; 61
		alba	줄은아가미미갑갯지렁이	partial sequence, 1737bp	partial cds; 65
		tridactyla	긴아가미미갑갯지렁이	partial sequence, 1786bp	partial cds; 55
		dentribranchia	다발아가미미갑갯지렁이		
		subaenea	청동미갑갯지렁이		
		unicornis	어리미갑갯지렁이		
		chirori	치로리미갑갯지렁이		
		decipiens	참미갑갯지렁이		
Goniadidae	Goniada	japonica	큰갈매기고리갯지렁이		
		maculata	작은갈매기고리갯지렁이		

NCBI National Center for Biotechnology Information

BOLD SYSTEMS

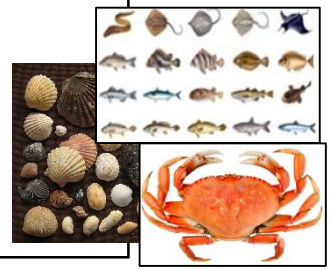


Problem : Damaged or lost sample through the washing process

Advantage : applied to damaged samples or sediments

Goal : Building a reference library about verified benthic sample

Estimate distribution and diversity of benthic species



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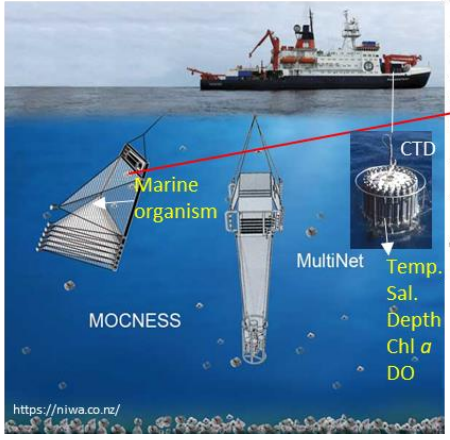
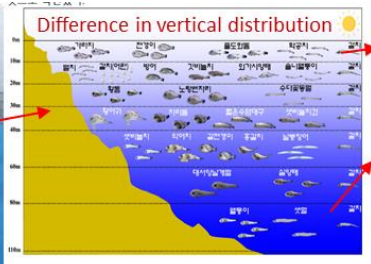
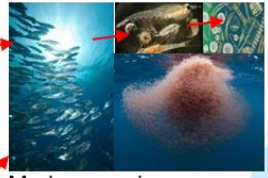
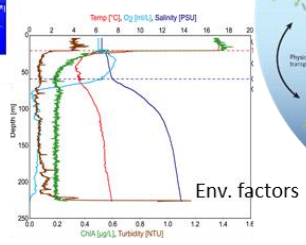
Ecological methods

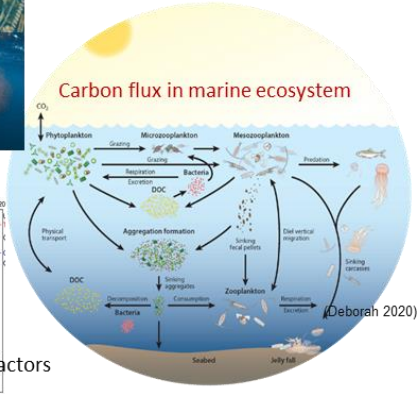
Biomass estimation based on individual carbon content











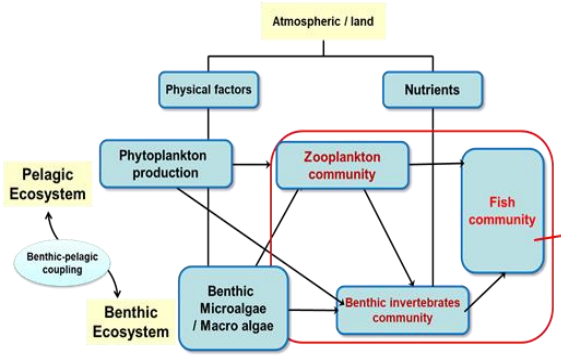
Mentioned **image** & **DNA methods** provide large data of **abundance** and **distribution**

Measurement of carbon content accurately estimates **biomass**

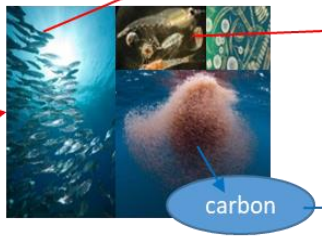
→ Abundance of a species X carbon content of a individual = carbon biomass of a species (fishes, shrimps, copepods..)

Ecological methods

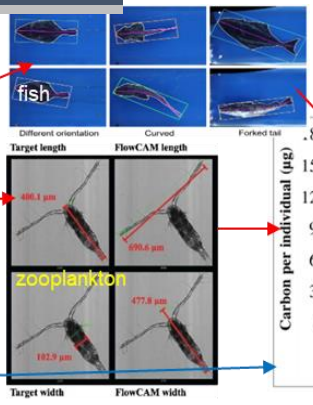
Carbon biomass of trophic levels in an ecosystem



Major animal taxa in ecosystem

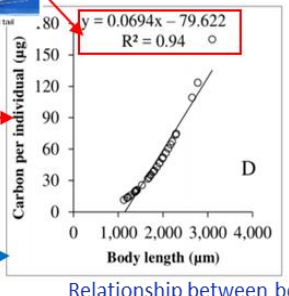


Representative organisms



Automated length measurement

Kerkar 2019

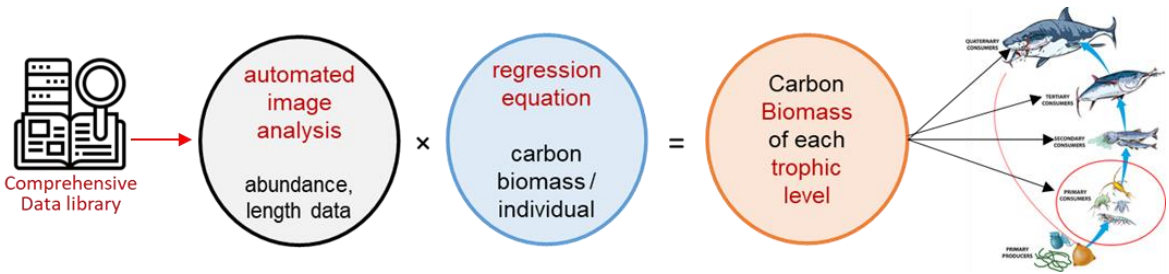


Relationship between body length and carbon content

Regression : estimated from individual length & individual carbon content

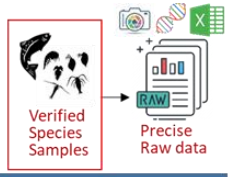
Goal : Securing regression equation for each major Korean taxon (by development, season…)

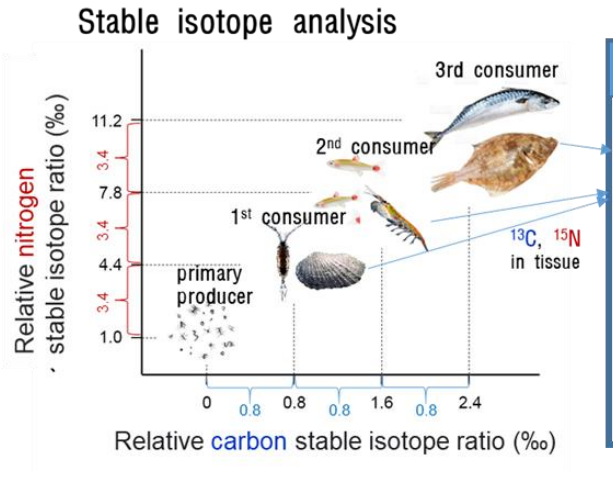
Automated image analysis → large data on abundance and length → determine carbon biomass



Ecological methods

Estimation of trophic relationship in an ecosystem





Biochemical reference database

Stable isotope ratio(^{13}C, ^{15}N) + Carbon contents

- Particle organic matter(POM) in sea water
- Phyto-pl.(nano/micro), benthic phyto-pl.
- 1st consumer(micro zoo-pl., bivalves..)
- 2nd consumer(macro zoo-pl., small fishes..)
- 3rd consumer(large fishes, top predator..)

Food web

Nitrogen and **Carbon** isotope : tracer of the trophic relationship in an ecosystem

→ In the upper trophic level, carbon (^{13}C) = 1‰, nitrogen (^{15}N) = 3-4‰ increased

Understand changes in food of major taxa (by season, development, and environment)

Biochemical DB for major taxa reveals feeding ecology of major fishes

→ Carbon contents : Biomass, C-N Stable isotope ratio : trophic relationship

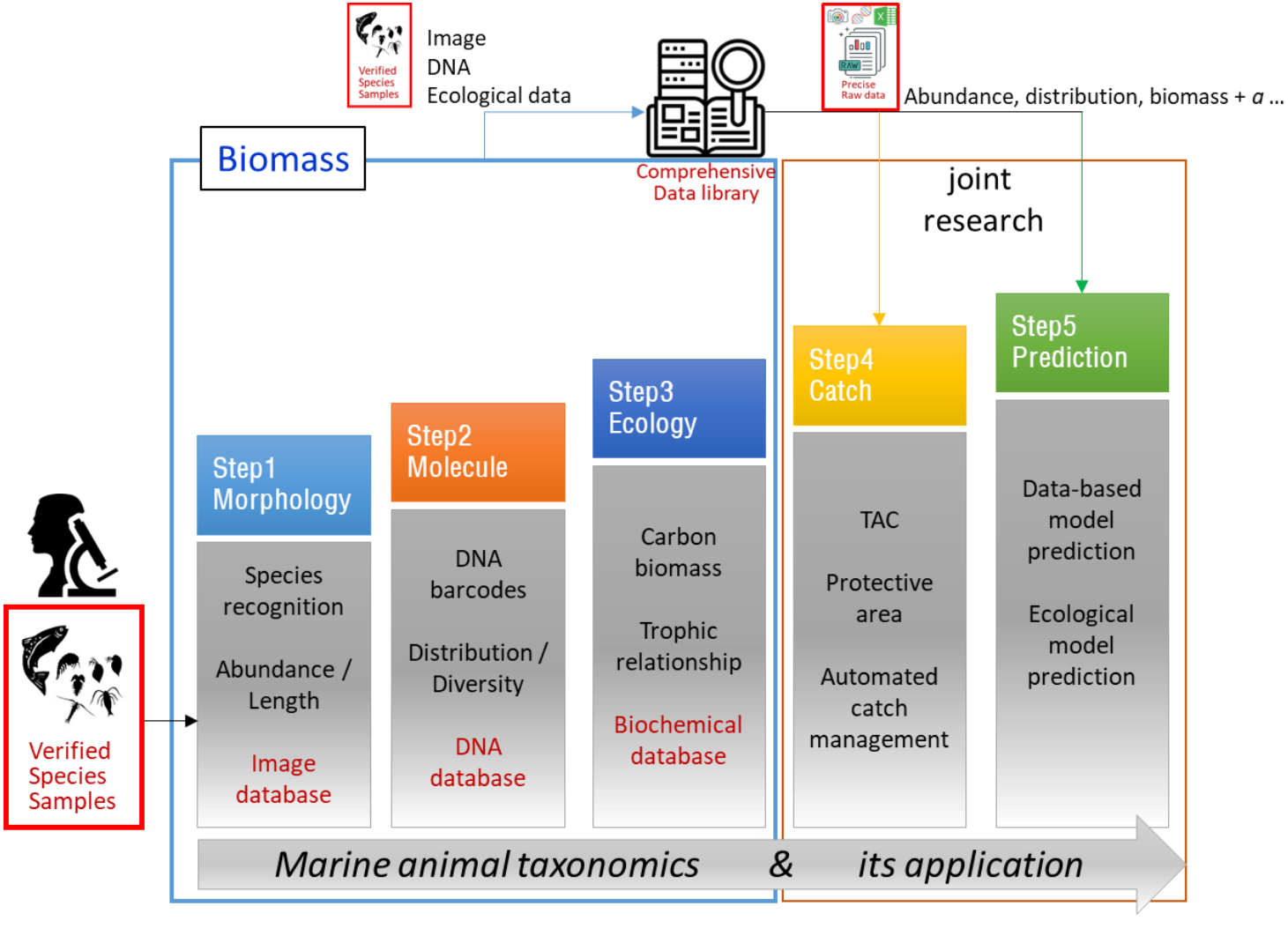
Marine Animal Taxonomics for Biomass Estimation

I. Morphological methods

II. Molecular methods

III. Ecological methods

IV. Future study plan


Verified Species Samples
Image
DNA
Ecological data
Precise Raw data
Abundance, distribution, biomass + *a* ...
Biomass
Comprehensive Data library
joint research
Step1 Morphology
Species recognition
Abundance / Length
Image database
Step2 Molecule
DNA barcodes
Distribution / Diversity
DNA database
Step3 Ecology
Carbon biomass
Trophic relationship
Biochemical database
Step4 Catch
TAC
Protective area
Automated catch management
Step5 Prediction
Data-based model prediction
Ecological model prediction
Verified Species Samples
Marine animal taxonomics & its application